ENVIRONMENTAL IMPACT ASSESSMENT OF THE BOR COUNTIES' DYKE REHABILITATION PROJECT, SOUTH SUDAN: INTEGRATED ASSESSMENT REPORT

PRODUCED FOR

The United States Agency for International development (USAID)

USDA Bor Counties' Road and Dyke Rehabilitation Project

Produced by

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Executive summary

The proposed project

The Government of South Sudan proposed construction of a dyke between Bor and Malakal, on the eastern side of the Sudd wetland in southern Sudan. The RDRP is to be implemented by the German Development Cooperation International Services (GTZ-IS) with funding from United States Agency for International Development (USAID) through the World Food Program (WFP). The primary purpose of the RDRP is to improve floodwater management by limiting the extent of flooding, in order to reclaim the land behind the dyke for the resettlement of people displaced by the massive flooding and recent civil wars, as well as improve the accessibility of the entire Bor area.

In addition to providing protection to homesteads, farms and villages, the proposed project will assist resettlement of more than 600,000 returnees (internally displaced persons and refugees) who together with an estimated 1 million livestock are expected to move back into the area. The project entails enlargement of dyke and elevation of the levels of its crest to the desired height above flood level across the Sudd. This will affect water flows, ecological functions and socio-economic life in the area, one of the world's largest freshwater wetlands.

Affected environment

The area where this development is taking place is part of the internationally significant Sudd wetland which is a key link in the hydrology of the Nile river system. It is also a large and relatively undisturbed wetland ecosystem, which is the major habitat of a number of species and including large concentrations of various species of migratory antelope.

The proposed dyke extends over three counties: Duk, Twic East, and South Bor. People of three main tribes, Dinka, Nuer, and Shiluk together with their livestock coexist in the Sudd wetland area. These people depend on the seasonal floods and rain to regenerate the floodplain grasses which feed their herds of cattle. Fishing in the Sudd is also a means of livelihood. Other more seasonal activities include cultivation of crops and cutting of wood for building in the wet season and hunting, thatch and reed cutting and charcoal burning in the dry season.

Interested and affected parties

The Dinka, Neur and Shiluk communities living in the area are the main interested and affected parties (I&AP). While the affected communities support the reconstruction of the dyke to provide the desired protection against flooding, they oppose the dyke alignment proposed under the current project plans. The current project alignment proposal branches off to the east at Jalle to return to the old dyke of 1983 from Maar northwards, leaving a 25 km wide gap open between Jalle and Maar.

The communities demand an alternative alignment that follows the old dyke of 1983 between Jalle and Maar, which would cut off the currently flooded Mabior Gol area of approximately 330 km^2. The main reason behind affected communities demand is to enable them return to and resettle in ancestors' homelands, which they used to inhabit before being displaced by the massive flooding that changed the regions' ecosystem dynamics since the 1960's. On the other hand, local government institutions, international environmental NGO's and development assistance agencies operating in the region have expressed concerns about the likely negative impacts of the Bor counties' RDRP activities on the region's biophysical and socioeconomic environment.

Policy requirements and approach of the study

Although construction work has commenced, an environmental impact assessment (EIA) was simultaneously commissioned by the donor agency funding the dyke project (USAID) to study and evaluate the likely environmental impacts of the project and to suggest sound mitigation options and environmental management and monitoring plans. This study therefore observed the donor (USAID) requirements for environmental assessment of foreign assistance projects.

The WFP Southern Sudan Project managing the Bor Counties' *"Road and Dyke Rehabilitation Project – RDRP"* commissioned this EIA study to be coordinated by the Centre for Environmental Economics and Policy in Africa (CEEPA) of the University of Pretoria in South Africa. CEEPA's involvement started after a preliminary scoping exercise of a team of experts directly recruited by WFP. Upon appointment as the EIA study coordinator, CEEPA undertook a second phase activity involving stakeholder consultation, pilot expert assessment of the key issues identified by the initial scoping exercise and planning for the full EIA. The phase II activity consolidated likely major impacts of the dyke project into five key areas that require commissioning of technical specialist studies, developed terms of reference for those and plans for implementing the full EIA study.

The WFP project management accepted CEEPA's recommendation to adopt EIA Guidelines of The Republic of South Africa (RSA) as no similar guidelines were issued yet by the Government of Sudan. This EIA study was therefore conducted in accordance with the RSA Guidelines for integrated environmental management-IEM (DEA, 1992).

The EIA was conducted in close collaboration and consultation with the WFP South Sudan Project Management, The project implementing agency GTZ-IS, local government authorities in Bor (which were at the time under the Sudan's People Liberation Movement-SPLM), local communities, NGO's and development assistance agencies operating in the area. Specialists with the required competence in the identified five key likely impact areas were recruited to develop adequate understanding of the technical aspects involved and assess significance of the identified impacts and propose appropriate measures for mitigation of negative impacts and enhancement of positive project consequences. The specialists' reports were subjected to external independent technical reviews and public consultations. The outcomes of specialists' studies together with technical reviewers' comments and

public consultations views are integrated in this EIA report. Details on comments of and responses to authority/government, public and technical external reviews are provided in Appendix 1 of this report.

The following five specialists' EIA studies were considered necessary:

1. Hydrological impacts' assessment
2. Assessment of impacts on wetland functions including fisheries
3. Impacts on grazing resources and livestock productivity
4. Impacts on wildlife
5. Economic and social impacts' assessment

In addition to the five specialized studies, the EIA process requires production of an integrated environmental impact assessment report which synthesizes and integrates the various specialized components of the EIA and their recommendations. The following sections summarize the main positive and negative impacts of the project and recommended damage mitigation or benefits enhancement measures and environmental management plans required.

Impact assessment and mitigation

Hydrological impacts: Flood depth, duration and extent

Two **negative** effects are **definite** in the swamp area to the west of dyke. First, a slight increase in inundation depth (0.05 m) will occur in the upstream area near the dyke mainly during the first half of the flooding cycle while in the downstream area the flooding curve is slightly delayed. The swamp area itself faces only minimal alterations to the flood pattern. Second, inundation time will slightly increase in the upstream areas near the dyke but in the downstream areas the inundation time is slightly extended causing a longer time span within which the area remains flooded. While there are no possible mitigation options to these effects, they have been assessed to be of **low significance**.

On the other hand, the **definite negative** effects of decreasing seasonally flooded areas to the east are inferred to be of **high significance**. This is where inundation depth is reduced for obvious reasons to rainwater flooding depth with relatively uniform area inundation reflecting the rainfall and evapo-transpiration in the area. The area will dry out quickly after the rainy season. An important measure for mitigating the negative dry season effects would be installation of gate structures to allow controlled flooding of parts of the protected areas to the east, which will **moderate** the described negative impacts.

It is important to note that the significant negative impacts of decreased river-flooded grassland areas in the east described above and in subsequent sections on ecological impacts need to be carefully weighed against the many **significant positive** socioeconomic impacts (benefits) associated with the protection of about 930 km^2 of the total floodplains cut off by the dyke to be discussed later.

Impacts of the dyke on groundwater recharge are predicted to be **negligible**. This is due to the fact that the affected area is formed of impermeable clay soils of average thickness of 8 to 10 m.

Ecological impacts: Vegetation distribution

The vegetation type that will be most affected is the river-flooded grassland to the east with dyke cutting off of flows into sections of these grasslands. The prevention of flooding will change the previously river-flooded grasslands behind the dyke to rain-flooded grassland systems with expected encroachment of woody components. The proposed dyke alignment will reduce the extent of this highly productive, high grazing value vegetation type by approximately 197 000 ha, about 17.56% of the total river flooded grassland in the study area. This **negative** ecological impact is assessed to be **highly significant** without mitigation. However, controlled flooding of sections of affected river-flooded grasslands is predicted to **moderate** these impacts.

Probable negative and positive ecological impacts on plant community structure and distribution on the western side include changing some vegetation from terrestrial or marginal wetland to river-flooded wetland due to anticipated displacement of water caused by the dyke. The extent of these changes however, could not be assessed due to the poor resolution of the hydrological data and hence their **significance** remains **unknown**.

Ecological impacts: Plant productivity and grazing potential

As a result of replacing high grazing quality river-flooded grassland by poor quality rain-flooded grassland species east of the dyke, **significant negative** impacts on available standing biomass are **definite** in the dry season without mitigation. This will have major implications for maintenance of livestock during the critical dry season period. The river-flooded grassland lost supports greater livestock grazing capacity than rainfed grassland in this area. A likely loss of grazing carrying capacity for 50 000 cattle, representing approximately 10% of the cattle population in this area is projected as a result of these changes. Controlled flooding of sections of the affected river-flooded grassland, controlled flooding of the Khor bed areas, artificial stock watering points and replacement nutrition are identified as mitigation measures that would **moderate** the significance of the described impacts. Note that this estimate is based on the change in the ability of vegetation to support livestock (i.e. the maximum potential carrying capacity), but does not consider current or future demands for the grazing resources. Another factor to consider that **lowers the significance** of such impact is the fact that the described impacts affect only about 18% of the total river-flooded grassland in the area, leaving still plenty of permanent river-flooded grassland as *toic* for grazing during the dry season. More over, these impacts should also be viewed against the fact that the current extent of the Sudd is much expanded relative to the pre-1960's condition, and is likely that sections of the currently river flooded grassland areas, and the associated high quality grazing were historically less nutritious rain flooded grassland.

Ecological impacts: Wildlife numbers and distribution

Blockage of wildlife migratory routes is expected to impact on the populations of the following species because of their migratory nature; Tiang (**negative low significance**), the mongalla gazelle (**positive very low significance**), white-eared kob and the reedbuck (**negative moderate**). The blockage is not expected to result from the dyke being a physical barrier but due to blockage by linear settlements that are expected to crop up along the dykes on the drier side. With increased human settlements, the dyke would displace wildlife in the east during the dry season, reduce the availability of game meat and thus negatively affecting the nutritional status of people. With increased dry land but no human settlement to the east (because of insecurity), the dyke will encourage the greater concentrations of wildlife around the Mabior Gol allowing for higher off-take rates of wildlife in the short run but increasing the possibilities of local extinctions of wildlife in the long run. Establishment of settlements free zones, settlements with migration corridors and hunting protection areas and seasons (dry season) are predicted to mitigate these impacts.

Ecological impacts: Fisheries potential

The **negative** impacts of the proposed dyke on local fish harvesting are assessed to be of **low significance**. On the other hand a **highly significant negative** impact on fish productivity due to loss of river flooding in the dry season is predicted east of the dyke. Reduction in available supply of fish biomass is estimated at 4000 tons in the dry season due to loss of about 200,000 ha of river-flooded grassland caused by the dyke. Controlled flooding of sections of the river-flooded grassland is proposed as a **moderating** measure.

It is predicted that the dyke will have a **definite positive** effect on fish output on the western side but the **significance** of such impact **remains unknown**.

Ecological impacts: Aquatic biodiversity

Several of the Sudd fish species are known to migrate into the river-flooded grasslands in response to the seasonal flood cycles in order to breed, or feed. They would effectively be stopped in any of the river flooded grassland areas cut off by a barrier to lateral movement such as the dyke. This will result in a reduction in the recruitment to the floodplain fish populations as a whole, and to both the artisinal and commercial fisheries resulting from loss of river-flooded grasslands providing potential spawning/juvenile nursery areas. While **negative** impacts on abundance of fish species is assessed to be of **moderate significance**, impacts on **local** fish migration and breeding is predicted to be of **high significance** without mitigation. Controlled flooding of sections of the river-flooded grassland behind the dyke and banning of fishing at inlets would **lower the significance** of the said impacts.

Geo-chemical impacts: Nutrient regime and salinization

Probable negative impacts of the dyke on amount of sediments delivered to the cut off river-flooded grassland on the east are assessed to be of **low significance** without mitigation. A **moderate negative** impact on water quality is **probable** that can be mitigated through improved sanitation. The predicted soil salinization impacts are assessed to be of **moderate significance** at a localised scale. Controlled flushing and

improved sanitation measures could be used to mitigate these effects. Increased eutrophication at localised points of discharge is **probable** but can be **moderated** through improved sanitation. The probability of some **moderate** impact on regional food chains and ecosystem productivity **remains unknown**.

Socioeconomic impacts: Human health

The expected rise in human population and livestock densities attracted by the dyke and their associated wastes is **likely** to increase exposure to disease transmitted from contaminated standing water in the previously flooded areas during the wet season. This together with absence of fish predation **may increase** exposure to vector borne diseases such as bilharzias and flukes. These can be reduced through introduction of fish for vector control and improved sanitation and health care services. On the other hand, reduced permanent presence of water bodies **will reduce** incidence of waterborne diseases such as malaria and typhoid.

Socioeconomic impacts: Domestic livestock health

It is likely that the dyke **will reduce** disease transmission/incidence in cattle causing a **moderate positive** effect.

Socioeconomic impacts: Economic Welfare and Food security

It is predicted that the dyke **will** have many **positive** impacts of **very high significance** on households food security and improved nutritional status. This will occur due to increased access to animal protein and cultivation of food crops. Also, the dyke is expected to lead to a **significant positive** impact on per capita income and wealth (increasing by 191% and 44%, respectively).

Socioeconomic impacts: Water supply security

It is predicted that the dyke **will reduce** access to water supply during the dry season **significantly** as a result of drying up of seasonally flooded grasslands to the east. This is confirmed by socio-economic surveys reporting 48% and 36% of resettled households perceive a negative impact of the dyke on water availability for domestic use and for livestock, respectively. However, managed alternative water supply systems are predicted to be effective in mitigating scarcity of water.

Socioeconomic impacts: Human habitation and flood disaster reduction

The dyke **will** bring many **benefits** to the communities returning to the area, most of **high significance**, through making more habitable land available for settlement and cultivation of crops, providing protection against the adversities of floods, reducing the need for maintaining two areas residence and associated socioeconomic disruptions caused by the need to migrate to cattle camps for some members of family, among other benefits.

Other risks associated with dyke design and construction

There are some risks involved in the dyke construction related to possibilities of structural failures. The nature of the materials used in the dyke construction coupled with the local system of grazing cattle is predicted to lead to slow destruction of the dyke body if not properly maintained. A possible failure of the dyke by local overtopping and erosion will lead to a localized high inflow of water into the protected areas.

Summary of major dyke impacts

Description of impact	Degree certainty	Significance rating		Mitigation measure
		Before mitigation	After mitigation	
Hydrological impacts				
Flood depth west of dyke	Probable	Low (+)		None
Flood duration west of dyke	Probable	Low (+)		None
Flow velocity west of dyke	Probable	Low (+)		None
Seasonally river-flooded area east of dyke	Definite	High (-)	Moderate (-)	Controlled flooding
Groundwater recharge – protected area east	Definite	No impact		None
Ecological impacts				
Change in plant community structure & distribution west of dyke	Definite	Moderate (+&-)	Moderate (-)	No mitigation
Change to natural ecological dynamics west of dyke	Unknown	Moderate (-)	Low (-)	If equal areas flooded west
Change in plant community structure & distribution east of dyke	Definite	High (-)	Moderate (-)	Controlled flooding
Change to natural ecological dynamics east of dyke	Definite	High (-)	Moderate (-)	Controlled flooding
Impacts on food chains and ecosystem productivity west of dyke	Unknown	Moderate (-)		None
Fish harvesting west of dyke	Unknown			
Fish migration and breeding west of dyke	Unknown	Low/moderate (-)		
Fish productivity west of dyke	Unknown	Low/Moderate (-)		
Changes in livestock and wild game carrying capacity east of dyke	Definite	High (-)	Moderate (-)	Controlled flooding
Impacts on food chains and ecosystem productivity east of dyke	Definite	High (-)		None
Fish productivity east of dyke	Definite	High (-)	Moderate (-)	Controlled flooding
Fish harvesting east of dyke	Probable	Low (-)	Low (-)	Controlled flooding
Fish migration and breeding east of dyke	Definite	High (-)	Moderate (-)	Controlled flooding

Ecological impacts: Wildlife				
Population of migrant antelope species preferring seasonally flooded	High	Moderate (-)	Low (-)	Settlement free zones, corridors
Population of water-dependant antelope (waterbuck, hippo, buffalo)	High	Low (-)	Low (-)	Controlled flooding
Population of dryland antelope (mongalla, zebra, roan and orbi)	High	Very low (+)		
Availability of wild game in dry season – regional	Probable	High (-)	Low (-)	Closed season hunting
Availability of wild game through the year – regional	Probable	High (-)	Low (-)	Settlement free zones, closed season hunting, migration corridors
Disappearance of game species – regional	Probable	High (-)	Low (-)	
Impact on breeding of migratory species	Definite	Moderate (-)	Low (-)	
Geochemical impacts				
Impacts on water quality east of dyke	Probable	Moderate (-)	Low (-)	Improved sanitation
Eutrophication east of dyke	Probable/localised	High (-)	Moderate (-)	Controlled dilution of nutrients
Socioeconomic impacts				
Disease transmission in humans east of dyke	Unknown	Unknown (+ & -)	Low (-)	Improved sanitation
Disease transmission in livestock east of dyke	Probable	Moderate (+)	Low (-)	Improved animal husbandry
Food security east of dyke	Definite	High (+)	High (+)	
Availability of habitable land	Probable	Very high (+)		Provision of public goods
Need for more than one separate homesteads	Probable	Very high (-)		
Socioeconomic disruption due to seasonal migration	Unknown	Don't know (-)		
Number of livestock owned per household	Possible	High (+)		Improved animal husbandry
Livestock production	Possible	High (+)		
Agricultural output at the household level	Possible	High (+)		Improved crop husbandry
Intensification of agricultural land use	Possible	High (+)		
Easier provision of collective consumption (public) goods	Possible	High (+)		
Availability of firewood and other timber resources	Possible	Don't know (+)		
Access to water east of dyke	Definite	Moderate (-)	Low (-)	Managed alternative supplies

Alternative dyke alignments

Impacts	Project proposal (option 1)	Community proposal (option 2)
Protected area (positive-benefits)	930 km^2 (3)	1260 km^2 (1)
Cut off river-flooded grassland (negative-costs)	800 km^2 (1)	1020km^2 (3)
Other ecological impacts (negative-costs)	(1)	(3)
Wildlife dryland population (positive-benefits)	(3)	(1)
Wildlife wetland population (negative-costs)	(1)	(3)
Net socioeconomic impacts (positive-benefits)	(3)	(1)

Conclusions and recommendations

- Socioeconomic benefits exceed costs of the dykes such that the affected communities are predicted to become economically better off with the dyke than without the dyke. Critical for realising and enhancing these benefits will be adoption of an integrated development strategy that ensures provision of critical complementary services such as improved access to technology (irrigation and modern crop and animal husbandry), improved access to markets and credit and provision of healthcare and sanitation and education services. It is also of critical importance to design policies that would encourage and provide sufficient incentives for communities to diversify their investments and wealth portfolio away from the currently predominantly livestock assets to take advantage of the new opportunities for transforming their current way of life to a more modern and market integrated agrarian system. This will also require prudent reinvestment of the proceeds of the regions' rich non-renewable natural assets such as oil especially in sustaining and enhancing its rich renewable resource base (the Sudd wetland).
- The dykes are expected to have important ecological costs with implications for the wellbeing of affected communities
- The trade-offs between socioeconomic development benefits and ecological intactness costs need to be carefully managed with appropriate mitigation and environmental monitoring measures
- One appealing option with fewer and less extensive negative ecological effects and important implications for the economic wellbeing of resettled communities is to minimize losses of river-flooded grassland by cutting off smaller areas. The current alignment along reconstruction of secondary dykes for protection of resettled villages is a good example
- Controlled flooding of part of the area east of the dyke would serve several purposes:
    - Maintain areas of highly productive seasonally-flooded grassland east of the dyke
    - Help retain current nutrient regime and control the build-up of harmful organisms in cut-off water bodies
    - Prevent permanent human settlement in a corridor of land that would permit the migration of antelope
    - Increase fisheries yields both east and west of the dyke
- To mitigate the anticipated localized salinisation and to limit the incidence of disease, a comprehensive sanitation plan should be developed for the resettling population
- To mitigate anticipated effects on water quality dynamics, flushing flows could be considered to remove accumulated organic matter behind the dyke
- Limited, or preferably no fishing and hunting of game should be permitted at the controlled flood release points along the dyke
- The concentration of predators (including man) at these points will reduce migration and
- Maintenance of fish populations in the water bodies behind the dyke to predate upon mosquitoes larvae (the malaria vector); possible spraying of water bodies

and homes, and general improved provision of and access to healthcare will assist in reducing the incidence of malaria in the population.

- If the displaced waters will flood new, currently terrestrial areas, many of the expected negative impacts may be offset by the creation of equivalent wetland areas elsewhere
- Recent water levels in Lake Victoria ***dropped by 1.5m over the last 18 months***
    - Attributed to increased withdrawals for power generation
    - Likely flows in the Sudd will therefore reduce in the future
    - ***It is possible that the flows are going to reduce to pre-1960's conditions*** or lower
- In light of the above it is recommended that efforts should be directed towards developing:
    - Improved understanding of the functionality of the Sudd system, particularly the hydrological connectivity on both sides of the dykes
    - A strategic environmental assessment and management plans for the entire Sudd area given current plans and expectations of massive future development efforts in the region
    - Appropriate plans for monitoring mitigation measures and underlying environmental and socioeconomic processes involved in the identified negative impacts of the dykes. A number of those are proposed in the environmental management and monitoring plans in this and specialists' reports
- The involvement of local communities in all decisions and implementation of plans for management and exploitation of the key natural resources on which their livelihoods are dependent (community-based) is necessary for socially desirable and environmentally friendly future economic development in the region.

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1. Introduction

1.1 Background

As part of its Bor Counties' *"Road and Dyke Rehabilitation Project – RDRP"*, the Government of South Sudan proposed construction of a dyke between Bor and Malakal, on the eastern side of the Sudd wetland in southern Sudan. The RDRP is to be implemented by the German Development Cooperation International Services (GTZ-IS) with funding from United States Agency for International Development (USAID) through the World Food Program (WFP). The primary purpose of the RDRP is to improve floodwater management by limiting the extent of flooding, in order to reclaim the land behind the dyke for the resettlement of people displaced during recent civil wars, as well as improve the accessibility of the entire Bor area.

Due to the breakdown of the old dyke system the Bor area has since the 1980s experienced floods that seriously affect the livelihood of communities in the area. In addition to providing protection to homesteads, farms and villages, the proposed project will assist resettlement of returnees (internally displaced persons and refugees) who together with an estimated 1 million livestock are expected to move back into the area with the completion of the peace process. The project entails enlargement of dyke and elevation of the levels of its crest to the desired height above flood level across the Sudd. This will affect water flows, ecological functions and socio-economic life in the area, one of the world' largest freshwater wetlands.

The area where this development is taking place is part of the internationally significant Sudd wetland. Its importance is based on two main issues: the Sudd is a key link in the hydrology of the Nile river system, which supplies water not only to Sudan, but also to Egypt; and secondly it is a large and relatively undisturbed wetland ecosystem, which is the major habitat of a number of species and is an important resource for migratory waterfowl. The eastern Sudd is a dry season dispersal area for large concentrations of various species of migratory antelope.

Although construction work has commenced, an environmental impact assessment (EIA) was simultaneously commissioned by USAID to study and evaluate the likely environmental impacts of the project and to suggest sound mitigation options and environmental management and monitoring plans.

1.2 Requirement for an EIA

The Bor RDRP is funded by USAID. The donor environmental regulations (22 CFR 216, commonly known as REG 16) establish procedures necessary for project review within the US Agency for International Development. The regulations define a class of actions that are normally considered to have a significant effect on the environment and therefore require identifying the significant issues relating to the proposed action and of determining the scope of the issues to be addressed in an EIA. Road/Dyke rehabilitation or improvement programs are included within this class of actions [216.2(d)].

Section 118(c)(15) of the United States (US) Foreign Assistance Act would deny assistance for the construction, upgrading, or maintenance of roads (including temporary haul roads for

logging or other extractive industries) which pass through relatively un-degraded lands, unless Environmental Assessment (EA) indicates that the proposed activity will contribute significantly and directly to improving the livelihood of the rural poor and will be conducted in an environmentally sound manner which supports sustainable development. It is on this basis that an Environmental Assessment (EA) is required to consider environmental impacts of the USAID funded road/dyke improvement project in Bor, South Sudan. The EA should help identify more environmentally sustainable strategies for achieving the project goals; identify the potentially adverse environmental impacts of project interventions; ensure that adequate mitigating measures are included to minimize adverse impacts; ensure that environmental monitoring activities are included in the project plan, including objectively verifiable indicators and means of verification; and finally, focus on the spectrum of most likely environmental impacts in order to facilitate their future management and help the project become a rational component of future development for the region and the entire South Sudan.

1.3 Structure of the report

This report is organised in five chapters. Chapter two, which follows this introductory chapter, describes the proposed Bor Counties' *"Road and Dyke Rehabilitation Project – RDRP"*. Alternative project designs are considered, together with a full description of the environment affected by the proposed project. The approach used for conducting the EIA is detailed in chapter three, where the terms of reference for the study and its assumptions, limitations and commissioned specialists studies are documented. Assessment of the identified project impacts and mitigation measures follows in chapter four, with comparisons of impacts with and without mitigation actions for the alternative project designs. Chapter five summarises the conclusions and recommendations of the study.

2. The proposed project and affected environment

2.1 Description of the proposed project

The Bor RDRP project entails the construction and rehabilitation of a dyke, which will involve enlargement and raising of dyke crests to the desired above flood level, and installation of side drains and cross drainage structures. The proposed dyke runs from South to North Bor over a distance of 100 km from Padak (approximately 25 km north of Bor) towards the north, ending some 20 km northwest of Mabior town. In general, the proposed works comprise of the reconstruction of a uniform clay dyke body 1.5-1.8 meters high, with a crest 4 m wide, 1:3 side slopes and a grassy surface cover[1]. The dyke will cut off parts of the seasonally flooded *toich* area, which is traditionally used for grazing and fishing purposes, depending on the season and state of flooding. The project implementation will include the following activities:

- Detailed survey of the existing dyke alignment and levels including permanent installation of benchmarks at intervals of 1km. Selection of the route (alignment) for the dyke will thus mainly follow the old dyke that existed before the onset of the internal conflicts, but in some areas, may require re-routing/realignment and re-construction for appropriateness. These infrastructures will run from South to North Bor, a distance of about 100 km (see Figure 1)
- Clearing and preparing some areas for campsite construction and new areas for realigning the dyke
- Selection and construction of semi-permanent campsites with offices, stores fuel depot of 100,000-liter capacity and workshop facilities at Padak, and later Mabior, Panyagor or Poktas to accommodate the crew and heavy machinery to be used in the dyke (and road) rehabilitation and construction
- Boreholes will be sunk and elevated water tanks put in place to supply water for domestic use
- Electric power will be supplied from a 45 KVA on-site generator supplemented by a 15 KVA stand-by generator
- Construction/Rehabilitation of a dyke with proposed crest width of 4 m, installation of new culverts (up to 2 m in diameter) at determined locations, removal of existing culverts and the sections backfilled and compacted to provide a proper functioning dyke and, the filling up of dyke to appropriate levels
- Establishment of quarries and borrow pits to provide the needed construction materials at various sites in neighbouring areas. Borrow pits, after being decommissioned will be rehabilitated by smoothening out soil dumps and creating gentle side slopes for using them as water storage ponds as described below
- Plans include insertion of gate structures into the dyke body to allow a controlled intake of water into the protected areas. Under original project plans, gate structures will be used to fill old rehabilitated borrow pits behind the dyke. These reservoirs will

[1] A slightly elevated maintenance road in the inner side will accompany the proposed dyke. Roads being built under the same project are expected to have hydro logically negligible impacts as they are only slightly elevated above the surrounding ground to be safe against rainwater flooding and they are equipped with culverts in certain intervals, allowing for the balancing of waters from both sides of the roads. As in the flat area no drainage structures other than the balancing culverts are used, the changes in the local hydrological conditions can be considered negligible (hydrological impacts study in Annex 1).

be used for livestock watering when waters from the seasonal floodplains retreat during the dry season. Original project plans also include digging of simple water supply channels from these ponds which will supply water to areas some distance from the pits, depending on the water levels in the pits

- Compacting to improve material performance and stabilizing the dyke embankments
- Establishment of floodgates at strategic points to control the flow of water down the stream
- Transportation of construction material from various sites to dyke embankment using heavy machinery.
- Training of equipment operators and dyke works crews in environmentally sound dyke construction and maintenance.

The old dyke system was found to be in a state of complete deterioration during the first pre-project assessment and planning in January 2004. The dyke was eroded to a remaining height of an average of 0.3 meters and a width of 0.5 meter. In addition, the remaining structure was breached at various locations, where water was flowing freely. In general the total length of dyke was overtopped during the flood season leaving the dyke with no effect (Hydrological impacts study in Annex 3).

The current alignment, for which construction has already commenced (Alignment Option 1), is based on the old dyke alignment as found in the Euroconsult (1981) documents, but adapted to realign around the Mabior Gol area without cutting off the flooded areas between Jalle and Maar, leaving an approximately 25 km wide gap. The Mabior Gol area, which is currently permanently flooded and which will be left out from the dyke construction activities in the current design has a size of approximately 330 km^2. From Maar northwards, the currently planned alignment returns to the old dyke of 1983 (Figure 1).

Stakeholders' consultations later revealed demands expressed by affected communities and parties for an alternative dyke alignment for several reasons, most important of which are the need for further protection from floods north of Jalle and larger land areas reclaimed for resettlement and grazing. The proposed alignment (Option 2) continues dyke construction through Mabior Gol cutting off the flooded area between Jalle and Mar (Figure 1). The original project dyke alignment proposal (Option 1) is opposed by affected communities who want to return to their ancestors' homelands they used to inhabit next to the old dyke of 1983. Three tribal groups inhabited this area for very long before being displaced by the high flows of the early 1960's which caused massive flooding of the area and changed the region's ecosystem dynamics since then. A displacement that was aggravated by the subsequent civil war that pushed them into areas further north or south.

Figure 1. Study area affected by the Bor counties' dyke rehabilitation project and proposed alternative dyke alignments

Source: Hydrological impacts study report (Annex 3)

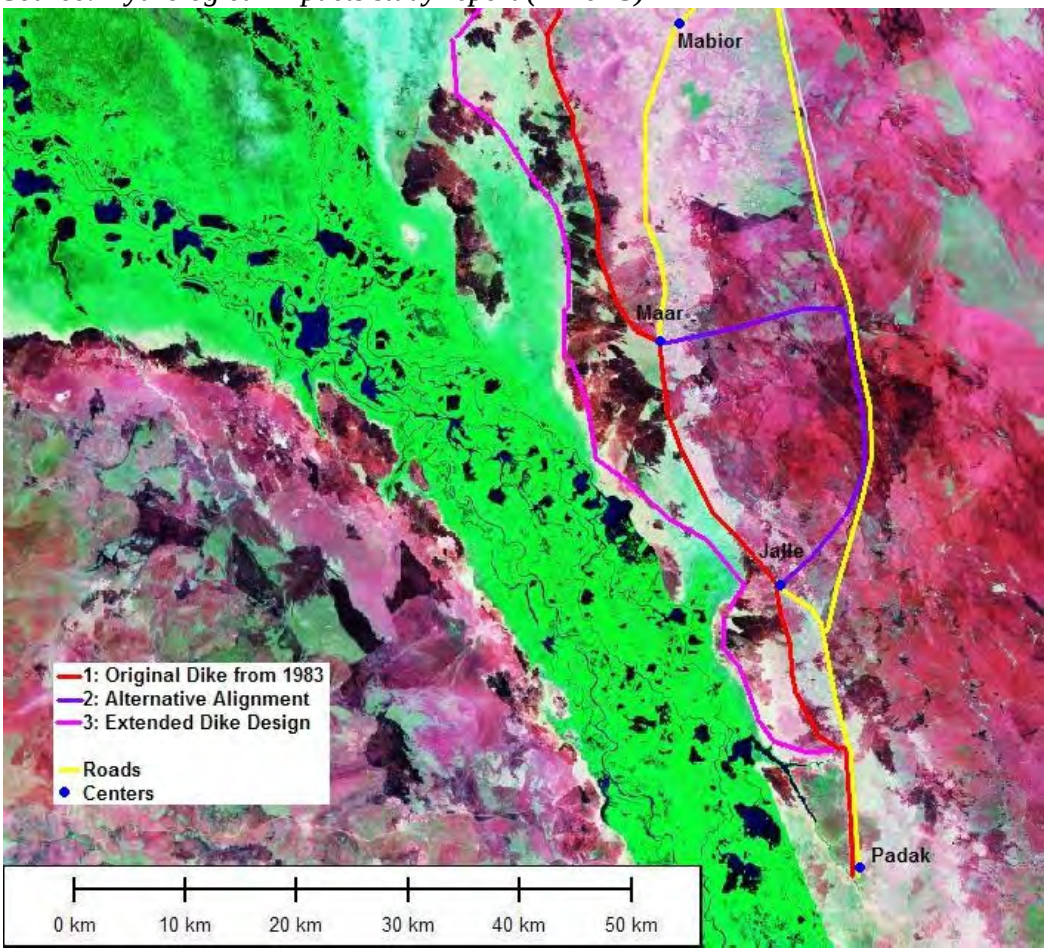


Figure 2 illustrates the likely appearance of the dyke, based on the old dyke and sections under construction.

Figure 2 (a.) Old dyke through river flooded grassland; (b.) new dyke through river flooded grassland; (c.) remains of the Jonglei canal; (d.) new road crossing rain flooded grassland; (e.) new road through river flooded grassland – note the water along the edge of the road; (f.) new road through wooded grassland and rain flooded grassland; (g.) settlement with an old dyke around it – notice the green *O. longistaminata* on the river side of the dyke; (h.) homesteads on teritaria/higher-lying ground in river flooded grassland. (Source: Wetland impacts study Report, Annex 4).

2.2 The affected environment

This study uses a broad definition of the environment, to include not only natural biophysical elements but also social, economic, political and cultural components.

Location and boundaries of the affected area

The environment affected by the dyke project comprises of permanent swamp and adjacent river and rain flooded plains extending over approximately 11,000 km^2 (100 km south-north by 110 km west-east) of the Sudd area of southern Sudan (Figure 1). The Sudd is one of the largest freshwater wetland areas in the world. It is the dominant feature in the region, situated in Sudan between 5° 30' and 9° 30' N and 30° and 32° E at 380-450 meters above sea level (masl). The main wetland extends from Juba in the south to near the Sobat confluence with the White Nile just upstream of Malakal in the north, and westwards along Bahr el Ghazal. The Sudd can essentially be divided into four sections: (1) the Bahr-el-Jebel or central system, (2) the Bahr-el-Ghazal system to the west, (3) the Sobat–Baro–Pibor river system to the east and (4) the smaller Machar marshes to the northeast. The central Bahr-el-Jebel system consists of two main rivers, the Bahr-el-Jebel (also known in various sections as the Bahr-el-Abiad, Albert Nile, Victoria Nile or simply the White Nile) to the west and the smaller Bahr-ez-Zeraf to the east.

The size of the Sudd varies from season to season and year to year. Estimates of the size of the Sudd wetland range from 30 000 km^2 (Baecher *et al*., 2000) to 55 000 km^2 (IUCN, UNEP, WCMC and World Heritage, 2005), to 130 000 km^2 (The Columbia Electronic Encyclopaedia, 2003). It is further estimated that the peripheral effects of the system extend over the entire 154 325 km^2 ecoregion (Seymour, 2001). Between 1961 and 1963 a great increase in the inundated area was observed when the level of Lake Victoria rose and the outflow increased. The total area is related to the amount of water reaching Bor from Albert Nile and from torrents or seasonal watercourses that can add substantial amounts to the flow in the upstream end of the Sudd. Since 1961, inflow to the Sudd has increased substantially, presumably due to increased rainfall in the headwaters of Lake Victoria. The inflow into the Sudd increased from 26, 83 billion m^3/year to 50, 32 billion m^3/year over the period 1961 to 1980 (Hughes and Hughes, 1992; Seymour, 2001). Flows at Mongalla have roughly doubled and increased 1.5 fold at Malakal. As a consequence of these higher flows, it is estimated that the area of permanent and seasonal wetlands has increased by approximately 2.5 times since the early 1960's (Mefit-Babtie, 1983).

Biophysical environment

Hydro logically the Sudd plays an important role in storing floodwaters and trapping sediments from the White Nile. On average, 55 % of the waters entering the Sudd are lost by evapotranpiration and thus less than half of the flow of the Bahr el Jebel at Bor reaches the northern outlet of the Sudd (Baecher, 2000). Historically, plans existed to divert the waters of the White Nile around the Sudd via the Jonglei canal. Work on the canal began in 1978 and stopped in 1984 for technical, financial, political and civil unrest reasons (Hughes and Hughes, 1992). The intention of the diversion was to prevent much of the evaporative loss of water that occurs in the Sudd, and also allow this water to be used for irrigation and other purposes downstream. This diversion would have caused the wetland to shrink dramatically from its extent at the time, possibly also impacting on climate, groundwater recharges, sedimentation and water quality and threatening the fauna and flora of the wetland (Mefit-

Babtie, 1983, Final report Vol. 8). The livelihoods of the people living in the Sudd that depended on the wetland would also likely have been negatively impacted, particularly in terms of the loss of fish and grazing areas (Mefit-Babtie, 1983, Final report Vol. 8).

The Sudd floods between May and October each year. Vertisols (dark, cracking smectitic clays, often referred to as black cotton soils) are the main soil form underlying the wetland. These are mostly alluvial in origin, derived from material transported by the Blue and White Nile, but some might have been formed *in situ* from basaltic rocks, such as the cracking clays of Gedarif State. These soils are characterized by clay contents of 60% or more, are alkaline in pH and have gypsum and calcium carbonate concretions, particularly in the lower horizons (Zaroug, 2000). Vertisols have impeded drainage and thus support the extensive flooding of the Sudd. Fluvisols or soils of recent alluvial origin and patches of luvisols are found along the river courses. The southern portion of the wetland is wetter than the northern portion, receiving on average about 800 mm/yr compared to the north's 600 mm/yr (Beadle, 1981). The rains fall between April and September (Moss, 1998), and temperatures average 30 - 33°C during the summer months, dropping to an average of 18°C in winter.

The perennial swamps and associated river flooded grasslands support a rich biota, including over four hundred bird species and one hundred mammal species. The perennial swamps include a number of vegetation zones ranging from open-water and submerged vegetation of the river and lake habitats, to floating fringe vegetation and extensive areas of tall rooted and floating *Cyperus papyrus* and *Typha domingensis*.

Seasonally flooded grasslands characterise the floodplains, while rain-fed grasslands and river and rain flooded woodlands as well as higher lying floodplain woodlands (Hickley and Bailey, 1987) also occur. The seasonal river flooded grasslands extend as far as 30 km from the perennial swamp, and patches of river-flooded grassland may extend up to 100 km from the perennial swamps. Wild rice (*Oryza longistaminata*) and *Echinochloa pyramidalis* dominate the seasonally river flooded grasslands while *Hyparrhenia rufa* is one of the most common species in the rain-fed grassslands. *Acacia seyal* and *Balanites aegyptica* woodlands border the floodplain and rain and river-flooded grasslands (Denny, 1991) and together with *Acacia drepanilobium* form the dominant component of the most of the wooded grasslands (Mafit-Babtie, Vegetation Study Report Vol. 3, 1983).

During the 1980s, southern Sudan had among the largest populations of antelope in Africa. The East and IUCN/SSC Antelope Specialist Group (1999) listed the Sudd as a key location for the recovery of threatened antelope in sub-Saharan Africa (Seymour, 2001). Among the most abundant species found here are the white-eared kob (*Kobus kob*), the tiang (*Damaliscus lunatus tiang*) and the Mongalla gazelle (*Gazella thomsonii albontata*). These three antelopes make large-scale migrations over the wetland. For example, it is estimated that one million white-eared kob undertake a migration of over 1 500 km, following the availability of the floodplain grasses (Denny 1991). Over 800 000 individuals were estimated to inhabit Boma National Park in 1982/83 with population densities up to 1 000 per km^2 near food sources during the dry season (Fryxell and Sinclair, 1988). The endemic Nile lechwe (*Kobus megaceros*) also occurs in the wetland, with 30 to 40 000 estimated to have occurred in the wetland in the early to mid 1980's (Estes, 1991). Listed as Threatened by the IUCN, the Nile lechwe is subject to hunting and constrained by competition from cattle (Kingdon 1997; Seymour, 2001).

The Sudd is one of the most important wetlands for birds in Africa (Birdlife International, 2005). Of the four sections of the Sudd, the central Bahr-el-Jebel is thought to be the most important for birds (see Appendix 6 for a list of key/important bird species from this section of the Sudd). The wetland supports the largest population of shoebill (*Balaeniceps rex*) in Africa (Stuart *et al.*, 1990). Aerial surveys between 1979 and 1982 counted a peak of 6 407 individuals (Birdlife International, 2005). The endangered white pelican (*Pelecanus onocrotalus*) flies over 2 000 km from Eastern Europe and Asia, to overwinter on the floodplains of the Sudd (Seymour, 2001). The black crowned crane (*Balearica pavonina*), designated as Vulnerable by the IUCN (Newton *et al.*, 1996; Shmueli *et al.*, 2000), and also occurs in large numbers on the floodplains of the Sudd. The wetland is probably also important for *Aythya nyroca* and, on passage, for *Falco naumanni*. In addition to those listed in Appendix 6, three species characteristic of the Sahel biome (A03 – see Appendix 6) and five of the Somali–Masai biome (A08) have also been recorded (BirdLife International, 2005). As a result of these ecological values as well as because of its immense size, the Sudd is recognised as a region with significant wetland values that may merit consideration for world heritage nomination (IUCN, UNEP, WCMC and World Heritage, 2005).

According to Hughes and Hughes (1992), there are three designated game reserves in the Sudd. These are Zeraf Island (6 750 km^2), Shambe (1 000 km^2) and Mongalla (75 km^2). Boma and Badingilo National Parks also encompass portions of the Sudd. An assessment in 1999 showed that there was little to no level of protection or management in Boma and Badingilo National Parks at that time (East and IUCN/SSC Antelope Specialist Group, 1999).

Socio-economic environment

The proposed dyke extends over three counties: Duk, Twic East, and South Bor. People of three main tribes, Dinka, Nuer, and Shiluk[2] together with their livestock coexist in the Sudd wetland area. These people depend on the seasonal floods and rain to regenerate the floodplain grasses which feed their herds of cattle (Denny 1991). Fishing in the Sudd is also a means of livelihood (Mefit-Babtie, 1983, Fisheries Study Report). Other more seasonal activities include cultivation of crops and cutting of wood for building in the wet season and hunting, thatch and reed cutting and charcoal burning in the dry season (Mefit-Babtie, 1983, Background Report).

Land tenure is predominantly communal. The only available population statistics for the South Sudan dates back to the 1983 Census, which estimated 344,000 people in Bor area (DRS, 1983). The Bor population is projected to have reached about 500,000 in 2006 if the average annual growth rate of 2.25% recorded in 1983 has continued (DRS, 1983). Tentative estimates of population in the area suggest that about 300,000 people are now living in the three counties[3], including the 11,600 returnees who moved into the area over the past year. Current crude projections indicate that an equal number of people will return to the area over the next few years making a total population size of more than 600,000.

The dominant economic activity in the region is pastoralist grazing of cattle and smaller ruminants (sheep and goats) with limited subsistence crop cultivation. While no data are yet available on the current population of livestock in the area, using estimates of an average number of livestock per person in 1981 of 1.34 (DRS, 1983), one would expect the total size

[2] Other groups (e.g. Murle, Mandari and Fellata) are found in small numbers, especially during the dry season. Other minority groups in the area consist of traders and government employees.

[3] An alternative source (Mwangi, 2004) provides an estimate of current total population in Bor area of 450,000.

of the livestock population to reach more than 960,000 (800,000 cattle and more than 160,000 sheep and goats) as human population approaches the projected 600,000 in the area. These animals are grazed mainly on the rain-flooded grasslands to the east during the wet season and most (mainly cattle) then move westward to graze on the river-flooded grassland (*Toic*) during the dry season.

It is estimated that each household (average size of 8.2 people – Mefit (1978) is currently using about three Feddans[4] for subsistence crop cultivation. In addition to the need to clear grassland for cropping in the permanent settlement area (east side), the resettled population is expected to use significant wood resources for construction and energy purposes (firewood), which are currently scarce.

The settled communities also depend on the permanent and seasonal floodplains for harvesting other ecosystem services such as fish for direct consumption (fresh fish) as well as for commercial purposes (sun dried and salted fish). Earlier estimates of annual fish catch in the area suggest a total of 27,000 tons from the permanent floodplains, mainly for commercial purposes. In addition, fishing in seasonal floodplains by communities for direct consumption provides a valuable contribution to their diet, especially in the dry season with estimated yields of 31 g/m^2. This includes fish stranded in hollows, depressions, small pools and those in the deeper khor channels. When fish taken by birds is added this figure jumps to 58 kg/m^2 from seasonal floodplains (DRS, 1983).

Earlier studies also showed the importance to local communities of wildlife dependent on the floodplains' water and grazing resources. One major value is the contribution of hunted wildlife to the total meat consumption by the local population in the area, which is estimated at 25% (DRS, 1983).

Infrastructure and services

All social and economic infrastructures were badly rundown as a result of the long civil war in the area. With the prospects of peace and the re-habilitation and construction of the road system the number of Internally Displaced People returning to the area has been steadily increasing over the past year. A number of basic social services and institutions such as schools, health centres and water points began to function regularly. Marketing activities also started to come back with noticeable growth in the number of shops, restaurants (tea kiosks) and bars. The availability and variety of food and non-food items traded has also improved with livestock products, sorghum, maize, rice, beans, charcoal and wood and basic clothing items being the dominant commodities. Nevertheless, food shortages continue specially during the dry season and food aid through the UN World Food Program and other relief organisations remain an important source for many of the returnees. All towns and villages remain without basic power and water supply and sanitation services. Apart from cargo trucks bringing food and non-food items mainly from Kenya and Uganda bicycles remain the main mode of local transport (Ngugi, various socio-economic impact monitoring surveys 2004/05).

Interested and affected parties

The Dinka, Neur and Shiluk communities living in the area are the main interested and affected parties (I&AP). Local government institutions, international environmental NGO's

[4] One hectare is 2.38 Feddans.

and development assistance agencies operating in the region have expressed concerns about the likely negative impacts of the Bor counties' RDRP activities.

3. Approach to the Bor Dyke EIA Study

The WFP Southern Sudan Project managing the Bor Counties' *"Road and Dyke Rehabilitation Project – RDRP"* commissioned this EIA study to be coordinated by the Centre for Environmental Economics and Policy in Africa (CEEPA) of the Faculty of Agricultural and Natural Sciences of the University of Pretoria in South Africa. CEEPA's involvement started after a preliminary scoping exercise of a team of experts directly recruited by WFP (Echessa, et al., 2004). Upon appointment as the EIA study coordinator, CEEPA undertook a second phase activity involving stakeholder consultation, pilot expert assessment of the key issues identified by the initial scoping exercise and planning for the full EIA (CEEPA, 2004). The phase II activity consolidated likely major impacts of the dyke project into four key areas that require commissioning of technical specialist studies, developed terms of reference for those and plans for implementing the full EIA study.

The WFP project management accepted CEEPA's recommendation to adopt EIA Guidelines of The Republic of South Africa (RSA) as no similar guidelines were issued yet by the Government of Sudan. This EIA study was therefore conducted in accordance with the RSA Guidelines for integrated environmental management-IEM (DEA, 1992). In addition, the EIA observed the donor (USAID) requirements for environmental assessment of foreign assistance projects as stated in chapter 1.

The EIA was conducted in close collaboration and consultation with the WFP South Sudan Project Management, The project implementing agency GTZ-IS, local government authorities in Bor (which were at the time under the Sudan's People Liberation Movement-SPLM), local communities, NGO's and development assistance agencies operating in the area. Specialists with the required competence in the identified four key likely impact areas were recruited to develop adequate understanding of the technical aspects involved and assess significance of the identified impacts and propose appropriate measures for mitigation of negative impacts and enhancement of positive project consequences. The specialists' reports were subjected to external independent technical reviews and public consultations. The outcomes of specialists' studies together with technical reviewers' comments and public consultations views are integrated in this EIA report.

3.1 The scoping phase

A scoping study was conducted during April 2004 to identify the significant issues relating to the proposed road and dyke project and to determine the scope of the issues to be addressed in a subsequent EIA study. The full scoping phase report (Echessa, et al., 2004) is found in Annex 1. Relevant issues identified by the scoping study are summarised below.

1. *Soil degradation*

   Soil erosion on short-term basis is expected to result from earth-moving activities during rehabilitation that will expose the soil to erosion. Removal of natural land cover, excavation, extraction of construction materials and other construction-related activities can result in sheet and gully erosion. The fact that road/dyke will be elevated in some areas implies increased steepness of slopes raising the potential for erosion. The use of heavy machinery and equipment may also result in soil compaction, changing surface and ground water flows and adversely affecting future use for agriculture. The ponding of

water on the soil (e.g. in borrow pits) could increase the acidity, salinity, and anaerobic organisms in the soil. Erosion can, in turn, lead to sedimentation in receiving waters. Sedimentation may reduce the capacity of ponds and reservoirs, increasing flood potential, or substantially alter aquatic ecosystems by changing streambed, lakebed and estuary conditions. Over the longer term, if erosion persists, it will result in reduced topsoil depth, which will affect soil water and nutrient holding capacity of crop soils and favorable soil structure for root development. Colonization of the dyke banks by woodland is expected to occur as happened along the raised banks of the unfinished Jonglei Canal. This would require routine maintenance and removal of woody species and cultivation of appropriate native vegetation for soil erosion control on the dykes and the sides of the roads.

2. Degradation of water quality

Water quality may also be damaged by soil erosion and the siltation of nearby rivers, streams, lakes and wetlands. The establishment of semi-permanent camp sites with offices, equipment stores, fuel depot and workshop facilities could cause negative impacts due to accumulation of solid waste, disposal of used machine oil, disposal of human waste, etc. Ground and surface water may also be contaminated from machinery repairs that result in spill or dumping of hydraulic oil, motor oil or other harmful mechanical fluids. These may harm the health of a local community, as well as the populations living downstream. Where sanitary facilities for the construction crew are inadequate, human waste may contaminate water.

3. Altered hydrology

Roads traversing areas with high water tables or wetlands may act like dams to block surface and sub-surface water flows. This is particularly true where large quantities of initial material must be added to raise the road above the land surface, and where new material must be added annually to keep the road/dyke elevated, as is the case with this project. Under these circumstances, land on one side of the road/dyke can become much wetter than it was before improvement, while land on the opposite side may be drier. This may adversely affect crop production, the composition of species in the local ecosystem, and road/dyke stability. Alternatively, poorly installed culverts in wet areas may concentrate water and then form gullies upslope and/or down slope of the road. These gullies can subsequently drain the area and contribute to drying up the wetland.

4. Conversion of grazing land

The dykes and part of the raised road system may have some minor ecological effects, notably, the blockage of the creeping flow, which may lead to a strip of seasonal swamp on the eastern side vegetated by *Echinochloa pyramidalis, Oryza longistaminata and E.Stagnina*; on the western side there would be a rise in the water level which might become permanent and could result into submersion of the dry season grazing land.

The river-flooded grassland – the *toic* (on the western side) where seasonal inundation produces grasses under a natural system of irrigation, are an absolute necessity for the pastoral component of the economy, necessary for dry season grazing. Wildlife tends to concentrate in these regions for the same reason that the cattle are driven there, for grazing and water.

5. Damage to wetlands

New roads, or the rehabilitation of the existing roads, may disrupt the integrity of plant and animal populations and permanently alter sensitive ecosystems. Road construction/rehabilitation or maintenance activities can involve the construction or rehabilitation of ditches and drainage structures to allow the rapid passage of rainwater runoff. Such structures can channelize the flow of water, change drainage patterns, and change the in situ hydraulic gradients at most locations along the road. This may result in impoundments and flooding, or the drainage and subsequent loss of naturally occurring ponds or wetlands. There might be some reduction in the numbers and therefore quantities of certain species of fish especially the *Heterotis*, *Gymnarchus* and *Glorias*. These are the species that make extensive use of the breading grounds afforded by swamp and floodplain habitats. The dyke will accumulate the flood water of the Nile, which may lead to the colonization of the *toic* by the water hyacinth and in the process also affect the fishery. The fish may die from deoxygenating.

6. Species and habitat loss

The widening, realignment and raising the levels of roads and dykes may modify the habitat of species including endemic, threatened and endangered plants or wildlife. The attraction of strip settlement along the road could further confine wildlife into areas, which may not be ecologically viable habitats. Increased pressure from hunting could also result from such secondary settlement activities. The dykes may also inhibit the movement of people and livestock to some extend. For the wildlife notably the migratory *tiang*, there is a possibility that the establishment of engineering structures could disrupt their migratory routes in addition to exposing them to greater hunting.

7. Human health issues

Vector borne diseases: Malaria is endemic in the project area. Hydrologic changes, resulting from road/dyke rehabilitation can lead to significant increase in mosquito breeding sites increasing the risk of water borne diseases such as cholera or malaria increases.

Water contact disease (schistosomiasis): Although schistosomiasis has not been known to be endemic in the project area, it is worth noting it can occur owing to the prevailing environmental conditions (standing waters).

Spread of communicable diseases: Road improvements increase communication among rural and urban populations. This in turn increases the potential for exposure to sexually transmitted diseases (including HIV/AIDS) and other communicable diseases such as tuberculosis. Although no data exists on HIV/AIDS prevalence in southern Sudan, prevalence among tea sellers in Juba town is estimated at 10% (Mwangi, 2004). No information in Bor area was available but it is possible that prevalence in the south could even be higher due to conflicts, frequent movement across borders, severe economic disparity and poverty. An influx of construction workers from other regions/countries and the improved road may introduce new diseases to the local population or increase the incidence of the local infection.

8. Social issues

Equitable distribution of the benefits road/dyke improvements and an assurance that the environmental impacts do not disproportionately burden the least powerful members of the community are required.

Land tenure in the project area is largely communal. Conflicts related to land use rights, particularly over grazing lands are is likely to be exacerbated by the construction of the dyke, which may reduce the *toic*. This matter is expected to be compounded by the anticipated return of about 1 million head of cattle from Western Equatoria (Mundri Counties) to Bor area, and could be a source of conflict among villages. It will be important to ascertain how disputes related to such conflicts are resolved. It is also worth noting that conflicts will arise whenever there is competition for scarce water and/or grazing as well as other resources between different tribes in the project area. Any change in the availability of water, pasture and other resources such as fisheries arising from dyke/road rehabilitation requires consultation to ensure equitable sharing and to avoid conflict.

9. Deforestation

The deforestation threats are unlikely to arise from dyke/road improvement activities since these activities will be largely restricted to the existing road/dyke. The major limiting factors to the growth of trees in the area have been seasonal water logging, flooding and the cracking clay soils. Only a few species can withstand these conditions. Even though road/dyke improvement may not have direct significant impact on woody vegetation, the indirect impacts are likely to arise from the anticipated resettlement of returnees to the project area as a result of increased demand for the construction material and wood fuel.

10. Invasive plants

The water hyacinth has infested the River Nile from Juba to Jebel Aulia as well as its tributaries and Sudd swamps (Philip *et al.*, 1983). Construction of the dyke will raise the level of floodwater on the western side leading to the submerging and killing of indigenous vegetation and colonisation by the water hyacinth weed with its well known many negative consequences.

11. Other issues

The scoping study found impacts such as displacement of inhabitants, culture shock, noise and air pollution, traffic and construction works hazards, vibration, and damage to sacred and historic sites to be of no significance.

The scoping study concluded that a full environmental assessment would be justified. The study therefore recommended that consultative process to continue engaging involved government, community, and project implementing and donor agencies in reviewing the prepared scoping report and planning for a full EIA. The scooping study proposed the following process forward.

Interim Period: During which the EIA team leader be appointed to prepare the scope of work for personnel of various disciplines to be involved in EIA based on this scoping statement and to develop a tentative schedule for field visits; firm up the budget; identify and acquire additional pertinent reference materials; and, recruit members of the team.

EIA Implementation Period: The proposed period of implementation of EIA will be about one year beginning September 2004. Three phases are envisaged in EIA process: i) two months of identification and review of additional relevant literature of the project area as well as literature related to dyke/road rehabilitation; ii) eight months of data collection and analysis; and, iii) two months of report preparation.

Post-EIA Process: After the EIA has been approved by the BEO the document will be distributed to all interested parties, including cooperating partners, USAID, SPLM, other donors and non-governmental organizations. Follow-up activities such as training will be discussed at this time as well.

The scoping study recommended a multi-disciplinary EIA team approach, including joint preparation for site visits (identification of key issues and their interplay); interviews; comprehensive screening of guidelines for each site to ensure that all issues are covered and team responsibilities for coverage are clearly understood; post-visit wrap-up and review sessions; and, focused inter-team discussions to identify mitigation and monitoring actions. The following disciplines were identified for participation in the full EIA assessment:

- Project Manager / Team Leader
- Hydrometerologist / Geographer
- Anthropologist
- Social Economist
- Wetland Specialist
- Wildlife Specialist
- Any other specialization deemed necessary.

3.2 Initial stakeholder consultation, expert assessment and planning for the full EIA

Following the completion of Phase I (Scoping Study – Echessah et al., 2004) in May 2004, a second task (Phase II) was defined in consultation with the Centre for Environmental Economics and Policy in Africa (CEEPA), USDA and GTZ to precede the implementation of the full EIA study. Phase II was seen as an essential pre-requisite for successful launching of the EIA activities to achieve the following objectives:

1. Present to and discuss the findings of the scoping study with interested and affected parties (I&AP) and stakeholders in the project area to confirm and augment the list of issues on major impacts of the Dyke system on people and their natural and economic environment identified by the study;
2. Conduct a quick pilot onsite expert assessment of the issues identified by the scoping study and I&AP to better define the scope and focus of the planned EIA study by concretizing areas of major impacts and risk to be adequately addressed;
3. In light of the knowledge generated in 1 and 2 above, identify the required expertise for conducting the EIA and accordingly develop concrete terms of reference (TOR) for the consultants implementing the various components of the study.

Based on the scoping study findings a team of experts was formed to conduct Phase II. The composition of the team was guided by the type of expertise needed to investigate the significance of the areas of major impacts identified. The team included wildlife management specialist, wetland ecology expert, agricultural economist, hydrology and numerical modelling engineer, and a natural resource management and environmental economics and policy specialist.

The team reviewed numerous background documents of relevance to the Dyke project and met in Nairobi for one day to plan for a three-day visit to the project site. The team then spent three days (June 30-July 2nd, 2004) in the field. During the field visit, the team conducted aerial and ground inspection surveys of the road and Dyke system in South Bor and Twic East Counties up to the Jonglei Canal area. During the visit, the team held meetings and interviewed a number of I&AP including:

1. Executive Secretary and Deputy Commissioner of Twich County
2. SRRC staff in Padak and Mabior
3. Other community leaders in Padak and Mabior
4. A number of NGO's operating in the area including WFP, GTZ, CARE among others
5. Bor counties' Road and Dyke project staff

The team then spent another day developing the EIA implementation plan and TOR for its components and preparing the Phase II draft report, which is found in Annex 2. The findings and recommendations of the Phase II report are summarised below.

3.3 Key issues and risk areas of the Dyke system impacts

Key issues are taken to further detail in the respective major impact areas to gain a better understanding of the nature and complexity of these impacts and to guide a more focused definition of the scope and TOR for the specialized full EIA studies to be undertaken.

A. Hydrological impacts and consequences for wetland functions

River flooding is the key factor influencing the biophysical environment and socio-economic systems in this wetland area. The dyke intervention is expected to alter existing hydrological regimes (particularly the depth and duration of flooding) influencing the dynamics of the grassland systems in the floodplains with significant impacts on prevailing ecosystems and associated economic and social life. The major consequences and impacts of these hydrological changes include:

1. Availability of water to people and their livestock as well as wildlife during dry season, including possible impacts on sub-surface water resources;
2. Particularly the river-flooded grassland adjacent to the dyke and to the east of the dyke will be affected. This includes changes in the origin, depth and duration of inundation on both the eastern and western side of the dyke with probably increased water levels on the western side, and floodings decreased in depth and extent on the eastern side with river floods being blocked off and rains being the only water resource for that area. This has consequences for plant species composition and succession;
3. Changes in the plant species composition and structure in the affected sections of the wetland has important consequences for indigenous fauna (including avifauna and

ichthyofauna). For instance, higher levels of floodwater on the western side of the dyke are expected to increase the depth and duration of inundation leading to colonization of the *toic* by less palatable hydrophytes associated with more permanent water and invasive plants such as the water hyacinth causing loss of current indigenous grass vegetation and negatively impacting the fisheries; (The duration of flooding will not necessarily be longer as the flood wave can be expected to be steeper but shorter. Duration of flooding is a composition of upstream rainwater runoff, downstream water levels of tributaries and rains in the area itself)

4. Drying of the river-flooded grassland to the eastern side of the dyke is likely to affect growth rates and hence productivity of the grasslands and this will also have consequences for dry season and dry year grazing of livestock and wild game;
5. Protection against river flooding is also expected to change vegetation to more woody species on the eastern side of the dyke, where people will be settled. This may lead to improved supply of timber for firewood and construction purposes;
6. There may also be a loss of breeding habitat for fish species occurring in the wetland system due to the drying out of the seasonally flooded grasslands to the east of the dyke and this is likely to have negative consequences for the ecosystem as well as fisheries;
7. Cutting off of sediment supply to the river flooded grasslands and other parts of the wetland to the east of the dyke may also have consequences for the geomorphology and dynamics of the wetland as well as soil fertility;
8. General wetland habitat loss and changes.

B. Impacts on grazing resources and livestock productivity

The hydrological impacts induced by the dyke intervention are likely to lead to changes in the structure and dynamics of the vegetation in both river-flooded and rain-flooded grasslands in the affected area. These ecological changes will have important implications for the quantity and quality of grazing resources and hence plant nutrients available for livestock and wild game dependent on these resources. The productivity of grazing animals in terms of growth rates, weight changes and milk production are very strongly influenced by the quality and quantity of grazing resources in the floodplains. This in turn is expected to have important implications for the local economy and livelihoods of the people in the affected areas that are highly dependent on the health and productivity of their livestock population and supplementary game food. The various ways in which ecological changes caused by altered flooding regimes affect the quantity and quality of grazing resources and hence livestock productivity include the following potential impacts of significance to the welfare of the local population:

1. The extent of areas protected from seasonal river-flooding as a result of the dyke system determine land available for permanent grazing and crop cultivation with consequences for carrying capacity and supplementary feed from farming;
2. Plant species composition in both protected (dried) and river-flooded areas is expected to undergo significant botanical changes in response to changes in flooding regimes affecting the depth and duration of flooding;
3. Changing grassland species composition directly influences the quantity (biomass production) and quality (nutritional value) of grazing resources;
4. Grazing animals respond to such changes through important adjustments in feeding strategies, growth rates, body size and weight and milk yield among other adaptive changes depending on reared animal breeds;

5. Increased interaction and contact with wildlife during the dry season quest for water and grazing resources leading to higher incidence of transmission of animal diseases.

C. Key impacts on wildlife

Wildlife is an important resource to the people in the entire Upper Nile Region and particularly in Twic East and Bor Counties, which if well conserved and properly utilized could bring large economic benefits to the inhabitants of the area now and in future. As a major land use competitor, wildlife gets affected positively or negatively whenever there are alterations to land use irrespective to how small the alteration may be. Among the expected impacts on wildlife are the following:

1. The widening, realignment and raising of levels of dykes may modify the habitat of species including endemic, threatened and endangered wildlife;
2. Attraction of strip settlement along the dyke system could further confine wildlife into areas which may not be ecologically viable habitats;
3. Increased pressure from hunting could also result from such secondary settlement activities and increased competition for water and grazing resources and hence contact with pastoralists during the dry season;
4. The dykes will also inhibit the movement of wildlife, notably potential disruptions of migratory routes in search for grazing resources and paths to breeding grounds in addition to exposing them to greater hunting pressure.

D. Key socio-economic impacts

The planned dyke reconstruction will substantially affect many aspects of the life of Bor area people and the functioning of the ecosystems and the natural resource base on which they depend. All I&AP confirmed that the dyke system is a desirable intervention that brings many benefits provided that some negative consequences are prevented or mitigated. The benefits resulting from the dyke system are mainly realized during the wet season, which include:

1. Protection of homesteads, people and their livestock and grazing lands from the adversities of seasonal river flooding;
2. This will also imply that as a result larger land areas will be available for permanent settlement of people and their livestock as well as for crop cultivation during the flooding;
3. Reduced exposure to, and hence incidence of, water borne diseases that severely affect peoples' health during flooding;
4. Favorable changes in vegetation to more woody species and hence improved availability of timber resources for the settled communities;
5. Favorable effects of higher water levels on the western side supporting additional fishing in supplement to the main fishing activities on the Nile itself.

On the other hand, the dyke system will cause significant disruptions to a number of ecosystem functions as identified above that have consequences for the livelihood of the local communities mainly during the dry season. The major impacts of the dyke system include:

1. Reduced access to water and grazing resources for people and their livestock and wildlife during the dry season with implications for increased competition for, and longer distances to reach, these scarce resources during the dry season;

2. Changes in grassland vegetation to lower quality species and lower biomass production and hence lower productivity of livestock and food supply, especially from cattle, the backbone of the local economy. This also has implications for pastoralists' livestock management strategies in response to such changes in availability of water and grazing resources, including changing grazing routines and movement of animals, herd size and slaughtering, length of lactation and off-take strategies;
3. Disruption of wildlife migration routes during the dry season and the consequent increase in competition with domesticated livestock for the limited dry season resources to the east. This is also expected to increase hunting and loss of wildlife;
4. As a consequence of drying the eastern side of the dyke systems (where permanent settlements will locate) other services of the wetland ecosystem are lost, which include:
    a. Availability and access to seasonal fishing during dry season
    b. Sediment deposition, which will also affect grazing land productivity
    c. Availability of grass and thatch for building homesteads
5. Disruption of wetland ecosystem functions that may have other long term consequences on the environment and in turn the wellbeing of people in the area (loss of fish, wildlife and bird habitat)

V. Needed specialists' studies

According to the key impact areas identified above, the following five specialists' EIA studies were considered necessary:

6. Hydrological impacts' assessment
7. Assessment of impacts on wetland functions including fisheries
8. Impacts on grazing resources and livestock productivity
9. Impacts on wildlife
10. Economic and social impacts' assessment

In addition to the five specialized studies an integrated environmental impact assessment report was specified, to synthesize and integrate the various specialized components of the EIA. The general and specific guidelines and TOR for the needed studies are presented below.

3.4 Terms of Reference for the specialists' studies

A. General guidelines and common TOR

All specialists working on the various components of the EIA study will be required to observe the following general guidelines:

1. Be mindful of the fact that the ultimate purpose of the EIA study is not to decide whether the project is to be undertaken or not but rather to produce scientific and objective assessment of the significance of the potential impacts of the project and risks involved and identify and propose mitigation measure for reducing negative impacts and enhancing positive effects that will assist concerned decision makers' judgment;
2. Carry out the assessment activities described in this report and the scoping statement prepared as a prelude to this EIA as relevant to their specialized tasks;

3. Participate in the study as an integral part of the multidisciplinary team of experts leading or involved in carrying out the various components identified above under the direct supervision of the Team Leader and Coordinator of the study;
4. Take note of the interdependencies between the impacts identified and pay careful attention to the strong connectivity between all components of the study in conducting their specialized assessments with the purpose of providing input into other specialists' assessments as necessitated by the overlapping nature of the TOR for the different components of the EIA;
5. Participate in multidisciplinary meetings and discussions and interact and share information with other specialists as much as possible in the course of conducting searches of relevant literature, field visits and actual impact assessments;
6. Ensure that key questions developed as essential to their part of the analysis are discussed with the team leader and other team members in preparation of site visit protocols and are discussed during field visits, as pertinent, with key stakeholders on the ground who will be asked to give their frank assessments of the impacts of the project;
7. Contribute to the consultative process essential to the satisfactory conduct of the EIA by taking the lead in identifying other individuals (relevant government, non-governmental, cooperating sponsors), as concerns his/her particular specialized area and maintain a record of those interviewed for inclusion in the EIA report as corroboration of public consultation;
8. In conducting their specialized assessments, expert reports should make quantitative analyses, to as much as data availability allows, and qualitative assessment of:
    a. The scope, extent, magnitude, significance and duration of potential impacts identified in the key issues section and specific TOR in respective sections of this document
    b. The level of risk involved, at least qualitatively in terms of whether each impact represents low, medium or high risk to the environment and society
    c. The degree of confidence in results and conclusions arrived at
9. Identify alternative options and measures for mitigating potential negative impacts and enhancing positive outcomes of the project and based on which develop environmental management and monitoring plans (EMP) to guide the redesign and implementation of the project.

B. TOR for the hydrological impacts study

1. Use appropriate numerical modelling and spatial analyses and mapping techniques to:
    a. Determine the extent, depth and duration of flooding under current dry and wet seasons' conditions as well as different flooding scenarios
    b. Assess the impact of the proposed dyke intervention as currently designed on the extent, depth and duration of flooding on both sides of the dyke during the dry and wet seasons
    c. Identify alternative designs/structures of the planned dyke that would reduce its hydrological impacts and accordingly assess and predict impacts on the extent, depth and duration of flooding on both sides under alternative design options
    d. Identify key low-lying corridors (with potential to work as main irrigation channels) in the east-west distribution of the wetland and river-flooded grassland to inform alternative dyke structural designs and operations for reduced impacts on access to water and grazing in the dry season and the

consequences of that for people, livestock, wildlife, fisheries and the general functioning of the affected wetland ecosystem

   e. Assess the impact of the current and alternative designs of the dyke on ground and surface water resources, particularly on the east side during the dry season
   f. Determine different typical scenarios for structure operation and failures

2. Implementing task 1 will require the use of a numerical model capable of characterizing the hydrodynamics of flooding in the affected area (in the appropriate cell size and time steps) and of predicting impacts of alterations to existing landscape caused by the dyke intervention. Such a model will need to be complemented by spatial analyses tools to capture the spatial dimensions of potential hydrological changes. As a base for setting up the model environment a digital elevation model (DEM) refined with raster survey data for specific ground disturbances not captured by the DEM grid will be necessary. This will also require bathymetry data, cross sections and longitudinal sections of the Nile, which could be acquired from historical sources or measured using echo sounding methods. Moreover, bed forms, bottom roughness and the vegetation have to be taken into account to describe the friction resulting from the stream boundaries and vegetation growth in the whole water column in many places. This will accordingly require comprehensive literature surveys and investigations to select and adapt the appropriate modelling and spatial analytical techniques to be used in support of assessing the potential hydrological impacts identified above.
3. Use the selected model to generate output data in the form of maps and time series for specific and representative locations over certain periods. Such output data will include:
   a. Area flooding by inflowing river waters from upstream rain events
   b. Area flooding by blocked river waters by downstream rain events
   c. Area flooding by local rainfall events
   d. Mapping of different flooding extents under specific scenarios
   e. Calculation of water levels and flows
   f. Flooding and drying of areas
   g. Overland sheet flow
   h. Evaporation
   i. Resistance to flow due to vegetation cover
   j. Structure operation like open culvert and gate flow
   k. Structure failure like overtopping and dyke break
4. Assess potential hydrological and fluvial impacts (in terms of above listed output data) under alternative dyke structure and operation options
5. In consultation with wetland, wildlife, livestock and socio-economics specialists identify alternative dyke structure and operation options to mitigate the identified potential negative impacts on:
   a. Access to grazing and water resources in the dry season
   b. The biology of rain-flooded and river-flooded vegetation (species composition, etc.)
   c. Wildlife migration routes during the dry season
   d. Availability and access to seasonal fishing during dry season
   e. Sediment deposition
6. Develop sound environmental management and monitoring plans (EMP) under the alternative dyke structure and operation options

C. TOR for the wetland impacts study

1. Undertake a comprehensive literature review of all relevant documentation pertaining to the wetland system and provide a summary report dealing with those aspects relevant to the construction of the dyke system;
2. Using available satellite imagery, identify and map the extent and distribution of wetland habitats and plant communities in the area that will be affected by the dyke system. This must be done in a format comparable with the spatial analysis tools used in the hydrological and other studies (preferably using ArcView) and in accordance with the vegetation community classification provided in the background Vegetation Study Report Vol. 3 (JEO, 1983). The accuracy of, and confidence in, the mapping must be provided;
3. In consultation with GTZ and the hydrologist on the project, determine the area of wetland (including river-flooded grassland) that will be affected (cut off) by the dyke and quantify the area of the different wetland plant communities associated with this;
4. Determine the likely changes in plant community composition, structure and distribution in the wetland area affected by the dyke;
5. Quantitatively establish the likely changes in the productivity of the vegetation in the wetland areas (including the river-flooded grassland) affected by the dyke;
6. Establish the likely dry and wet season and dry and wet year consequences of the changes in the productivity of the vegetation for livestock and wild game. This must be done in consultation with the livestock, wildlife and socieconomics experts on the project team;
7. Establish the role of sedimentation in determining the productivity of the wetland system (including the river-flooded grassland) and what effect the dyke will have on sedimentation in the affected areas of the wetland;
8. Establish the natural dynamic of the wetland system based on the key drivers/processes in the system and indicate whether or not there is evidence of a trajectory of change outside the bounds of the natural dynamic. Describe any such trajectory and provide suitable motivation for this. It will be important to consult with the hydrologist on the project as well as other team specialists in this regard (including the wildlife and fish specialist);
9. Establish the importance of the river-flooded grassland and particularly the seasonal and longer-term dynamics in the system, for the breeding cycles and productivity of fish species that are found in the wetland. Particular attention should be paid to those species that comprise the fisheries in the area;
10. Establish the impact of the dyke on the fish populations given the findings from 9 above. Ensure that the findings are made available in a format that can be used to assess the affect on the fisheries in the area;
11. Establish the importance of the Mabior Gol in particular, as well as any other key low lying east-west hydrological corridors, in terms of all of the above;
12. In consultation with the hydrologist on the project and using input data from the hydrological modelling (river as well as rain fed flows), produce a scenario assessment (that must include a spatial component) to identify suitable environmental mitigation for the dyke alignment and design. This must be based on an integrated assessment of all the aspects addressed above. Note that while this must be based on the proposed alignment and design, alternative options should be considered as well.

D. TOR for the wildlife impacts study

1. Identify and document the major and most important wildlife species that are likely to be affected by the project;
2. Assess the nature of the project impacts on the identified species;
3. Record the migration routes before the construction of the Jonglei Canal and now in the dyke project area;
4. Assess how existing routes are likely to be affected during and after the project?
5. Assess the impact of disrupting migration routes on the wildlife populations and their distribution (area and habitat);
6. In consultation with other specialist team members, assess the impacts of changes in access to water, grazing resources and the quality of the vegetation during the dry season on wildlife productivity;
7. Assess the impacts of human and livestock population settlements in the area on the populations and distribution of wildlife;
8. Identify and propose suitable measures for mitigation of the potential negative impacts of the dyke on wildlife under the alternative design and operation options considered;
9. Suggest an environmental auditing plan to monitor compliance with the proposed mitigation measures and evaluate their effectiveness during and post-implementation of the project.

E. TOR for the study of impacts on grazing resources and livestock productivity

1. Using input data from the hydrological, wildlife and wetland impacts studies' results, assess and quantify (including spatially) the impacts of the dyke on:
    a. Land area available (dried) for permanent grazing and crop cultivation
    b. Extent and nature of changes in quality and productivity of grazing resources and consequences for livestock productivity
2. Assess the potential impacts of changes in wildlife movements and distribution patterns on transmission of animal diseases to livestock;
3. Identify suitable mitigation measures to manage the potential negative impacts of the dyke under alternative design options;
4. Contribute suggestions to the development of an environmental monitoring plan to audit implementation of recommended mitigation measures and their effectiveness.

F. TOR for the socio-economics impacts study

1. Using input data from all other specialists' studies and own surveys and other sources of information required, assess and quantify the economic costs and benefits of the dyke to settled communities and the society at large. This will involve the use of appropriate environmental valuation techniques to measure:
    a. Direct and indirect economic benefits, which include:
        i. Protection to people and their livestock from flooding
        ii. Availability of land for permanent settlement and grazing
        iii. Reduced exposure to and incidence of water borne diseases
        iv. Favorable changes in vegetation to more woody species
        v. Favorable effects of higher water levels on river flooded areas supporting additional fishing
    b. Direct and indirect economic costs including:

        i. Reduced access to water
        ii. Reduced access to grazing resources
        iii. Unfavorable changes in vegetation and livestock productivity
        iv. Unfavorable changes in wildlife population and its distribution
        v. Availability and access to seasonal fishing
    c. Non-market environmental values such as:
        i. Cutting off of sediment supply
        ii. Lost ecological functions of wetlands including change and loss of fish, bird and wildlife habitat affecting breeding and productivity
2. Identify suitable mitigation measures to manage the potential negative impacts of the dyke under alternative design options. This will require an assessment of the needs of the communities to be settled, which will consequently necessitate estimation of the expected size of the population and their livestock to be settled in the area and their needs in terms of the various environmental services of wetland and grassland systems including building material and wood fuel requirements, etc.;
3. Contribute suggestions to the development of an environmental monitoring plan to audit implementation of recommended mitigation measures and their effectiveness;
4. Assess other social impacts of the dyke such as tribal conflicts as related to potential disputes over land, water and grazing resources.

VI. TOR for the Integrated Impact Assessment Report

A key aspect often overlooked in a comprehensive study of this nature is the requirement to ensure that the individual specialist and/or specialist components:

- Talk to one another on a regular basis;
- Develop their projects with a similar format, style and structure;
- Use the same rating scales for assessing impacts;
- Work on, or according to the same spatial base maps;
- Use the same glossary of terms and definitions in order to prevent any misunderstandings in the interpretation of the findings and assessments;
- Make their data available in formats that can be used by other specialists on the project team; and
- Cross-reference and link well.

It is therefore critical to ensure that the project as a whole integrates well and that gaps and overlaps between individual projects or specialist components are minimized, boundaries and scales at which each project operates are clarified, schedules are met and that deliverables are staged based on the requirements of the different specialist studies and the overall project. During this study for example, many of the specialist studies will depend on the outputs of the hydrological study, which in turn also requires input from the various specialists. It is therefore anticipated that for each specialist study, team members will be required to identify the following in order to ensure coherence between the components and that the data are presented in a format that can be used by the other team members:

- Outputs (what products or deliverables would be forthcoming when);
- Outcomes (what these products or deliverables would achieve and which specific ToR would they address); and

- Linkages (what information will be needed from other specialists/components, and also what information each study would supply to other specialists).

Developing the integrated report is thus as much about project management as it is about specialist study integration. Ultimately, the end product should form a coherent synthesis of the findings and recommendations of the various studies. It is anticipated that in addition to general project management, at least two project team workshops will be required to achieve this.

The report also developed time frame and plan for implementing the full EIA study.

3.5 The EIA study team

Couple of changes have been made to the above plan due to budgetary constraints expressed and the difficulty with finding the appropriate expertise within the set time frame set by the funding agency for completion of the EIA study. First, the impact on grazing resources and livestock productivity was added to the wetlands and fishery study component. Second, the social impacts' component planned for addressing communal and land-tenure issues could not be implemented. This led to forming the following team of specialists for conducting the EIA studies integrated in this report and presented in the appendices.

Table 1. Bor dyke Environmental Impact Assessment team of specialists

Name	Speciality	Institution/affiliation
A. Batchelor (PhD)	Wetlands ecology	Wetland Consulting, Pretoria
P. Echessah (MSc)	Agricultural economics	Independent consultant, Kenya
R. Hassan (PhD)	Environment. economics	CEEPA, University of Pretoria
L. Ipoto (MSc)	Ecologist	Independent consultant, Sudan
C. Lo-Liyong (MSc)	Environmental science	WITS University, RSA
G. Marneweck (PhD)	Wetlands ecology	Wetland Consulting, Pretoria
E. Mungatana (PhD)	Environment. economics	CEEPA, University of Pretoria
G. Petersen (MSc)	Hydrologist	World Food Program
M. Rountree	Wetlands hydrology	Wetland Consulting, Pretoria
R.J. Scholes (PhD)	Ecologist	CSIR, Pretoria
M. Thompson	Environm remote sensing	GeoTerralImpage(GTI), Pretoria
G. Wahungu (PhD)	Wildlife ecology	Moi University, Kenya
P. Kuot Jel	Hydrologist	World Food Program

3.6 Assumptions and limitations

The EIA made the following key assumptions:

1. The project will be implemented according to the specifications provided to the team, that is, an earthen dyke with a grassy cover, about 2 m high, 14 m wide at the base and 4 m wide at the crest, about 100 km long stretching from Padak (approximately 25 km north of Bor) towards the north, ending some 20 km northwest of Mabior town. Two

options were considered, one of which crossed the Mabior Gol, while the other skirted around it

2. That the population of the affected region will reach approximately 600,000 people and 1 million livestock, as a result of returning displaced people
3. That the flow records available for the Nile River are a reasonable reflection of future flow. Large fluctuations in Nile flow since the 1950's, and still-uncertain projections of climate change in the region in the coming century, make this a suspect assumption, but one that must be made in the absence of other firm indications
4. That for both alignment options 1 and 2 the entire river flooded grassland to the east of the dyke would no longer be flooded at any time, meaning that the depth, frequency and duration of inundation of these grasslands to the east of the dyke would be reduced to zero from river flooding. All connectivity with the river will be lost behind the dyke
5. That there would at least be some rain flooding of the river flooded grassland to the east of the dyke for both alignment options, but that the extent and magnitude of this would be insufficient to maintain the dominant river flooded grassland plant species
6. As a consequence, all the biomass and productivity estimates have been based on a complete replacement of river flooded grassland species with rain flooded grassland species

The principle limitations of the EIA are:

1. Sparseness of datasets relating to virtually all aspects of the study. In particular, the hydrological regime is not known from observations, so it had to be modelled using flood stage data from the Nile.
2. The digital elevation model used in this process was the best available, but in this flat landscape, lacks the vertical resolution and accuracy to reliably predict the area and duration of flooding.
3. Another key gap relates to nutrient budgets and balances
4. Partial understanding of key processes operating in the study area. The study area is an isolated region in a part of Africa that has not attracted a large number of scientific researchers. Details about the ecological and social processes operating there are speculative, especially with respect to long-term processes
5. The fate of floodwaters that will be displaced by the dyke is unknown. It is possible that rain-flooded grasslands to the west of the main Sudd system may now be flooded by the river, leading to possible expansion of the wetlands into previously terrestrial areas.

4. Impact Assessment and Mitigation

4.1 Introduction

The assessments carried out by the specialist teams all followed the same format, as specified by the EIA coordinators in accordance with the environmental impact procedures adopted (DEA 1992). Following a description of the processes and issues involved, they were required to tabulate each identified impact, along with the spatial scale of the impact, its expected duration, the degree of certainty that it would occur, its significance (with and without mitigation) and note the nature of the mitigation. An important feature is the use of standardised language for spatial scale, time scale, certainty and significance. The rating scale is a compromise between complexity (in which results become hard to grasp) and over-simplification (which produces dubious results). Four introductory notes are important in making sense of, and using, the notion of scale:

1. The scale embraces the notions of extent and magnitude, but does not clearly define these since their importance in the rating scale is very relative. For example, the magnitude (i.e. the size) of the impact (area effected by the dyke) may be large (1000 km^2) but the significance of this effect is dependent on the effects on the depth and duration of flooding. If it is great, the significance would be <u>high</u> or <u>very high</u>, but if diluted it would be <u>low</u> or <u>very low</u> even though the same area is affected, i.e. the magnitude or extent is the same. Likewise, if say for example 600 ha of flooded grassland is to be destroyed, the impact would be <u>very high</u> if only 1000 ha of that grassland type occurs in the wetland but would be <u>very low</u> if the grassland type was common. The significance is therefore not always dependant on the magnitude of the effect/impact, and therefore a clearly defined scale cannot be given. In general, much depends on the common sense of the evaluator.

2. The notion of duration simply means how long the impact will affect the party or systems, i.e. will it last a few days, a few months, a few years or longer. The duration of impacts will need to be described at all relevant temporal scales.

3. The notion of reversibility is closely related to duration. An impact with a <u>very high</u> significance cannot be reversible. If it were, then its significance would be <u>low</u> or <u>very low</u>. However, an impact with a high significance may be reversible after a number of years. Similarly a <u>low</u> impact may be reversible after a few months.

6. The word “mitigation” should not be seen to mean ‘compensation’ alone, since it includes here, the ideas of containment and remedy. Hence mitigation means anything, which can mitigate the effects (i.e. reduce the significance of the effects) of an impact.

The definitions of the terms follow:

SIGNIFICANCE

VERY HIGH Of the highest order possible within the bounds of impact which could occur. In the case of adverse impacts, there is no possible mitigation and/or remedial activity that could offset the impact. In the case of beneficial impacts, there is no real alternative to achieving this benefit.

HIGH Impact is of substantial order within the bounds of impacts, which could occur. In the case of adverse impacts, mitigation and/or remedial activity is feasible but difficult, expensive, time-consuming or some combination of these. In the case of beneficial impacts, other means of achieving this benefit are feasible but they are more difficult, expensive, time-consuming or some combination of these.

MODERATE Impact is real but not substantial in relation to other impacts, which might take effect within the bounds of those, which could occur. In the case of adverse impacts, mitigation and/or remedial activity are both feasible and fairly easily possible. In the case of beneficial impacts, other means of achieving this benefit are about equal in time, cost, effort, etc.

LOW Impact is of a low order and therefore likely to have little real effect. In the case of adverse impacts, mitigation and/or remedial activity is either easily achieved or little will be required, or both. In the case of beneficial impacts, alternative means for achieving this benefit are likely to be easier, cheaper, more effective, less time consuming, or some combination of these.

VERY LOW Impact is negligible within the bounds of impacts that could occur. In the case of adverse impacts, almost no mitigation and/or remedial activity are needed, and any minor steps that might be needed are easy, cheap, and simple. In the case of beneficial impacts, alternative means are almost all likely to be better, in one or a number of ways, than this means of achieving the benefit. Three additional categories must also be used where relevant. They are in addition to the category represented on the scale, and if used, will replace the scale.

NO IMPACT There is no impact at all - not even a very low impact on either the key issue as a whole or one of the components (party or system) within the key issue.

CAN'T KNOW The consultant believes an assessment is not possible even with additional research.

DON'T KNOW The consultant cannot, or is unwilling, to make an assessment given available information.

SPATIAL SCALE

- International
- National – at the scale of the country concerned

- Regional – at the scale of the province or district
- Local - within a 10 to 30 km radius of the actual impact
- Site specific - within a 1 km radius of the actual impact

TIME SCALE

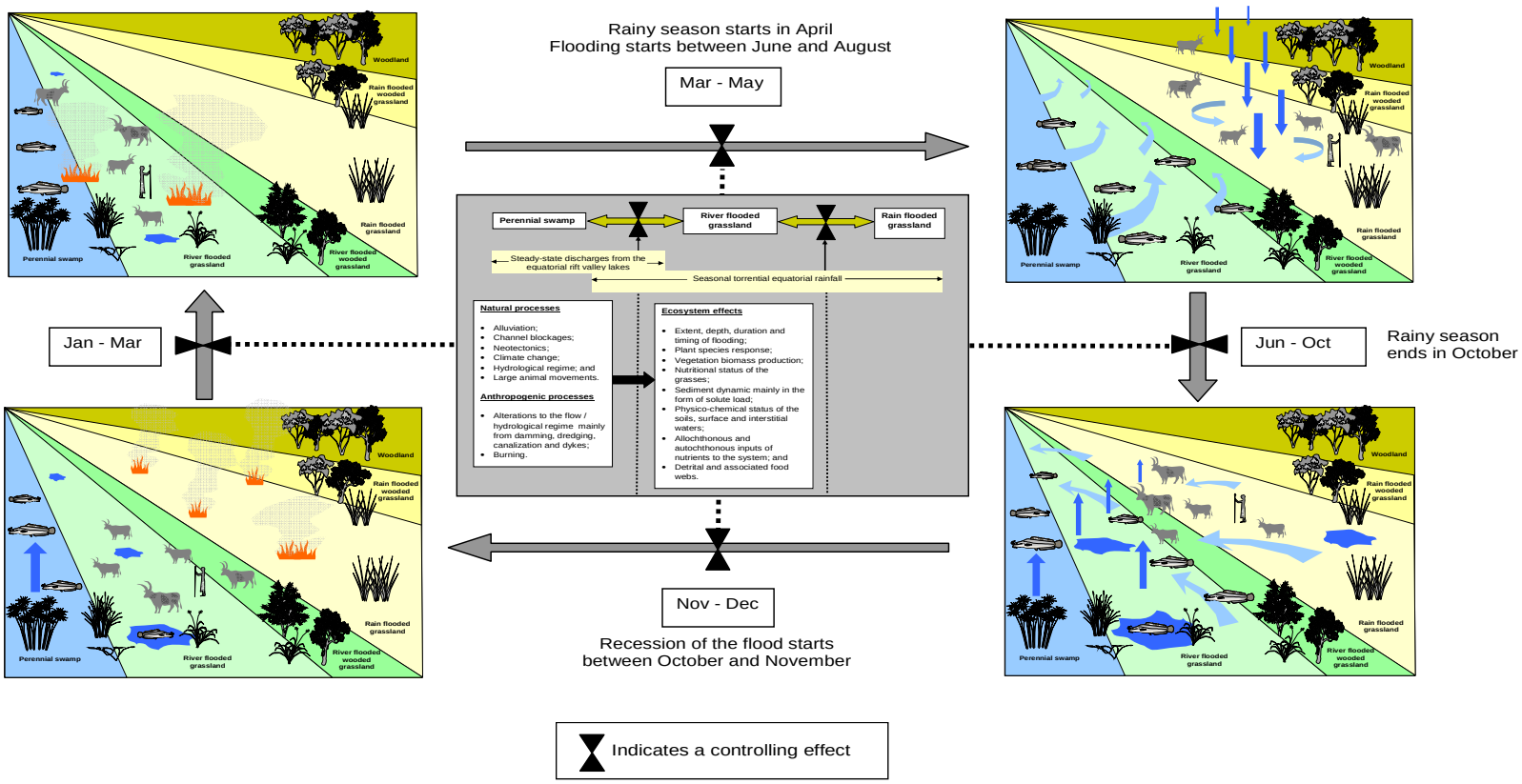
- Short term 0 -5 years
- Medium term 6 -20 years
- Long term more than 20 years (beyond the life of the mine)

DEGREE OF CERTAINTY

The following definitions enable the reader to ascertain how certain an effect is likely to be.

Definite:	You are more than 90% sure of a particular fact. To use this you will need to have substantial supportive data.
Probable:	You are 70-90% sure of a particular fact, or of the likelihood of that impact occurring.
Possible:	You are only 40-70% sure of a particular fact or of the likelihood of an impact occurring.
Unsure:	You are less than 40% sure of a particular fact or the likelihood of an impact occurring.

Figure 3. A general conceptual understanding of the functioning of the eastern Sudd floodplain system to assist with the interpretation of the impacts that are listed below. (Source: Wetland impacts study report, Annex 4)



4.2 Hydrological impacts: Flood depth, duration and extent east and west of the proposed dyke

The hydrological effects of the dyke were simulated using a very simple hydrological model (Mike11 GIS, a one-dimensional model from DHI, Danish Hydraulic Institute), driven with flow data from Mongalla and a coarse resolution digital elevation model. The construction of the dyke will cause the floodwaters on its west side to rise somewhat higher, especially at the upstream end and remain in place somewhat longer, than if the dyke were not present. Increased water levels in the south are expected to lead to higher gradients of the water surface towards the north, causing higher current velocities, which can be expected to have a destructive effect on the vegetation. Uprooted vegetation may then, as a secondary effect cause increased channel blockages downstream. However, the impact of water level rises in the flood season is negligible compared to observed annual fluctuations. Accordingly, for the area further to the north, impacts can be assumed to be negligible as well, since with the widening up of the floodplains a smoothening and fanning effect can be expected so that downstream changes will not be noticeable.

While the slightly increased water levels to the west of the dykes (0.05 m), will, despite the above described effects, not cause significant changes to the environment of the permanent swamp area, the cutting off and drying out of areas to the east, being protected behind the dykes, will have considerable ecological impacts. The proposed dyke will cutoff about 16% of the total floodplain area and provide protection to an estimated area of 930 km^2 east of the dyke from river flooding (under mean flooding event). The protected area east of the dyke is assumed to become isolated from flooding from the main river. It may well flood at a reduced frequency and duration, due to water inputs from the east and from local rainfall events. This indicates the necessary tradeoff between the need for habitable land and the need for grazing land during the dry season that needs to be carefully weighed.

While during rainy season (July to October) grass is available in higher areas for grazing the cattle, the seasonal river-flooded grasslands or *toic* are used for grazing through most of the rest of the year (November to June). In this way, traditionally, the cattle herds follow the progressing and retreating flood waters with their green belt of grass. The dyke will exclude Nile floodwaters from the area east of the dyke, except if they are permitted through by opening floodgates in the dyke, causing a reduction in inundation depth and duration to that which is permitted by leakage through the dyke, inflow from the east, and local rainfall.

Therefore an important measure for mitigating the negative dry season effects of the dyke system would be installation of gate structures to allow controlled flooding of parts of the protected areas to the east. Due to the minimal slopes of the area which in addition have the “wrong” gradient, sloping up towards the southeast, the key area with a great potential for effective mitigation of this kind would be the Mabior Gol depression. Along other parts of the dyke south of Jally such gate structures have limited potential to mitigate the negative effects of the dyke and could be used for more localized effects.

Impacts of the dyke on groundwater recharge are predicted to be negligible. This is due to the fact that the affected area is formed of impermeable clay soils of average thickness of 8 to 10 m.

Description of impact	**Spatial scale**	**Time scale**	**Degree of certainty**	**Significance rating**		**Mitigation measure**
				Before mitigation	**After mitigation**	
Increased peak flood height west of the dyke	Local	Long term	Probable	Low		None possible
Increased flood duration west of the dyke	Local	Long term	Probable	Low		
Decreased seasonally flooded area east of dyke	Regional	Long term	Definite	High	Moderate	Managed flooding of part of the area east of the dyke using flood control gates
Increased flow velocity west of dyke	Regional	Long term	Probable	Low		None possible
Ground water augmentation	Local		No impact	No impact		

4.3 Ecological impacts: Vegetation distribution

Each vegetation type in the wetland part of the study area has a characteristic relationship to the duration and depth of flooding that it experiences (Figure 4). Therefore, using the limited information available from the hydrological assessment, it is possible to make the following predictions regarding changes in vegetation distribution.

River flooded grassland is the type that will be most severely affected by the dyke, through the cutting off of flows into sections of these grasslands. Approximately 197 000 of this vegetation type will be affected by dyke alignment option 1 (current plan with Mabior Gol realignment), while approximately 220 000 ha will be affected by alignment option 2 (original alignment through the Mabior Gol). This amounts to 19.64% and 17.56% of the total river flooded grassland in the study area. It has been assumed that no flooding will occur in future in these areas when the dyke is completed. This vegetation type comprises extensive, predominantly mono-specific stands of *Oryza longistaminata* with fringes of *Echinocloa pyramidalis* in the deeper water. We have assumed that, since there will no longer be any river flooding, most of these river flooded grassland areas behind the dyke will change to rain flooded grassland systems, and that there will be an encroachment of woody components. The prevention of flooding on the previously river flooded grasslands will reduce the extent of this highly productive, high grazing value vegetation type. Twenty three thousand ha of river-flooded grassland in the Mabior Gol would be retained if Option 2 were the preferred alignment. Without any mitigation, Option 1 would effectively cut off the entire Mabior Gol.

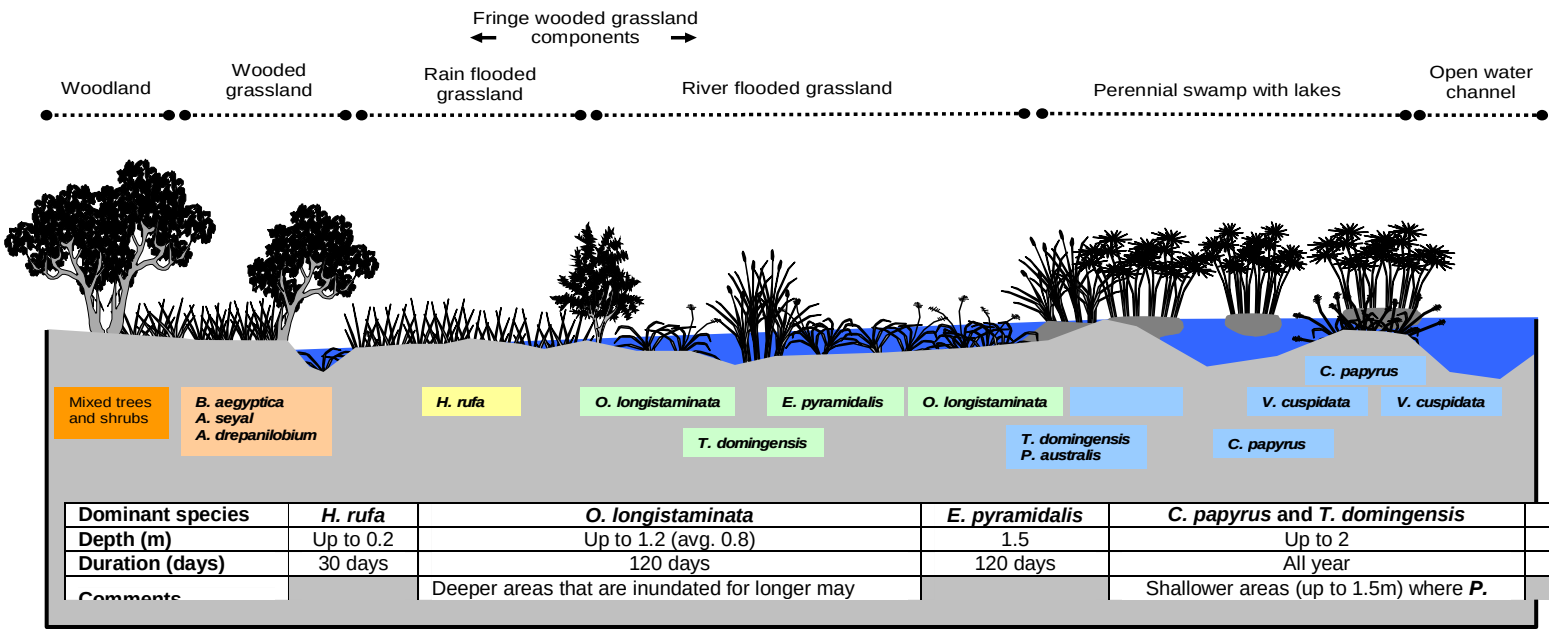
It is anticipated that some of the areas on the western extent of the Sudd (i.e. not only west of the dyke, but west of the Nile channel as well) may change from marginally wetland or terrestrial vegetation types to river flooded wetland types, since some displacement of water due to the dyke is anticipated. The general changes in the western section of the Sudd that could be anticipated are as follows:

In river flooded grassland areas, the increase in depth and duration of flooding could lead to encroachment of less palatable hydrophytes (egg. *T. domingensis*) that are tolerant of the deeper water;
In terrestrial and rain flooded grassland areas, flooding could possibly extend into these areas (due to the displacement of water from the eastern sections of the Sudd as a result of the dyke). This may result in the creation of new river flooded grassland areas.
In woodland areas, increased flooding may result in tree deaths and a switch to grass dominated vegetation types.

These possible changes could not be quantified because of the poor resolution of the hydrological data.

Figure 4. Schematic of the different vegetation types in the study area in relation to depth and duration of inundation.

Source: Wetland impact study report (Annex 4)



Dominant species	*H. rufa*	*O. longistaminata*	*E. pyramidalis*	*C. papyrus* and *T. domingensis*
Depth (m)	Up to 0.2	Up to 1.2 (avg. 0.8)	1.5	Up to 2
Duration (days)	30 days	120 days	120 days	All year
Comments		Deeper areas that are inundated for longer may		Shallower areas (up to 1.5m) where *P.*

Description of impact	Spatial scale	Time scale	Degree of certainty	Significance rating		Mitigation measure
				Before mitigation	After mitigation	
Change in plant community structure and distribution	Regional	Long term	Definite	MODERATE (negative)	MODERATE (negative)	Controlled flooding of extensive sections of the river flooded grasslands behind the dyke
	Local	Long term	Definite	HIGH (negative)	Moderate (negative)	
Changes to natural ecological dynamics of the coupled vegetation-hydrological system	International	Long term	Unknown (possible new flooded areas)	MODERATE (negative)	Low (negative) Preliminary hydrological analyses suggest that this mitigation is an unlikely scenario	Assumption for mitigation is that an approximately equal area of river-flooded grassland will be created on the west
	Local	Long term	Definite	HIGH (negative)	Moderate (negative)	Controlled flooding of extensive sections of the river flooded grasslands behind the dyke

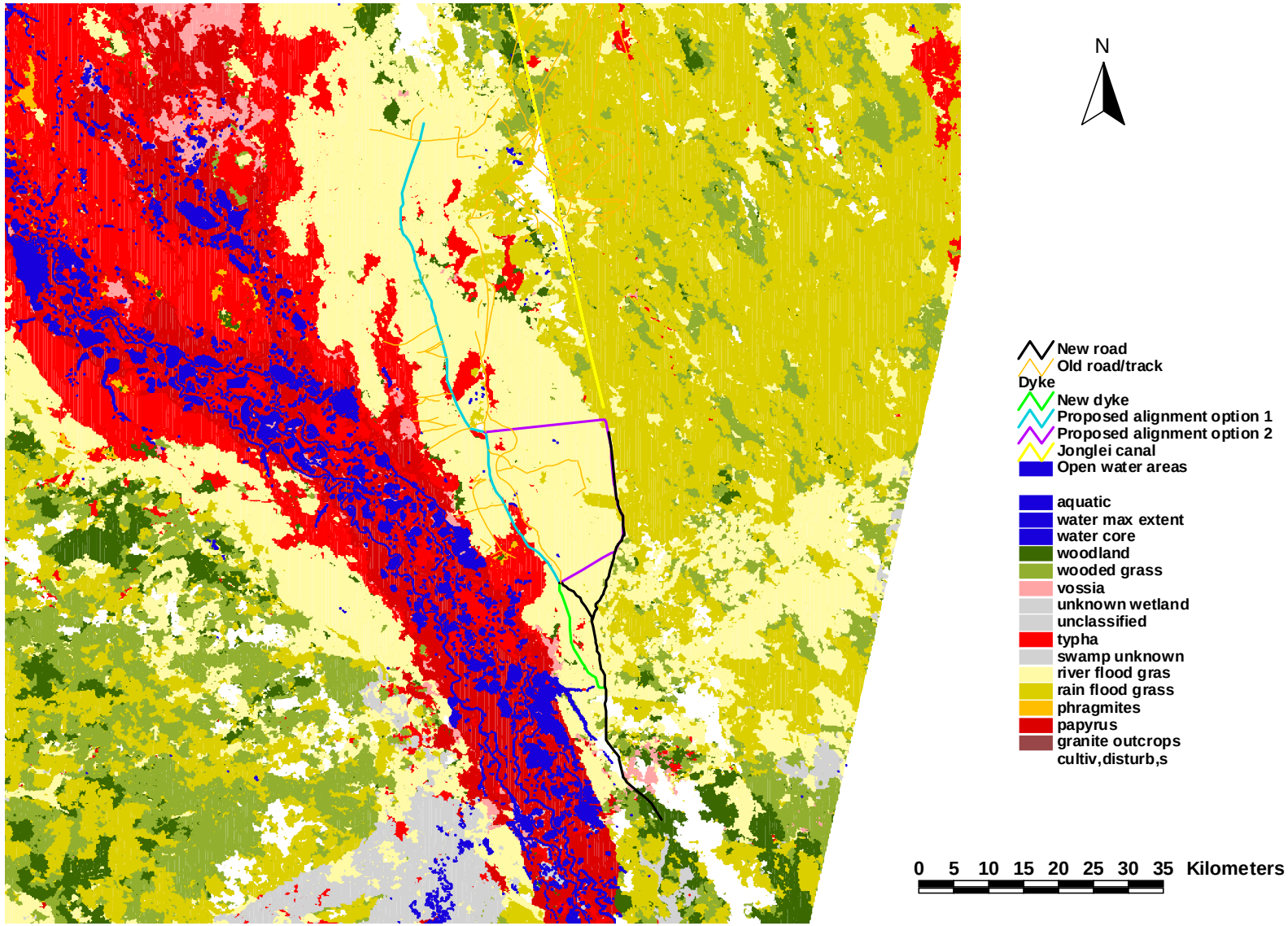
4.4 Ecological impacts: Plant productivity and grazing potential

In the medium term (6-20 years) it is expected that the river-flooded grasses will be replaced by rain flooded grassland species east of the dyke. Due to expected species changes, the available biomass in the grassland areas is likely to increase in the medium term in the grassland areas protected from flooding behind the dyke. However, the ***available standing biomass is likely to decrease by up to ten times in the dry season months***. This is the critical period for livestock, when weight loss is greatest, mortality is highest and milk yield lowest. It is also the time when rain flooded grasslands are of critically poor quality and are inadequate for the maintenance of cattle. The river-flooded grasslands are by contrast of consistently high quality and are available in larger quantities, and are adequate for maintenance throughout the dry season. The loss of river-flooded grasslands will have a negative impact on the local livestock. River flooded grassland supports a greater livestock grazing capacity than does rainfed grassland in this area. Currently and historically, local people have relied on the river flooded grassland areas for grazing during the dry season, using the comparatively drier rain flooded grasslands in the wet season, and moving into the river flooded grasslands during the dry season when the waters subside. The anticipated reduction in available biomass for grazing in the dry months thus poses a significant limitation on livestock and wildlife carrying capacities for the region. The projected loss of river-flooded grassland, and increase in rainfed grassland resulting from the dyke translates into a likely loss of grazing carrying capacity for 50 000 cattle, representing approximately 10% of the cattle population in this area.

This is a locally high impact that will probably persist in the long term. This estimate is based on the change in the ability of vegetation to support livestock (i.e. the maximum potential carrying capacity), but does not consider current or future demands for the grazing resources. These impacts should also be viewed against the fact that the current extent of the Sudd is much expanded relative to the pre-1960's condition, and is likely that sections of the currently river flooded grassland areas (Figure 5), and the associated high quality grazing were historically less nutritious rain flooded grassland.

Description of impact	Spatial scale	Time scale	Degree of certainty	Significance rating		Mitigation measure
				Before mitigation	After mitigation	
Plant productivity in the river flooded grasslands	Regional	Long term	Unknown (possible new flooded areas)	MODERATE (negative)		Controlled flooding of extensive sections of the river flooded grasslands behind the dyke.
	Local	Long term	Definite	HIGH (negative)	Moderate (negative)	
Changes in livestock and wild game carrying capacity as a result of changes in plant productivity and vegetation distribution	Regional	Long term	Unknown (possible new flooded areas)	Unknown (not known if similar distributions and migration routes exist in the west)		Replacement nutrition for livestock and artificial watering points. Controlled flooding of extensive sections of the river flooded grasslands. Controlled flooding of the Khor bed areas.
	Local	Long term	Definite	HIGH (negative)	Moderate (negative)	
Impacts on food chains and ecosystem productivity	Regional	Long term	Unknown (possible new flooded areas)	MODERATE (negative)		No mitigation possible.
	Local	Long term	Definite	HIGH (negative)		

Figure 5. The wetland classification of the intensive study area showing the extent of the river flooded grassland that would be directly affected east of the dykes (Source: Wetland impacts study report, Annex 4).



4.5 Ecological impacts: Wildlife numbers and distribution

The expected consequence of the physical presence of the dyke network is blockage of wildlife migratory corridors. Analysis of wet and dry season census data indicate significant differences in the local abundances of the following species of ungulates, Tiang (*Damaliscus korrigum tiang*), Mongalla gazelle(*Gazelle rufifrons albonotata*), white eared Kob (*Kob kobus leucotis*), Reedbuck (*Redunca redunca cottoni*), Warthog (*Phacocoerus aethiopicus*) and Oribi (Ourebi ourebi). Tiang were clearly the most common as estimates around Mabior Gol show that at least 1 million Tiang come into the Toic in the dry season.

Wildlife migration patterns were determined locally from census data and extrapolated regionally using available literature on known species distributions. Based on the results, the following species are likely to be moderately impacted on because of their migratory nature; Tiang, the mongalla gazelle, white-eared kob, reedbuck and oribi. The blockage of migratory routes will not result from the road or dyke being a physical barrier. Migratory wildlife arrives in the study area from the south at the end of the wet season and the beginning of the dry season (Fig 6). At this time the dyke is dry and low enough and can not be expected to provide any difficulty to wildlife crossing. We do not expect that the reduction in area that is currently seasonally river flooded will significantly affect wildlife directly; rather the impact is expected to result from blockage of migratory routes by linear settlements that are expected to crop up along the eastern side of the dyke. However, we predict that the exclusion of wildlife from Mabior Gol will result in significant population reductions in many of the migratory species that use this area as a breeding site. The species-specific impacts are discussed in the table below.

Our assessment is that the impact resulting form corridor blockage is high and significant. Wildlife forms a very significant component of the dry season protein diet of the people in Bor counties and is also of high cultural value. With increased availability of more dry land, the dyke would result in increased human settlement and a resultant displacement of wildlife in the east during the dry season. This would reduce the availability of game meat and thus negatively affect the nutritional status of people. With increased dry land but no human settlement to the east (because of insecurity), the dyke will encourage the greater concentrations of wildlife around the Mabior Gol section of the toic, allowing for higher off-take rates of wildlife in the short run but increasing the possibilities of local extinctions of wildlife in the long run. We propose that the impact of the dyke can be mitigated by either excluding the Mabior Gol from settlement altogether, allowing settlement but giving leaving corridors for wildlife as well as banning dry season hunting within Mabior Gol. Whatever the settlement scenario, we can predict that with no mitigation, the dyke will disrupt wildlife migration, interfere with wildlife breeding and result in reduced local abundances of wildlife.

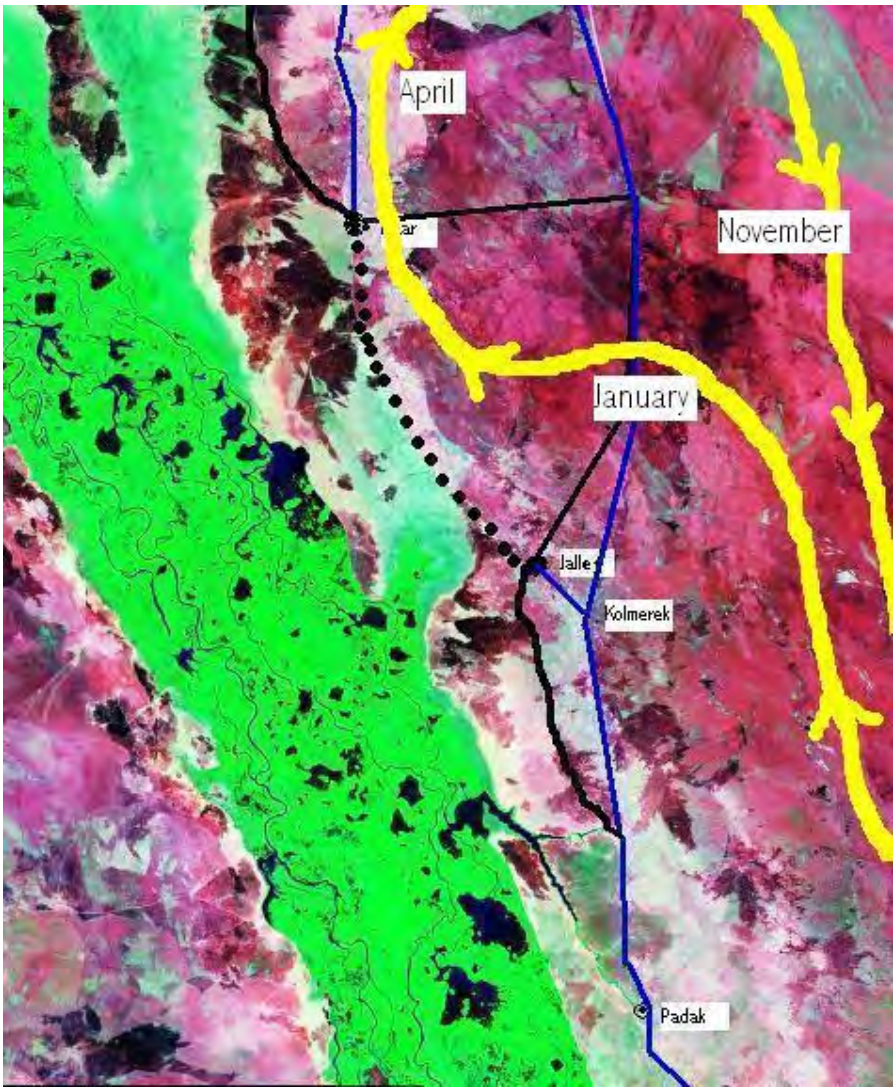


Figure 6. Seasonal migration of the Tiang showing the route through and the period of occupancy of the study area

Source: Wildlife impacts study report (Annex 5)

Description of impact	Spatial scale	Time scale	Degree of certainty	Significance rating		Mitigation measure
				Before mitigation	**After mitigation**	
Populations of migrant antelope species preferring seasonally flooded grassland	Regional	Long term	High	Moderate negative (kob and reedbuck) Low negative (tiang)	Low (negative)	Settlement free zone, settlement with migration corridors, hunting protection area and season
Population of water-dependent species (waterbuck, sitatunga, lechwe, hippo and buffalo)	Local	Long term	High	Low (negative)	Low (negative)	Controlled flooding
Populations of dryland antelope species (mongalla, zebra, roan and oribi)	Local	Long term	Probable	Very low (positive)	Very low (positive)	
Availability of wild game during the dry season affecting nutritional status of people	Regional	Long term	Probable	High (negative)	Low (negative)	Closed season hunting in Mabior Gol
Availability of wild game through the year resulting in increased off-take rates in the short run	Regional	Long term	Probable	High (negative)	Low (negative)	Controlled flooding and Closed season hunting
Eventual disappearance of game species either due to increased human settlements in former wildlife range after the dyke or increased wildlife off-take rates.	Regional	Long term	Probable	High (negative)	Low (negative)	Settlement free zones, closed season hunting, hunting ban zones
Impact on breeding of migratory species	Regional	Long term	Definite	Moderate (negative)	Low (negative)	Migration corridors

No significant impacts are anticipated on elephant and giraffe populations, which are low to start with, are anticipated.

4.6 Ecological impacts: Fisheries potential

Conservative estimates of fish biomass of the river-flooded grasslands are in the order of 37 g/m^2. Given the potential loss of 200 000 ha this results in a reduction of biomass in the order of almost 4000 tons. The loss of this mass of fish will have a considerable negative impact on fish predators, both man and wildlife. At least four fish species that occur in the river flooded grasslands contribute to the commercial fish catches.

Description of impact	Spatial scale	Time scale	Degree of certainty	Significance rating		Mitigation measure
				Before mitigation	After mitigation	
Fish productivity	Regional	Long term	Unknown (possible new flooded areas?)	Low/Moderate (negative)		
	Local	Long term	Definite	HIGH (negative)	Moderate (negative)	Controlled flooding of extensive sections of the river flooded grasslands and no fishing at inlets.
Fish harvest east of dyke	Local	Long term	Probable	Low (negative)	Low (negative)	
Fish harvest west of dyke	Regional	Long term	probable	Don't know		

4.7 Ecological impacts: Aquatic biodiversity

The river-flooded grasslands support a fish species assemblage different from that of the permanent swamp system. Since the relative area of flooded grassland and permanent swamps will change, there will be consequences for the sizes of the various fish communities. Many fish in the Sudd have evolved to use detritus as a food and energy source, with one of the sources being the vegetation on the floodplain. The removal of a large section of the river-flooded grasslands will reduce the quantity of organic and nutrient inputs into the water column and river during flooding and in particular during the recession of the floods. This will cause a ripple effect through the permanent swamp, as it would seem that the primary productivity in the main river system is limited by the physical structure and depth of the system.

Several of the Sudd fish species are known to migrate into the river-flooded grasslands in response to the seasonal flood cycles in order to breed, or feed. They would effectively be stopped in any of the river flooded grassland areas cut off by a barrier to lateral movement such as the dyke. This will result in a reduction in the recruitment to the floodplain fish populations as a whole, and to both the artisinal and commercial fisheries resulting from the annexation of between 197 000 and 220 000 ha of potential spawning/juvenile nursery areas

Description of impact	Spatial scale	Time scale	Degree of certainty	Significance rating		Mitigation measure
				Before mitigation	After mitigation	
Changes in the abundances of fish species	Regional	Long term	Unknown (possible new flooded areas?)	MODERATE (negative)		No mitigation possible.
	Local	Long term	Definite	MODERATE (negative)		
Fish migration	Regional	Long term	Unknown (possible new flooded areas?)	LOW/MODERATE (negative)		
	Local	Long term	Definite	HIGH (negative)	Moderate (negative)	Controlled flooding of extensive sections of the river flooded grasslands behind the dyke and no fishing at inlets.
Fish breeding	Regional	Long term	Unknown (possible new flooded areas?)	LOW/MODERATE (negative)		
	Local	Long term	Definite	HIGH (negative)	Moderate (negative)	Controlled flooding of extensive sections of the river flooded grasslands behind dyke and fishing at inlets.

4.8 Geo-chemical impacts: Nutrient regime and Stalinization

The following diagram (Figure 7) encapsulates the key linked hydrological and nutrient-related processes in the affected area. Building the dyke will have the effect of cutting the area east of the dyke off from nutrient replenishment by silt from the Nile River. The available data suggests that 50% of the phosphorous coming into the Sudd wetlands remain on the floodplains. It will also prevent the eastern grasslands from being regularly flushed to leach out excess salts, which in the long term could lead to salinization. . There will be minor changes to the nutrient cycles due to the change in grazing patterns that result from the new distribution of habitats that result, and more significant changes resulting from extension of permanent agriculture east of the dyke. The soils of the region are deep and nutrient rich, and by the time the Nile floodwaters have penetrated across many kilometres of *Papyrus* and grassland they have already dropped much of their silt. Therefore the magnitude of these effects is relatively small.

There are a number of what appear to be key linkages between the river flooded grasslands and the eastern sections of the greater area that are likely to be intercepted by the dyke. These drainages provide a conduit for floodwaters to flush salts and mobilize nutrients remote from the permanent swamps, as well as contribute to increasing soil moisture content and possibly groundwater recharge. The potential interruption of these flow lines could have serious negative consequences for an area considerably larger than the area affected directly by the proposed dyke.

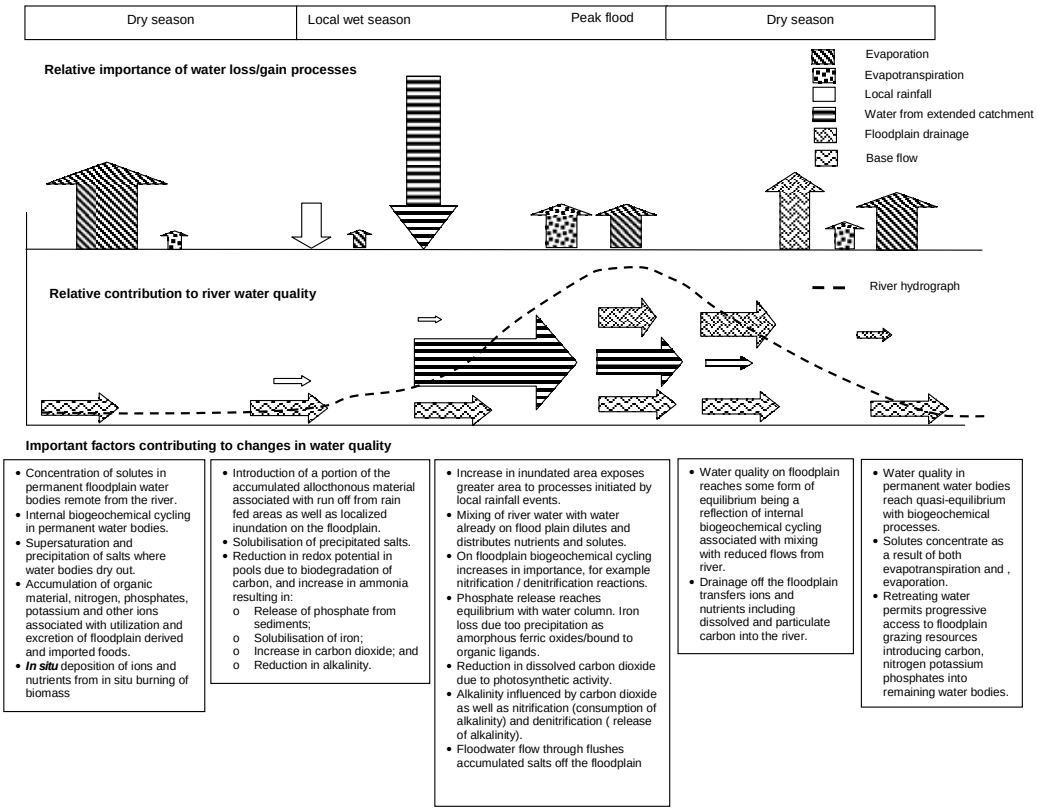


Figure 7. Simplified concept schematic illustrating the principle hydro-geo-chemical processes associated with the Sudd wetland. Source: Wetland Impact study report (Annex 4)

Description of impact	Spatial scale	Time scale	Degree of certainty	Significance rating		Mitigation measure
				Before mitigation	After mitigation	
Changes in the amount of sediments delivered to the flooded grasslands east of the dyke	National	Long term	Probable	LOW (negative)		No mitigation possible.
	Local	Long term	Probable	LOW (negative)	LOW (negative)	Controlled flooding of sections of the river flooded grasslands.
Impacts on water quality dynamics	Local	Long term	Probable	MODERATE (negative)	LOW/MODERATE (negative)	Improved sanitation
Soil Stalinization	Local	Long term	Probable	MODERATE (negative)	LOW (negative)	Controlled floods to dissolve/dilute accumulated nutrients (particularly sodium)
Eutrophication	Local (at points of discharge)	Long term	Probable	HIGH (negative)	MODERATE (negative)	Improved sanitation
Impacts on food chains and ecosystem productivity	Regional	Long term	Unknown (possible new flooded areas?)	MODERATE (negative)		No mitigation possible.

4.9 Socioeconomic impacts: Human health

The flooding of depressions previously filled by river flooding will still be inundated during periods of rainfall. It is likely that in the short term molluscs will proliferate given the absence of predation. This could cause an increase in the occurrence of vectors which transmit diseases such as (such as bilharzia and helminths flukes), given that fish colonisation and subsequent predation of snails is no longer likely. The presence of high people numbers could cause an increase in infection rates. However, the much reduced extent of water in the landscape, and general protection of people from continula water exposure, may offset these effects. Given these conflicting potential effects, we can not predict the changes in infection rates for these vector-associated diseases amongst people.

Similarly, the changes in malaria incidences are also difficult to predict. The incidence of malaria could potentially increase as a result of the dyke because:

1. The presence of high numbers of people and their livestock associated wastes, in previously river-flooded areas, is likely to locally increase the organic and nutrient content of (the now rain-) flooded depressions, leading to improved conditions for mosquito breeding
2. The absence of fish in these seasonally-inundated depressions will reduce predation on mosquito larvae, thus increasing the vector survival rate
3. Both factors favour the *Anopholes* (malaria vector) mosquito species, because this species favours seasonal water bodies with little competition or predation.

However, these negative effects may be offset by the much reduced extent of water in the landscape. There will be a smaller extent where the malaria vector could potentially breed, and people (particularly in the wet season) would be protected from flooding and continual exposure to extensive water bodies. These effects should result in a reduction of malaria incidences. Additionally, with the development of infrastructure, the anticipated provision of improved healthcare services should also result in a reduction of malaria incidences in the population. The overall effect of the dyke development on malaria incidence is thus unknown at this stage.

Description of impact	Spatial scale	Time scale	Degree of certainty	Significance rating		Mitigation measure
				Before mitigation	After mitigation	
Disease transmission in humans	Local	Long term	Unknown	Don't know (negative)	Low (negative)	Spraying water bodies, introducing predatory fish to control vector, improved health care

4.10 Socioeconomic impacts: Domestic livestock heath

Wetlands harbour a number of parasites, such as *Fasciola* (liver fluke) species and with the drying up of river flooding to the east of the dyke it is predicted that the dyke will have a moderate beneficial impact on reduction of incidence of animal disease caused by this parasite.

Description of impact	Spatial scale	Time scale	Degree of certainty	Significance rating		Mitigation measure
				Before mitigation	After mitigation	
Disease transmission in livestock	Local	Long term	Probable	MODERATE (positive)		

4.11 Socioeconomic impacts: Economic welfare and food security

The dyke is likely to have a significant impact on the household's nutritional status. In particular, where the dyke has been reconstructed and rehabilitated, households have higher off-take rates from beef and dairy cattle, goats and sheep and they have higher output of milk from all species of livestock. The dyke is likely to increase the number of beef cattle units owned by each household by 1.70 on average (valued at US$ 435), the number of dairy cattle units owned by each household by 4.72 (valued at US$ 1,976), the number of goats units owned by each household by 9.76 (valued at US$ 212) and the number of sheep owned by each household by 2.45 (valued at US$ 80). The dyke is likely to increase milk production at the household by 930 litres (valued at US$ 433). The reconstruction and rehabilitation of the dyke is associated with a decrease in the average size of land dedicated to the cultivation of various crops by the household during the wet season. In our assessment, this is mostly a consequence of the higher population attracted to the area where there is a dyke (i.e., the dyke avails more land for settlement but because of the higher human population attracted by the dyke, we observe that the area of cultivation per household reduces). This is however a short term increase in population as we expect that as the dyke extends further north, more of the population will spill northwards. The reconstruction and rehabilitation of the dyke motivates households to intensify agricultural productivity (i.e., higher output per unit area of cultivated land). In particular, it increases mean output of maize per Feddan by 69%., sorghum per Feddan by 31%., groundnuts per Feddan by 49%., and simsim per Feddan by 8%. This translates to an additional income to the household of US$ 652 from maize production, US$ 159 from sorghum production, US$ 524 from groundnuts production and US$ 28 from simsim production.

The value of production and per capita incomes will increase by 191% and value of household assets (wealth) will also grow by 44% after dykes are constructed.

Description of impact	Spatial scale	Time scale[5]	Degree of certainty	Significance rating		Mitigation measure
				Before mitigation	After mitigation	
Support an extra 41,573 persons (or an extra 5,256 households).	Regional	Long	Probable	Very high (positive)		Appropriate integrated development strategy and policies to enhance benefit, facilitate transforming social way of life and modernize economic activities
Capacity to support an additional 1.70 units of beef cattle per household.	Regional	Long	Possible	Low (positive)		
Capacity to support an additional 4.72 units of dairy cattle per household.	Regional	Long	Possible	High (positive)		
Capacity to support an additional 9.76 units of goats per household.	Regional	Long	Possible	Low (positive)		
Capacity to support an additional 2.45 units of sheep per household.	Regional	Long	Possible	Low (positive)		
Capacity to support the extra production of 930 litres of dairy milk per household.	Regional	Long	Possible	High (positive)		
Increases mean output of maize per Feddan by 69% (841kg).	Regional	Long	Possible	High (positive)		
Increases mean output of sorghum per Feddan by 31% (195kg).	Regional	Long	Possible	High (positive)		
Increases mean output of groundnuts per Feddan by 49% (375kg).	Regional	Long	Possible	High (positive)		
Increases mean output of simsim per Feddan by 8% (30kg).	Regional	Long	Possible	Low (positive)		
Increases income to household from maize output per Feddan by US$ 652.	Regional	Long	Possible	High (positive)		
Increases income to household from sorghum output per Feddan by US$ 159.	Regional	Long	Possible	High (positive)		
Increases income to household from groundnut output per Feddan by US$ 524.	Regional	Long	Possible	High (positive)		
Increases income to household from simsim output per Feddan by US$ 28.	Regional	Long	Possible	Very low (positive)		

[5] All impacts are long-term as long as dyke system is in place and there is no extra-ordinary flooding event

4.12 Socioeconomic impacts: Water supply security

As a result of drying up seasonally flooded grasslands to the east of the dyke it is expected that access to water supply will be significantly negatively affected during the dry season. Socio-economic surveys indicated that settled households perceive a negative impact of the dyke on water availability for domestic use (48%) as well as for livestock (36%). Among the measures proposed to be effective in mitigating water scarcity during the dry season are development of managed alternative water supply systems such as bore holes and watering points for both community and livestock use.

Description of impact	Spatial scale	Time scale[6]	Degree of certainty	Significance rating		Mitigation measure
				Before mitigation	After mitigation	
Households perception of scarcity of water for domestic use	Regional	Long term	Definite	High (negative)	Low (positive)	Managed alternative water supply sources (watering points, bore holes, etc.)
Households perception of scarcity of water for livestock	Regional	Long term	Definite	High (negative)	Low (negative)	
Access to water	Local	Long term	Definite	High (negative)	Low (negative)	

6

4.13 Socioeconomic impacts: Human habitation and flood disaster reduction

Comparison of communities in the region that are and are not protected by existing dykes allow the following conclusions to be reached.

1. The dyke is likely to increase the number of households settled permanently in the area protected by the dyke, by about 9% during its first year of operation.
2. The dyke would make the land more attractive to households displaced from their original areas of settlement.
3. A dyke would minimize (in fact it almost eliminate) the need by the household to maintain two areas of residence.

Extrapolating to the study area suggest that the extra 930km^2 of land to be made available under the current dyke alignment can support an extra population of 41,573 persons, which is equivalent to supporting extra 5,250 households.

Assessment of the influence of the dyke on the demography of the Bor Counties allows us to make the following conclusions:

1. The dyke encourages household members to reallocate from the cattle camp to the homestead. In particular:
    a. At the aggregate level, the household members staying at the cattle camp during the dry season reduced by 5%.
    b. The number of household members of the age group 6-17 years staying in the cattle camp during the dry season reduces by 50%.
    c. The number of household members of the age group 18-55 years staying in the cattle camp during the dry season reduces by 8%.
2. As a consequence, the dyke releases more labour to the household during the dry season when labour is needed most.
3. By releasing children from the cattle camp during the dry season, the dyke enables them to avail themselves to go to school.
4. The concentration of more people at the homestead during the dry season makes it easier to provide collective consumption goods.

Description of impact	Spatial scale	Time scale[7]	Degree of certainty	Significance rating		Mitigation measure
				Before mitigation	After mitigation	
Number of households settled permanently	Regional	Long term	Possible	High (positive)		Appropriate integrated development strategy and policies to enhance benefit and facilitate transforming social way of life and modernize economic activities
Land more attractive for displaced households	Regional	Long term	Possible	High (positive)		
Almost eliminates number of households needing to maintain two areas of residence	Local	Long tem	Probable	High (positive)		
Reducing the socio-economic disruption associated with migration to cattle camps.	Regional	Long tem	Unsure	Don't know (positive)		
Average number of livestock units owned	Regional	Long term	Possible	High (positive)		
Enhancing various measures of livestock productivity	Regional	Long tem	Possible	High (positive)		
Frequency of trips to fetch wood supplies for energy and other purposes	Regional	Long term	Possible	Moderate (positive)		
Time spent travelling to sources of wood supply	Regional	Long term	Possible	Moderate (negative)		
Time spent harvesting wood supplies	Regional	Long term	Possible	Moderate (negative)		

4.13 Other risk areas in design and construction of the dyke

There are some risks involved in the dyke construction related to possibilities of structural failures. According to hydrology modelling of water levels, the dyke body with its currently implemented design will withstand all common flood situations up to a 30 year flood event. The nature of the materials used in the dyke construction however, coupled with the local system of grazing cattle roaming grasslands on both sides and hence extensive crossing over the dyke, will lead to slow destruction of the dyke body if not maintained, the same process which has lead to the destruction of the 1983 dyke system.

A possible failure of the dyke by local overtopping and erosion will lead to a localized high inflow of water into the protected areas. The inflowing waters will then spread relatively slowly within a timeframe of days as vegetation, assumed to be relatively strong and dense at the end of the rainy season at a time when peak floods occur, causing major restrictions to the flow and distribution of water. Nevertheless a gap in the dyke body will, depending on the waterhead, will be quickly widened by the inflowing waters as the nature of the clays used for the construction of the dyke body does not allow it to withstand higher current velocities.

4.14 Assessment of alternative dyke alignments

Alignment Option 1: Original project plan bypassing Mabior Gol

A slightly elevated (0.05 m) water level west of the dyke, mainly in the southern part of the area of interest as a result of the narrowed floodplains is predicted for this option. This option will cutoff about 16% of the total floodplain area and provide protection to an estimated area of 930 km^2 east of the dyke from river flooding (under mean flooding event). The protected area east of the dyke is assumed to become isolated from flooding from the main river. It may well flood at a reduced frequency and duration, due to water inputs from the east and from local rainfall events. This is estimated to cause the loss of about 18% of the total river-flooded grasslands in the region with its above described negative and positive ecological and socioeconomic consequences.

Alignment Option 2: On the old dyke cutting off Mabior Gol

While water levels west of the dyke will also only rise by a small amount with this option, the main impact is the drying out of additional 330 km^2 of permanent wetland area east of the dyke. In contrast to the seasonally flooded grasslands, the Mabior Gol area provides an all year water and pasture source for wildlife and livestock, which extends into the dry eastern grassland plains. By dyking off the area, this option will increase the share to 21% of the total floodplain that would dry out during the dry season. Nevertheless, as the area lies in a slight depression, it would still be prone to rainwater flooding. As a result an additional area of 23, 000 ha of river-flooded grasslands will be lost increasing expected ecological damages and consequent socioeconomic implications.

4.15 Environmental impacts management, mitigation and monitoring

This assessment identified two key environmental processes and impacts as the main areas of concern requiring adoption of suitable environmental management and mitigation measures:

1. The key driver of the system is the flooding, and, if the dyke is built, flooding of the productive river flooded grasslands will cease and these wetland areas will change to rain flooded grasslands. Rain flooded grasslands have lower nutritional value, particularly in the dry season when forage is limiting, and this would have implications for the grasslands to support the anticipated high numbers of cattle associated with resettlement. This is anticipated to be the most important negative ecological impact associated with the dyke. The dyke alignment option which goes around the Mabior Gol area (Option 1) would cause less river-flooded grassland to be affected than option 2
2. Disruption of wildlife migration routes not from the dyke being a physical barrier but due to blockage by linear settlements that are expected to crop up along the drier side of the dykes is one key negative impact. With increased human settlements, the dyke would expose access routes and breeding sites to heavy human and livestock utilization and increase competition and incidence of hunting and disease transmission. While alignment option 1 excludes Mabior Gol area, this is expected to encourage greater concentrations of wildlife around the Mabior Gol section of the *toic*, allowing for higher off-take rates of wildlife in the short run but increasing the possibilities of local extinctions of wildlife in the long run leading to reduced availability of game meat, an important source of protein for the local population.

The dykes are at the same time expected to bring significant socioeconomic benefits to the local communities, especially in opening opportunities for transforming the current way of life and economic activity from an underdeveloped and isolated nomadic system to a more modern and market integrated agrarian system. Appropriate plans and policies are therefore needed to enhance such benefits. Critical for realising these benefits will be adoption of an integrated development strategy that ensures provision of critical complementary conditions and services such as well planned improvements in access to technology like irrigation and modern crop and animal husbandry, improved access to markets and credit and provision of basic social services such as healthcare and sanitation and education. This is of high importance considering the future dynamics for the region as its rich non-renewable natural assets such as oil are being liquidated for development purposes. This particularly calls for prudent reinvestment of theses proceeds especially in sustaining and enhancing the rich renewable resource base of the region and its people (the Sudd wetland).

Some mitigation options for the negative impacts of the dyke are possible, and have been mentioned in the appropriate sections throughout the report. The possible mitigation options are summarised below.

POSSIBLE MITIGATION OPTIONS

Controlled flooding behind the dyke

Managed flooding of selected areas of grassland would allow some of the river flooded grasslands to persist behind the dyke. There would thus be some opportunity to maintain selected areas of the river flooded grassland areas, which have higher grazing value than the rain flooded grasslands (which these areas would become in the absence of flooding). This would offset some of the anticipated negative impacts associated with the dyke.

Westward expansion of swamp due to water displacement

It is possible that the waters displaced by the dyke will cause an expansion of the swamp on the western edge of the Sudd. If this is occurs, many of the regional, national and international impacts will be substantially mitigated. Unfortunately the scale and resolution of hydrological understanding of the system, and effects of the dyke, are too coarse to predict the likelihood of this westward expansion. Preliminary indications from the hydrological analyses suggest that this expansion is unlikely. Instead, it is more likely that the dyke will cause increase channel velocities and more efficient discharge downstream,

Improved sanitation

To mitigate the anticipated localized salinisation effects associated with more concentrated people and animals, and absence of seasonal flooding due to the dyke, and to limit the incidence of disease, a comprehensive sanitation plan should be developed for the resettling population. Pit latrine systems are unsuitable for the dominant black cotton soils in the region.

Dilution ("flushing") flows

To mitigate the anticipated effects on water quality dynamics, flushing flows could be considered to remove accumulated organic matter behind the dyke, and maintain some of the nutrient transfers between the seasonally-flooded areas (now behind the dyke) and the permanent swamp.

Manage fishing at in/outlet points along the dyke

Limited, or preferably no, fishing should be permitted at the controlled flood release points along the dyke (if flooding behind the dyke is going to be considered). The concentration of predators (including man) at these points will reduce migration and breeding efficieny in those fish species that migrate into the seasonally flooded areas during the wet season. Prevention of fishing at these points will allow for increased transmission of fish from the main swamp into the (controlled) seasonally flooded areas, and thus increase fish migration, production and breeding, with associated effects on the sustainability of fish harvesting practices.

Controlled settlement with zonation

We propose that the impact of the dyke can be mitigated by either excluding the Mabior Gol from settlement altogether, allowing settlement but leaving corridors for wildlife as well as banning dry season hunting within Mabior Gol and passage corridors. Example plans for resettling returning communities with settlement free

corridors for wildlife passage are given in the wildlife impact study component (Annex 5).

Community-based natural resource management

It is imperative that before initiating any of the recommended mitigation measures such as settlement zonation, controlled season hunting and managed seasonal flooding and fishing regimes, the local community is involved in every step of decision making and implementation. For instance, communities should decide where and when hunting should be carried out, what would be the most appropriate hunting methods and where to locate managed flooding areas, etc.

Malaria control

The maintenance of fish populations in the water bodies behind (cutt-off by) the dyke to predate upon mosquitoe larvae, the malaria vector; possible spraying of water bodies and homes, and general improved provision of and access to healthcare will assist in reducing the incidence of malaria in the population.

MONITORING RECOMMENDATIONS

The following section describes recommendations related to (1) future monitoring of the dyke impacts, and (2) refinement of the understanding of the Sudd wetland system itself.

The latter issue is important given that there are likely to be numerous development, rehabilitation and other projects in and around the Sudd in the near future. At present, our understanding of how the system functions is poor, particularly with respect to the dependency of different vegetation communities on flooding; the extent and duration of flooding across the region; and the longer term (decadal to century) natural dynamics and fluctuations of the Sudd.

The impacts of increasing numbers of local and regional developments, as well as likely flow reductions due to upstream development in the Nile headwaters, will place increasing stress on the Sudd ecosystem. Accurate assessment and understanding of these impacts on system functionality will improve the ability for accurate monitoring of the impacts, as well as for effective management and mitigation.

Development of improved hydrological understanding

Despite the fact that the Sudd is a flood-driven ecosystem, there has been little development of any detailed hydrological understanding of the Sudd and its floodplain. This has limited the assessments that can be made in terms of predicting the impacts of this development. Specifically, this has impacted the following issues:

1) The fate of the displaced water is currently unknown. The hydrological modelling has not been able to clarify if the waters displaced by the dyke will flood additional, currently terrestrial, areas to the west of the Sudd, or if the more constricted Sudd will convey the floodwaters through the swamp more efficiently. If

the displaced waters will flood new, currently terrestrial areas, there are no data to indicate to what extent this will occur. This is an important issue, since many of the expected impacts may be offset by the creation of equivalent wetland areas elsewhere.

2) The vegetation of the Sudd has responded in the past to changes in flood flows and in particular to the increased flows from the mid 1960's, which resulted in a large increase in the extent of the Sudd wetlands. Recent observations suggest that the water level in Lake Victoria, one of the primary sources of the water in the White Nile, has dropped significantly (by more than 1.5 metres) over the last 18 months. Therefore it is highly probable that flows in the Sudd will reduce in the future. The impact of such flow reductions on the nature and extent of flooding should be assessed, as it is possible that the dyke is unnecessary as flows are likely to reduce in the near future. Before the increased discharges that began in the 1960's, the degree of flooding and extent of associated wetlands in the Sudd was much smaller than the present condition. A cheaper option, which would have far fewer and less extensive negative effects, would be to dyke smaller areas for villages, rather than the proposed alignments currently under consideration. Such an option would not result in the decline of nutritional value of extensive grazing areas, nor in a significant decline in fish biomass.

3) There is some evidence, from vegetation indicators, that subtle depressions in the landscape convey floodwaters deeper into the interior (to the east) than was surveyed in this study. Thus we do not know the degree of hydrological connectivity (through surface flows and groundwater) between the areas immediately adjacent to the dyke area and those areas far to the east (essentially terrestrial areas).

An improved hydrological understanding of the system may be able to assist particularly with the last point made above, since an improved understanding of the hydrological connectivity and lateral water movement may allow improved mitigation measures to be designed along the dyke. More generally, an improved hydrological understanding of the dyke would enable more informed decisions to be made with regard to any future developments.

Development of a strategic environmental assessment and management plan for the Sudd region

There are numerous development, rehabilitation and other projects currently underway or proposed for the near future, both within the immediate region as well as upstream in the Nile headwaters. A strategic environmental assessment and development of a strategic management plan for the region is highly desirable to properly manage these proposed developments and their impacts.

Determination of the environmental flow requirements for the Sudd wetlands

At the regional and international scale, it would be highly desirable for an environmental flow assessment to be undertaken for the Sudd wetland. This is a wetland of international importance, and as such the quantity and pattern of flows to maintain the ecological integrity of the wetland should be ensured from upstream regions and countries.

Wildlife monitoring

There is need to monitor wildlife migration patterns after the construction of the dyke and when the mitigating situations have been effected. Particular valuable to monitor include:

- Wildlife use of the proposed corridors in all seasons. Particularly monitor diurnal use and interaction with livestock and humans.
- Adherence to the closed season hunting and settlement zonation. Continuously monitor encroachment into wildlife corridors by settlements and livestock camps and secure the corridor
- Wildlife off take by the local community throughout the whole region. Monitor numbers of each species taken in the dry and in the wet season as well as adherence to recommended off take methods.
- Wildlife breeding patterns, particularly the species that have traditionally been known to breed in the dry season around the *toic*.
- Disease transmission between livestock and wildlife
- Dry season competition for water and pasture between wildlife and livestock

Habitat monitoring

There is also a need to monitor:

- Changes in grassland and woodland composition east and west of the dyke
- Flood dynamics across the dyke and road system
- Presence of invasive species of plants both west and east of the dyke

5. Conclusions and recommendations

Comparing net economic gains and losses to society during the wet and dry seasons, at the scale of the project, our assessment is that society is economically better off with the dyke than without the dyke.

Recent observations suggest that the water level in Lake Victoria, one of the main sources of the water in the White Nile, ***has dropped by 1.5m over the last 18 months.*** Reasons for this are not known but have been attributed to increased flows for power generation. It is likely that flows in the Sudd will therefore reduce in the future. The impact of the dyke on the nature and extent of flooding should be modelled given these anticipated changes in flow, as ***it is possible that the flows are going to reduce to pre-1960's conditions*** or lower. Before the increased discharges that began in the 1960's, the extent of flooding in the Sudd was much smaller. One appealing option, which would have fewer and less extensive negative ecological effects with important implications for the economic wellbeing of resettled communities, would be to minimize losses of river-flooded grassland by cutting off smaller areas. The current alignment along reconstruction of secondary dykes for protection of resettled villages is a good example.

The fate of the displaced water is currently unknown. The hydrological modelling has not been able to clarify if the waters displaced by the dyke will flood additional, currently terrestrial, areas to the west of the Sudd, or if the more constricted Sudd will convey the floodwaters through the swamp more efficiently. If the displaced waters will flood new, currently terrestrial areas, there are no data to indicate to what extent this will occur. This is an important issue, since many of the expected impacts may be offset by the creation of equivalent wetland areas elsewhere.

It is possible that the waters displaced by the dyke will cause an extension of the swamp to develop on the western edge of the Sudd. If this occurs, many of the regional, national and international impacts will be substantially mitigated. However, indications from the hydrological analyses suggest that this extension of the Sudd, due to the displaced water, is an unlikely scenario. Instead, it is more likely that the dyke will increase channel velocities and more efficient discharge downstream,

Consideration should be given to allowing controlled flooding of part of the area east of the dyke for several months per year, by the use of controllable sluices on the dyke. This mitigation measure would serve several purposes. It would maintain areas of highly productive seasonally-flooded grassland east of the dyke, it would help to retain the current nutrient regime and control the build-up of harmful organisms in cut-off water bodies, and would prevent permanent human settlement in a corridor of land that would permit the migration of antelope from the east to west and back again. It could also increase fisheries yields both east and west of the dyke.

To mitigate the anticipated localized salinisation effects associated with more concentrated people and animals, and absence of seasonal flooding due to the dyke, and to limit the incidence of disease, a comprehensive sanitation plan should be developed for the resettling population. Pit latrine systems are unsuitable for the dominant black cotton soils in the region.

To mitigate the anticipated effects on water quality dynamics, flushing flows could be considered to remove accumulated organic matter behind the dyke, and maintain some of the nutrient transfers between the seasonally-flooded areas (now behind the dyke) and the permanent swamp.

Limited, or preferably no, fishing should be permitted at the controlled flood release points along the dyke (if flooding behind the dyke is going to be considered). The concentration of predators (including man) at these points will reduce migration and breeding efficieny in those fish species that migrate into the seasonally flooded areas during the wet season. Prevention of fishing at these points will allow for increased transmission of fish from the main swamp into the (controlled) seasonally flooded areas, and thus increase fish migration, production and breeding, with associated effects on the sustainability of fish harvesting practices. The same applies to hunting of wildlife during critical breeding seasons.

The maintenance of fish populations in the water bodies behind the dyke to predate upon mosquitoes larvae (the malaria vector); possible spraying of water bodies and homes, and general improved provision of and access to healthcare will assist in reducing the incidence of malaria in the population.

The involvement of local communities in all decisions and implementation of plans for management and exploitation of the key natural resources on which their livelihoods are dependent is necessary for socially desirable and environmentally friendly future economic development in the region.

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Appendix 1. Consultation and Review Processes

This EIA study followed the standard procedures and requirements for a comprehensive review and consultation process. As documented in the main report, from the scoping phase and through the initial stakeholder and the intermediate consultation and planning stages to the production of this final report, study team of specialists have extensively consulted all interested and affected parties. In addition to consultations and discussions with local communities, the teams presented findings and recommendations of their studies to various local and regional government agencies and ministries. All studies have also undergone external technical peer reviews. While most of the public, community and authority reviews and consultations were verbal (at workshops and meetings), some written comments were received and addressed, which are reported below.

The following individuals and institutions have been consulted and/or participated in workshops and meetings where presentations were given on study results:

1. The Governor of Junglei State and his staff, GOSS
2. Under Secretary and staff of the Ministry of Transport and Roads, GOSS, Juba
3. Under Secretary and staff of the Ministry of Environment, Wildlife Conservation and Tourism and staff, GOSS, Juba
4. Winrock International SSAR Program (Dr. Jamus Olum Joseph), JUba
5. Under Secretary and staff of the Ministry of Water Resources and Irrigation, GOSS, Juba
6. Executive Secretary and Deputy Commissioner of Twich County
7. SRRC staff in Padak and Mabior
8. Other community leaders in Padak and Mabior
9. A number of NGO's operating in the area including WFP, GTZ, CARE among others
10. Bor counties' Road and Dyke project staff, Nairobi
11. GTZ, Padak
12. UMAP USDA/USAID PASA – Sudan Program office; Nairobi office
13. USAID-REDSO, Nairobi
14. WHO, Nairobi
15. UNEP, Nairobi
16. ECA, Regional Environmental Office, Nairobi
17. ESF Consultants for Sudan Transition Environmental Program (STEP), USAID, Nairobi
18. STEP, USAID, Nairobi
19. USAID Sudan Field Office, Nairobi - Engineering, Program Management, Economic Growth
20. VEGA volunteer, University of Maryland

External peer reviews and other public review comments

External peer review – JI Barnes, 31 May 2006

Environmental Impact Assessment of the Bor Counties Dyke Rehabilitation Project, South Sudan, SOCIO-ECONOMICS IMPACTS ASSESSMENT COMPONENT, Draft report - by ED Mungatana and A Njenga

1. General

The draft report for the socio-economics impacts study appears to be thorough and generally sound. It follows the terms of reference closely, and generally deals well with the treatment of expected impacts, as listed in these terms of reference.

I consider the approach to estimating impacts, with emphasis on the likely changes in material household welfare and livelihoods, attributable to dyke rehabilitation, as a very good one. This is especially given the lack of available information on the household economy and the biophysical processes in the study area. The use of market-based valuation is also very appropriate.

I have some problems with specific details regarding the welfare assessments. The use of a household survey with comparison between the south Bor (where the dyke is already rehabilitated) and the north Bor (where the dyke is not yet rehabilitated) is very good. Similarly, the comparison between survey results in both the wet and dry seasons is good. However, the very small sample (roughly fifty households in each zone, makes the comparative findings only indicative at best. The report attempts to extract far too much from a data base of this size, particularly since no statistical rests of significance appear to have been performed to test whether the differences found were valid. Given that the findings are only indicative, detailed calculation of welfare impacts to the second decimal point becomes spurious. While calculations are definitely in order, the figures should be rounded and the interpretations qualified as being indicative only.

Use of key informants for getting price data is also a very good approach but again prices are calculated to the last cent. The estimates would benefit from rounding and some qualification regarding their validity. Further, for international readership, it would be good if the exchange rate between SD and US$ at the time of the study could be given.

Generally, however, the indicative results coming out of the analysis appear sound. Thus, the impact assessment tables are generally fine, particularly as they appear in the draft integrated report. However, I think that the descriptions of impact (column 1 in the assessment tables) could be toned down (reflecting that the measures are only rough and indicative).

The emphasis on market-based valuation of welfare is good, but there is some evidence given (in the integrated report, page 22) that communities have specific preferences for the dyke alignment allowing resettlement of ancestral lands. I feel that something could be said about these ‘non-use’ values, as perceived by the communities, in relation to the likely non-use values perceived by the international (and national?) communities for the conservation of fish, bird and wildlife habitat, etc. This would fit under ‘1c’ in the socio-economics impacts terms of reference. This part of the terms of reference could be dealt with in more detail.

The draft does not yet contain treatment of mitigation measures and or environmental monitoring plans (section 2 and 3 of the socio-economics terms of reference). Here, I think the report could bring in the mitigation measures proposed by the other specialist reports and the integrated report regarding hydrological management and dyke alignment, as well as make recommendations for interventions involving community-based approaches to resources management, which might help ameliorate negative impacts.

2. Specific comments

Page 12, paragraph 2: Suggest changing this sentence to: "The study found that society is worse off…."

Page 28, Table 5: suggest a comment here about the limitations of the very small sample size, and that fact that this survey can only provide indicative results.

Page 30, Table 7: Here is an example of an attempt to extract far too much from extremely small samples. These figures are useful only as indicators, unless statistical significance can be shown. Even then, providing percentages to 2 decimal points is misleading. Thus, for e.g., in the associated text, words such as 'indicates', and 'suggests' should be used rather than 'means' and 'shows'.

Page 37, Table 11: This table makes good sense of the preceding indicative data and the assessment here, appears sound. The 'after mitigation' column could also have an assessment (e.g. mitigation might raise the overall carrying capacity for livestock).

Page 40, general: The rough calculation of carrying capacity using the Barotse floodplain figures is fine for a conservative estimate, but there is possibly even more room for expansion. The Barotse floodplain overlies very infertile sands, while the Bor counties overly much more fertile soil. With an average rainfall of some 800mm per annum the Bor counties could possibly support sustainably even higher densities of settlement, more like the Lower Shire wetlands. This could be noted.

Page 41, Table 14: All these tables show only indicative estimates, so I suggest rounding to the nearest thousand or further.

Page 48, Section 8.1.1.3: Given the negative indicative results, I don't think one can insist that the effect of the dyke will be positive regarding incidence of waterborne diseases. Any conclusion on impact would need much more rigorous analysis of the effects of factors such as rainwater stagnation, flushing effects of flooding, access to medical care, population densities, proximity of permanent water bodies, etc. Table 19 gives the degree of certainty for a positive impact as 'definite'. I think this is wrong – the impact may in fact be negative.

Page 53, Table 21: I find the reasoning in the interpretation of this table a bit faulty. Higher human population cannot be used to deduce that demand per household is higher. The indicative figures suggest that higher number of trips in the south Bor may be offset by lower travel times and lower quantities. Any useful interpretation of these results would need a more informed analysis (as the report does state at bottom of page 54).

Page 64, Section 8.2.2.1: I can't see how comparing northern and southern households' perceptions on reduced access can provide a measure of the impact of the dyke on water availability. The data only suggests that both northern and

southern households perceive a negative effect, and that (for a possible host of reasons) perceptions may be higher in the north.

Page 68, second sentence: I don't think this sentence is right. I think it should be something like: "A comparison between Table 28 and Table 9 suggests that for all measures of livestock productivity, the improvements attributable to the dyke will be less in the dry season than in the wet season." Also on page 69, second line: I can't see where the 'losses' are in the dry season. To me, Table 28 suggests that there may still be gains due to the dyke in the dry season, but that these would be less than the gains in the wet season. My interpretation of the conflict between the findings of the socio-economic and wetlands study groups is as follows. The positive likely welfare gains regarding livestock, as measured by the socio-economic study, will only take place while stock numbers remain within the overall carrying capacity of the land. Once stocking rates reach the carrying capacity, such gains will not be possible and furthermore, as determined by the wetlands study group, the dyke will actually reduce the overall carrying capacity. Successful mitigation (controlled flooding) might reverse the negative effect on overall carrying capacity.

Page 78, Table 8.2.3: I find this table a little too simplistic. Fish are not included. The statements to the effect that: "In our assessment this does not constitute a major cost of the dyke" need to be at least qualified. This statement, for e.g., does not agree with the finding in Table 29 that there are 'probable, high, negative' effects on wildlife due to the dyke.

Page 80: The section on identification of appropriate mitigation measures has still to be done. Here, I suggest that consideration be given to possible extension and institutional support for households and communities. For e.g., interventions in, and support for, community-based natural resource management may well be critical to ensuring the success of biophysical mitigation measures. If mitigation measures are to be successful it will be important that the existing and returning communities are involved in their design as much as possible. Thus, as far as is possible within the current socio-economic and security environment, dyke rehabilitation and design and operation of mitigation measures should be accompanied by a community-based rural development initiative, including spatial planning, services provision, and conservation components.

External peer review – JI Barnes, 31 May 2006

Environmental Impact Assessment of the Bor Counties Dyke Rehabilitation Project, South Sudan, WILDLIFE IMPACTS COMPONENT - by Dr GM Wahungu

1. General

The draft report for the wildlife impacts study appears to be thorough and generally sound. I find that it follows the terms of reference closely, and generally deals well with the treatment of expected impacts, as listed in these terms of reference.

I consider the approach adopted in estimating impacts attributable to dyke rehabilitation a very good one. This has emphasis on measuring current dry and wet season wildlife densities in the Mabior Gol, and measuring the current impacts of

hunting there, within the context of what is known about the broader wildlife picture from the earlier work, most notably that of Merfit-Babtie (1983). Despite the fact that more long-term, intensive research and monitoring will be needed for a good understanding of the local and regional biophysical processes, the approach does provide a reasonable basis for impact assessment. The summarised impact assessment for wildlife (Table 8) appears sound.

Although impacts are treated in a regional and local context, the report does not make very clear to the reader, how the wildlife resources in the study area fit in the broader context of south Sudan. For e.g., what proportion of the whole south Sudan Tiang population, is the (very large) one in the study area likely to constitute? Are there likely to be other large numbers elsewhere in designated and/or potentially protected areas? Similarly, are there likely to be other relatively secure or potentially secure populations of White-Eared Kob and Mongalla Gazelle elsewhere in eastern south Sudan? These issues may already be implicitly incorporated, but some discussion on them might help the reader understand the accuracy of the regional impact significance.

Any measure of impact needs to take into account the different values associated with the resources in question. The large dry season populations of wildlife on the floodplain have value as a meat source for the local population, and this is dealt with in the report. But these resources also have value nationally and internationally, reflected in willingness to pay for their preservation, to ensure either the option to use them later, or simply to ensure their existence. Such non-use values may, or may not be significant, and are very difficult to measure. But they have potential to be captured and reinvested in the local economy, and are thus worthy of consideration in impact analysis and mitigation planning. I feel it would be good to include some more discussion on these.

The section on mitigation contains good recommendations. My comment here would be that more emphasis could be put on the need for involvement of communities in mitigation design. Mitigation, especially if it involves seasonal and spatial control over hunting, settlement planning and management of flooding, will have little chance of working unless it is accompanied by community-based rural development initiatives. Whether this is possible, given security and other concerns, needs to be discussed. Depending on the potential for support to local rural development and governance, the nature of most appropriate mitigation design may change. Although it is mentioned, a little more emphasis could also be put on future research on, and monitoring of, wildlife and rangeland. This could also be part of any development initiative.

2. Specific comments

Page 20, Table 5: The very large and significant difference found between warthog numbers in the wet and dry season would suggest that this species does move seasonally in and out of the Mabior Gol. It may be worth mentioning this – the species may be migratory in this setting.

Page 26, third last sentence: The Tiang population estimate of a million is for the whole Mabior Gol, while the daily hunting off-take estimate of 17 animals for Tiang seems to be based on a sample from Transect 1 only. I think it would be worth making this comparison valid by extrapolating the off-take to the whole area and then estimating a total annual dry season harvest. The current hunting impact will still be negligible, say 15,000 per annum, but this figure could be compared with off-takes

that might be unsustainable for the population (probably more than 110,000 per annum).

Page 40: The evaluation section could ultimately be expanded, incorporating some of the considerations, above.

Page 41, References: The reference to Merfit-Babtie (1983) needs to be placed here.

Alex Gary (USAID-REDSO, Nairobi)

I have finally gotten through the two draft reports distributed at the debriefing on the EIA. These are considerably delayed so it will be good to wrap up the final report on the EIA so that we can move on. If these comments are too late to incorporate, that's probably fine. I think there has been adequate time given for comment so you can go ahead and finalize the reports. It may however be good to give a firm deadline for people who would potentially comment to send in any comments.

The Scoping Statement identified 10 significant issues. Only two of these were extensively addressed in the draft reports—hydrology and socio-economic impact. Others were touched on but not addressed in detail. I suspect there are other draft reports that I have not yet read, perhaps on the CD. There probably should be a short summary overview of all the reports if there are more than the two.

The final report should have he standard 'branding' and note that this is a report from USDA for USAID review and consideration and does not necessarily reflect views of USAID. (Or maybe it is from the University of XXX.)

On the Hydrology Report: Not much in the way of comment:

1. I didn't realize that Lake Victoria discharge had increased. In fact I thought that I had heard that there had been a recent decrease. Maybe there has been a recent decrease which still leaves the discharge rate above historical levels. (I really don't know much about this.)
2. It would be helpful to have more detailed recommendations as to follow up action recommendations, more specificity on additional studies and data collection requirements.
3. The study looks at impact of the current dike work. That's fine, but if this turns out to be good, there are likely to be more dike projects. Are there implications for spread of the technology over a wider area of the Sudd and at what point does this become an issue?
4. There has been stated the expectation (hope) that some one will continue monitoring water levels and conditions, but no indication of efforts to put in place such a system. I suspect that this was always beyond the scope of this study, but it is an issue for WFP to deal with.

On the Socio-Economic Impact Report: I have some serious misgivings about some of the report, but it should probably go into final, as these, even if well founded, aren't easily fixed:

1. The report seems to be biased towards positive changes. When changes indicate a benefit, they are accepted without much question. On the other hand, if they are negative and not as expected (as with health status changes), they are discounted.
2. The survey work looking at the difference between North Bor and South Bor is, as I understand it intended to reflect the impact of dikes. This assumes that situations were equivalent before the dikes. It also assumes that any changes due to the dikes will have occurred within the one year (or less) since the dike construction. The report notes that changes in vegetation (increase in woody plants) have not yet occurred. However, it assumes that differences in livestock numbers have occurred as a result of the dikes. I doubt that herd size would have adjusted in this short time period and change in carrying capacity of the land probably wouldn't have adjusted to whatever the new equilibrium will be.
3. Likewise, population numbers are not likely to have changed because of the dikes. If they have, the narrative should explain how and why.
4. Modeling of productivity with and without dikes might be a better approach than comparing North and South Bor.
5. On the argument for the dike's benefits in terms of increasing population that can be settled in the area, it would seem that there needs to be a discussion of land tenure arrangements or social factors that will allow/facilitate the increased settlement in the area. Are there any mechanisms that facilitate settlement or will this stimulate conflict over land.
6. There is no statistical analysis of the data. It may not be valid for statistical analysis, but then this should be noted. For some of the indicators, changes are stated as fact, e.g., 8 % increase, though I doubt that there is any justification for taking this as a significant change.
7. It would be useful to convert the projected economic benefits into US $$. (There may be question as to the values, but if they are calculated, it is useful to give them also in US$.)
8. Current prices are used. I suspect that once the road is open and the economy adjusts to peace time conditions, prices are apt to change considerably. This should be noted or justification given for why current prices are valid.
9. I would finalize this –making note of those issue above that may be relevant – and move on.

Hope that this is useful. Let me know if there are other reports and if there is still time to comment on them.

Comments on EIA: Hydrological Impacts Report (Mark Rountree, Wetlands Consultant, Pretoria).

Overall, the amount and level of detail of information provided in the hydrology report do not allow for the extent of environmental impacts to be determined. I would suggest that the level of information that has been supplied would not even allow the extent and severity of the ecological impacts to be guessed at, at this stage.

Specifically, no detailed data are provided which explain the change in flooding extent in the study area. This is a serious omission in such a study, since the extent of flooding in the swamps is the KEY driver for the ecosystem. It is impossible to predict the extent and severity of the impacts of the dyke, or other scenarios, if the change in the hydrology (flooding extent and duration) is unknown.

The terms of reference cited in the hydrology report do adequately address the needs of the ecologists, but it would seem that the study had not met the terms of reference, since much of the requested information is not provided in this version (Version 3) of the hydrology report. If the terms of reference for the hydrological study can be met, I believe that the ecologists should have sufficient information to assess the extent and degree of environmental impacts associated with the various scenarios.

I have copied the terms of reference, and addressed specific points relating to them, below in more detail.

Terms of reference for the hydrology study

The terms of reference for this study (pg 3) indicated that appropriate "numerical modeling and spatial analyses and mapping technique" would be used to determine the extent, depth and duration of flooding under current dry and wet seasons' conditions as well as different flooding scenarios. Specific points (in bold) which have reference to the prediction of ecological impacts are detailed below.

1) The impact of the proposed dyke intervention as currently designed on the extent, depth and duration of flooding on both sides of the dyke during the dry and wet seasons" would be determined. Specifically, it is stated that the model would generate output data in the form of maps and time series for specific and representative locations over certain periods. Such output data would include:

- **Area flooding by inflowing river waters from upstream rain events**
- **Area flooding by blocked river waters by downstream rain events**
- **Area flooding by local rainfall events**
- **Mapping of different flooding extents under specific scenarios**
- **Calculation of water levels and flows**
- **Flooding and drying of areas**
- **Overland sheet flow**
- **Evaporation**
- **Resistance to flow due to vegetation cover**

- **Structure operation like open culvert and gate flow**
- **Structure failure like overtopping and dyke break**

No maps of the altered extents of flooding have been provided**.** The only maps provided are those showing the maximum extent of flooding under an average and peak flow year, under the historic (no dykes) scenario. In terms of the various scenarios, the only data provided are that 16%, 21% and 25% of the floodplain would be cut off under alignment scenario 1, 2 and 3 respectively (pgs 16 and 17). However, there is no clear indication of the extent of the floodplains that are mentioned here, so it is not possible to determine where these affected areas are.

2) Key low-lying corridors (with potential to work as main irrigation channels) in the east-west distribution of the wetland and river-flooded grassland to inform alternative dyke structural designs and operations for reduced impacts on access to water and grazing in the dry season and the consequences of that for people, livestock, wildlife, fisheries and the general functioning of the affected wetland ecosystem, would be identified.

No such information is provided in the hydrology report. If such corridors are to be created or maintained, this may compensate for some of the river-flooded grasslands that are to be lost due to the dyke development. However, to predict the impacts of the dyke alignments, this sort of information is necessary to assess how much of the grasslands behind the dykes may still be able to function as river-flooded (rather than the much less productive rain flooded) grassland.

Additional data required for ecological impacts to be determined

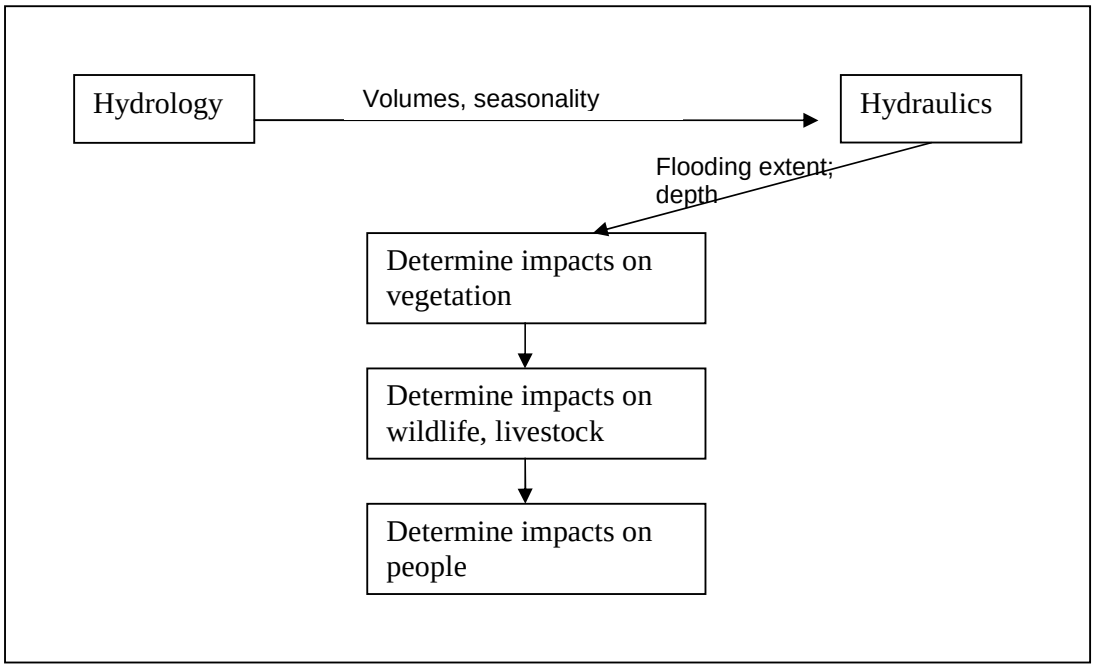
Whilst the depth and duration data are presented in the hydrology report, there are no maps or other spatially referenced data provided to indicate the extent of the flooding under either the current proposed dyke alignment, or any of the alternative pathways. The only maps of flooding extent that are provided are Figure 5 (*Area inundation under historical average conditions during flood season*) and Figure 6 (*Area inundation under historical peak conditions during flood season*). These only reflect the maximum extent of flooding in an average and peak flood year, under historical conditions. No such similar information is provided to show the extent of flooding in the low flows season, or to show the extent of flooding under other scenarios (current proposed dyke alignment or alternative scenarios). These data are presumably available, since reference is made to the altered percentage changes to the extent of flooding under the different scenarios.

For the ecological studies, where the hydrological inputs are vital to assist in the determination of impacts of the various scenarios, it becomes impossible to predict impacts with the level of data provided.

I would thus suggest, for ecological impacts of the various scenarios to be predicted, that at least the following information be provided:

- maps of (1) average and (2) above average runoff years be generated which show the extent of flooding in the marshes in BOTH the peak of the dry and peak of the wet season, for the historical condition, as well as for the three dyke alignments options.
- I would additionally recommend modeling a below-average flow year, since the information coming from Lake Victoria suggests that the lowered lake level there will lead to below-average flow conditions downstream in the near future, and this condition may persist for some time until the lake level has recovered.

Such data (which are requested as part of the original terms of reference) would allow the change in river-flooded grasslands (with reference to the historic condition) to be determined for each alignment scenario. Once the changes in vegetation are predicted, this should allow effects on wildlife, livestock and people to be determined.



General comments

It is a concern that the model has only been calibrated with water levels and not the flooding extent (pg 13). Given this limitation, some explicit indication of the expected accuracy of the model with respect to predicting flooding extent should be provided.

Possibly some general information of the flow patterns could be included. In particular, it should be noted that excess ("flood") flows "spill over the river banks and flow through the floodplain parallel to the river and back into the river channel downstream" (Sutcliffe and Parks, 2001, p. 129.).

Wetlands impacts study proposal
To be conducted by GC Marneweck, Wetlands Consulting Services (Pty.) Ltd., Pretoria, South Africa.

Appraisal by WN Ellery, August 2005
School of Environmental Sciences, University of KwaZulu-Natal, Howard College, Durban, South Africa.

Introduction and terms of reference of this appraisal

The Sudd wetland is a vast wetland on the Nile River that occurs on extensive plains of southern Sudan. It is recognized as one of the great inland deltas of Africa (McCarthy 1993), comprising approximately 16 600 km^2 of permanent swamp, flanked by approximately 14 000 km^2 of seasonally flooded grassland.

Rehabilitation of a dyke and road system extending over approximately 95 km between Bor and Mabior in southern Sudan, will impact significantly on the natural and socio-economic systems of the region, including particularly the wetland and the people who depend on ecosystem goods and services provided by it.

Phase I of the project was a Scoping exercise preceding a full Environmental Impact Assessment. The intention of Phase II of the present study is to consult stakeholders, assess expert opinion and plan the full EIA. My role is to assess the terms of reference for the Wetlands Impacts Study Proposal as presented to me in the document compiled by the consultant GC Marneweck.

The context of the present study

The Dyke will prevent flooding of a large area of floodplain to its east, leading to desiccation of these areas. This will reduce water supply to the area where people live and deprive them of water. The livelihoods of people will thus be affected in the absence of some mitigation, including reduced water supply (especially during the dry season), deterioration of groundwater quality and possibly supply, loss of fisheries, conversion of floodplain grassland to woodland with concomitant reduction of dry season grazing and other natural resources for subsistence purposes. However, it will also provide local benefits that seem to outweigh the costs – at least in the short-term – including reduced risk of flooding and increased availability of hardwoods.

Water that is excluded from the floodplain by the Dyke will be forced into the remainder of the wetland to the west and north of the Dyke, leading to increased flooding in these areas. This will lead to habitat changes and increase the likelihood of invasion by unpalatable as well as invasive plant species. Forcing water into portion of the wetland will focus sediments locally within the system, increasing rates of sedimentation and aggradation locally in the system, thus accelerating the frequency of channel avulsion. It will also limit the focusing of detrimental (potentially toxic) solutes such as sodium and chlorine within the system, possibly leading to increased risk of salinisation of surface waters.

Identification of key issues and risk areas

The following key issues and risk areas of the impacts of the Dyke have been identified:

- Hydrological impacts as they relate to wetland functioning
- Impacts on grazing resources and livestock productivity
- Impacts on wildlife
- Socio-economic impacts

Based on these issues, specialist studies were identified as:

- Hydrological impacts
- Impacts on wetland functions
- Impacts on grazing resources and livestock productivity
- Impacts on wildlife
- Economic and social impacts

With respect to the impacts on wetland functions a series of key issues was raised as follows:

9. Availability of water to people and their livestock as well as wildlife – particularly during the dry season, including possible impacts on sub-surface water resources;
10. Changes in the depth and duration of inundation on both the eastern and western side of the dyke that will experience desiccation and increased inundation respectively;
11. Changes in the vegetation composition and structure in the affected sections of the wetland, which will have important consequences for indigenous fauna (including avifauna and ichthyofauna) as well as for invasive species;
12. Drying of the river-flooded grassland to the eastern side of the dyke is likely to affect:
    a. growth rates and productivity of the grasslands, as well as the quality of forage, which will have consequences for dry season and dry year grazing of livestock and wild game;
    b. vegetation structure due to encroachment of woody species on the eastern side of the dyke where people will be settled, which may lead to improved supply of timber for firewood and construction purposes;
13. Loss of breeding habitat for fish species occurring in the wetland system due to drying out of the seasonally flooded grasslands to the east of the canal, which is likely to have negative consequences for the ecosystem as well as fisheries;
14. Cutting off of sediment supply to the river flooded grasslands and other parts of the wetland to the east of the dyke may have consequences for the geomorphology and dynamics of the wetland as well as soil fertility;
15. General wetland habitat loss and changes.

Based on these key issues and risk areas, terms of reference for specialist studies have been compiled, together with the inclusion of a general code of practice for specialists in terms of the EIA study as a whole.

Terms of reference of the wetland impacts and functions study

The terms of reference have been paraphrased from the document compiled by Gary Marneweck as follows:

1. Undertake a comprehensive literature review of relevant documentation and provide a summary report dealing with those aspects relevant to the construction of the dyke system;
2. Use available satellite imagery to identify and map the extent and distribution of wetland habitats and plant communities in the area that will be affected by the dyke system;
3. Determine the area of wetland (including river-flooded grassland) that will be affected (cut off) by the dyke and quantify the area of the different wetland plant communities associated with this;
4. Determine the likely changes in plant community composition, structure and distribution in the wetland area affected by the dyke;
5. Quantitatively establish the likely changes in the productivity of the vegetation in the wetland areas affected by the dyke;
6. Establish the likely dry and wet season and dry and wet year consequences of the changes in the productivity of the vegetation for livestock and wild game;
7. Establish the role of sedimentation in determining the productivity of the wetland system and determine what effect the Dyke will have on sedimentation in the affected areas of the wetland;
8. Establish the natural dynamic of the wetland system based on the key drivers/processes in the system and indicate whether or not there is evidence of a trajectory of change outside the bounds of the natural dynamic as a result of the Dyke;
9. Establish the importance of the river-flooded grassland and particularly the seasonal and longer-term dynamics in the system, for the breeding cycles and productivity of fish species that are found in the wetland, with articular attention to those species that are commercially or socio-economically important in the area;
10. Establish the impact of the dyke on the fish populations given the findings from 9 above, and ensure that the findings are made available in a format that can be used to assess the affect on the fisheries in the area;
11. Establish the importance of the Mabior Gol in particular, as well as any other key low lying east-west hydrological corridors, in terms of all of the above;
12. Produce a scenario assessment that is spatially explicit in order to identify suitable environmental mitigation for the dyke alignment and design – including consideration of alternative options.

Appraisal of terms of reference of the wetland specialist study

The terms of reference have been carefully considered and developed, although I am concerned that issues that have been raised relate to short-term impacts and benefits. They also reflect the assumption that is integral to the way that ecologists think: plants and animals respond to the external environment. Therefore, all of the issues that have been raised are relevant. However, it is increasingly accepted that plants and animals exert striking feedback on the external environment, and in some cases they may fundamentally affect the structure and functioning of ecosystems. This is particularly true in wetlands.

Based on this I would consider it important to add two additional components, with a third component that integrates the first two:

- The impact of the Dyke on the fate of all incoming clastic sediment has not been included as a component of the study – with the exception of the impact of reduced flooding frequency on the floodplain, which may lead to reduced sedimentation to the east of the Dyke, possibly reducing soil fertility and plant productivity (issue 7 above). Focussing of clastic sedimentation locally in the wetland as a result of the construction of the Dyke will have a far greater impact than this – it may lead to accelerated rates and frequencies of channel avulsion that will threaten the Dyke in the medium term, and therefore the newly established livelihoods of people on the floodplain. The issue of channel change has also been addressed superficially (issue 8 above), but I consider that the links between clastic sedimentation and channel change needs to be semi-quantitative in order to be meaningful. Therefore, the impact of the Dyke on patterns of clastic sedimentation and therefore on wetland dynamics is an important issue that needs to be addressed in more detail.
- The impact of the Dyke on the fate of dissolved sediment has not been included at all as a component of the study, which is a potentially fatal flaw. The Sudd is a region in which potential evapotranspiration exceeds rainfall in every month of the year (McCarthy 1993). Given this, the dissolved solid load in surface water should increase in proportion to the amount of water lost to the atmosphere. However, salt build-up in surface water does not occur due to transpiration being the dominant mode of water loss. However, transpiration rates vary spatially in the marsh and its floodplains, leading to localized focusing of detrimental (possibly toxic) salts such as sodium and chlorine. The study needs to attempt to understand the dissolved solute budget – particularly the location of sites of substantial water loss and detrimental solute disposal, in order to ensure that the Dyke does not interfere with this mechanism of salt removal. Failing this, the system may rapidly salinise, with disastrous consequences for the ecosystem and people who depend upon it. The best example of such salinisation as a consequence of manipulating the distribution of water in a large wetland system, is the wetland system in Iraq linked to the Tigris and Euphrates Rivers.
- It needs to be recognized that these two types of sedimentation are linked in a general way in that clastic sedimentation may promote renewal of soils through channel avulsion, such that salinisation is prevented. Initiatives such as the construction of the Dyke will invariably attempt to stabilize flow within the system, leading to continued focusing of clastic and dissolved sediments locally in the system. This will increase the risk of rapid salinisation of the system, with disastrous ecological and socio-economic consequences for many people in the region as well as those downstream.

I strongly urge the team to add these to their list of issues to consider.

For further background on these issues, useful references are:

- Ellery & McCarthy (1994), which raises issues with respect to the sustainable utilisation of a large African inland “Delta” – the Okavango Delta in Botswana.
- McCarthy (1993), which describes features of great inland deltas of Africa, including the Sudd.

In the former publication, activities at the head of the wetland system are viewed as problematic since it is often in this region that sediment is focused and deposited. Impacts on the natural sedimentation processes at the head of a system such as this (as is the case in the present case of the Sudd) can have far-reaching and long-term consequences for the entire system as a whole. Thus, people at the head of the system may benefit, while downstream users pay the full social and environmental cost.

The latter publication provides a general description of the Sudd with special emphasis on the most important biophysical characteristics, including morphology and geological controls, climate, hydrology, water chemistry, clastic sediment and vegetation. It also describes factors that unify the great inland Deltas of Africa, with an emphasis on ecosystem processes.

References

Ellery WN & McCarthy TS 1994. Principles for the sustainable utilization of the Okavango Delta ecosystem, Botswana. Biological Conservation 70:159-168.

McCarthy TS 1993. The great inland deltas of Africa. Journal of African Earth Sciences 17:275-291.

External Peer Review of the SS EIA proposed socioeconomic impacts study

By Dr. Jane Turpie, Department of Zoology, University of Cape Town (see attached PDF file)