



**Ministry of Agriculture, Irrigation
and Water Development**



**Lilongwe
Water Board**



LILONGWE WATER BOARD

Environmental and Social Impact Assessment for Rehabilitation and Raising of Kamuzu Dam I

ESIA REPORT

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ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT FOR REHABILITATION AND RAISING OF KAMUZU DAM I

— ESIA Report —

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ACRONYMS

ABC – African Bird Club

ACR – African Chiroptera Report

ADD – Agricultural Development Division

ADMARC – Agricultural Development and Marketing Corporation

APINA – Air Pollution Information Network for Africa

BA – Baseline Assessment

BGS – British Geological Surveys

BOD – Biochemical Oxygen Demand

BP – Bank Procedures

BP – Before Present (Chapter Cultural Heritage)

Ca – Calcium

CBD – Convention on Biological Diversity

CCAP – Church of Central Africa, Presbyterian

Cd – Cadmium

CEC – Cation Exchange Capacity

CHM – Malawi Clearing-House Mechanism

CITES – Convention on International Trade in Endangered Species of Wild Fauna and Flora

CMS – Convention on the Conservation of Migratory Species of Wild Animals

dB(A) – Decibel (A-weighted)

DTM – Digital Terrain Model



DWM-MWS – Department of Water Ministry of Works and Supplies

E – East

EA – Environmental Assessment

EAD – Environmental Affairs Department

EARS – East African Rift System

EC – Electrical Conductivity

EHS – Environmental, Health and Safety

EIA – Environmental Impact Assessment

EMA – Environment Management Act

ESIA – Environmental and Social Impact Assessment

EuDASM – European Digital Archive on Soil Maps of the World

EWB – Environmental Water Requirements

FAO – Food and Agriculture Organization of the United Nations

FSL – Full Supply Level

GE_{PWM} – General Extreme Value Using probability weighted moments

GE_{VMM} – General Extreme Value using methods of moments

GIIP – Good International Industry Practice

GIS – Geographic Information System

H – Horizontal

ha – hectare

HIV/AIDS – Human Immunodeficiency Virus-Acquired Immunodeficiency Syndrome



IBA – Important Bird Area

ICH – Intangible Heritage Convention

ICOMOS – International Council of Monuments and Sites

IDA – International Development Association

IDP – Internally Displaced Person

IFC – International Finance Corporation

IMM – Modified Mercalli Intensity

ISO – International Standard Organisation

ITN – Insecticide-Treated Net

IUCN – International Union for Conservation of Nature

JICA – Japan International Cooperation Agency

KD1/2 – Kamuzu Dam I/II

KIX – Kids In Christ

km – Kilometre

km/h – Kilometre per hour

LAeq – A-weighted equivalent sound pressure level

LB – Left embankment

LCDS – Lilongwe City Development Strategy

LDDP – Lilongwe District Development Plan

LMP – Lilongwe Master Plan

LN – Log-Normal

LPIII – Log-Pearson Type III



LREP – Land Resources Evaluation Project

LSA – Late Stone Age

LWB – Lilongwe Water Board

m – metre

m.a.s.l. – metre above sea level

m² – square metre

m³/day | m³/sec– cubic metre per day | per second

MAP – Mean Annual Precipitation

MASDAP – Malawi Spatial Data Portal

MBS – Malawi Bureau of Standards

me/100g – milliequivalents of adsorbed cations per one hundred grams soil

mg/l – milligrams per litre

MGDS – Malawi Growth and Development Strategy

mm – millimetres

MS – Malawi Standard

MV – Malawi Vision

MWK – Malawian Kwacha

MWL – Maximum Water Level

NEAP – National Environment Action Plan

NEP – National Environmental Policy

NGO – Non-Governmental Organisations

NOC – Non Overspill Crest



NPDP – National Physical Development Plan

NPK – Nitrogen, Phosphorus and Potassium

NSO – National Statistical Office

NTU – Nephelometric Turbidity Unit

NWDP – National Water Development Project

°C – Celsius degrees

OP – Operational Policy (World Bank)

PGA – Peak Ground Acceleration

PM – Particulate Matter

PMF – Probable Maximum Flood

ppm – parts per million

RAMSAR – Convention on Wetlands of International Significant

RAPIDC – Regional Air Pollution in Developing Countries

RB – Right embankment

RBL – River bed level

RDF – Recommended Design Flood

RL – Reduced Level

RMF – Regional Maximum Flow

S – South

SABONET – Southern African Botanical Diversity Network

SADC – Southern African Development Community

SCS – Soil Conservation Service



SDNP – Malawi Sustainable Development Network Programme

SEF – Safety Evaluation Flood

SMEC – Snow Mountains Engineering Consultant

SPI – Standardized Precipitation Index

SRTM – Shuttle Radar Topographic Mission

STA – Sub-Traditional Authority

t/ha/yr – tonnes per hectare per year

TA – Traditional Authority

TDC – Teachers Development Centre

ToR – Terms of Reference

UNAIDS – Joint United Nations Programme on HIV/AIDS

UNDP – United Nations Development Programme

UNDP – United Nations Development Programme

UN-DTCV – United Nations Department of Technical Cooperation for Development

UNESCO – United Nations Educational, Scientific and Cultural Organization

UN-HABITAT – United Nations Human Settlements Programme

UNHCR – United Nations High Commissioner for Refugees

USD – United States Dollars

USGS – United States Geological Surveys

V – Vertical

VECEA –Vegetation and Climate Change in Eastern Africa



WB – World Bank

WHO – World Health Organisation

WRA – Water Resources Areas

WRIS – Water Resources Investment Strategy

WRU – Water Resources Units

µg – micrograms

µS/m – microSiemens per centimetre



Executive Summary

In order to manage and tackle water supply limitations and deficits, the Lilongwe Water Board (LWB) intends to increase the storage capacity of Kamuzu Dam I and cater to the current water supply deficit and growing water demand in Lilongwe City.

Kamuzu Dam I, located in Traditional Authority Masumbankhunda, Lilongwe District, is a composite concrete and earth embankment on-channel dam on the Lilongwe River, approximately 25 km southwest of Lilongwe in Malawi (see Appendix 1 – Map 1).

At this stage, the LWB envisages three preliminary project options for the raising of the dam by 5 m (to establish a new Full Supply Level of 1,105 masl), along with a set of rehabilitation actions and measures:

- Raising through the use of the Fusegate® System;
- Fixed raising;
- Fixed raising with side channel.

The proponent of the project is the Lilongwe Water Board (LWB), which is a parastatal organisation and not a subsidiary in the Ministry of Agriculture, Irrigation and Water Development. LWB was established through an Act of Parliament as defined in the Water Works Act (17) of 1995.

The present section summarises the contents of the ESIA Report for the Environmental and Social Impact Assessment (ESIA) for Rehabilitation and Raising of Kamuzu Dam I, conducted by NEMUS – Gestão e Requalificação Ambiental, Lda.

The following report refers to a study area that comprises the project and intervention areas available at this stage, as well as to its immediate surroundings – a 100 m study area around the new Full Supply Level (1,105 masl) and a 50 m buffer area around the new dam structures (spillway and embankments). Although no rigorous estimate for the FSL at 1,105 masl is available, an approximation of current and predicted full supply levels is presented in Map 2 (Appendix 1).



Baseline Assessment

The hypsometry ranges from 1,090 masl to 1,109 masl in the downstream and upstream limits of the water reservoir, respectively.

Pot-holed areas are common in this section of the Lilongwe River. Generally this stretch of the river is characterised by gently sloping margins. In the 100 m buffer and the area occupied by the future water reservoir, slopes only exceptionally exceed 20%.

The South Lilongwe Plain and Dzalanyama Range are largely underlain by granulites, gneisses and schists of the Precambrian Basement Complex; on the plains, this basement complex is for the most part obscured by thick superficial deposits which include residual soils, alluvium and colluvium. According to the geological map (1:100,000), red-brown sandy clay soils dominate the study area.

Malawi is within the most seismically active belt of the East African Rift System. In its actual configuration, it presents two main rift branches, the Western and the Eastern Rifts. The Western Rift area, where Malawi is located, is characterised by moderate magnitude earthquakes ($M \leq 6.0$). Historical records highlight the 1989 Salima Earthquake, a magnitude 6.6 quake which occurred on March 10 in central Malawi and claimed at least 9 lives, injuring 100 people and damaging property in the Salima-Dedza-Mchinji area.

Mineral resources with economical interest exist in the vicinity of the study area. In the Malingunde Hill, located less than 1 km away from Kamuzu Dam I to the north, iron sulphide deposits are present – quartzites and quartzo-feldspathic gneisses and granulites. Sand suitable for building purposes is available in the upper parts of many dambos and along the major rivers. Dambo clays and red-brown lateritic clay soils such as those found within and around the study area are often suitable for brick-making.

In regards to hydrology, Kamuzu Dam I is located in Lilongwe River, which is part of the Linthipe River catchment, flowing into lake Malawi. Lilongwe River itself spans from the Mountain Range of Dzalanyama on the Western Malawi-Mozambique border to its confluence with Linthipe River near Salima.



Kamuzu Dam I was built between 1963 and 1966 and has a storage capacity of 5 million m³. Together with Kamuzu Dam II, they regulate the flow of the Lilongwe River, ensuring an adequate water level at the intake near Lilongwe City, 20 km downstream. The catchment area upstream of Kamuzu Dam I is 757 km² and its most important tributary is the Katete River, with a catchment area of 197 km² (approximately 26%).

According to historical data, water levels in Kamuzu Dam I are often above Full Supply Level (FSL – 1,100 masl), usually peaking in March. In those months water from Kamuzu Dam I is freely discharged through the dam's spillway towards the Kamuzu Dam II reservoir. Usually from August or September to December, operation control valves in both Kamuzu Dams are opened as needed in order to ensure Lilongwe River's minimum flow and an adequate water level for the intakes of Lilongwe City's water treatment plants.

A drought in the Lilongwe District occurs once every 4 to 10 years and the 50-year return drought represents an extreme drought. From 1985 to 2010 the Lilongwe District has been severely affected by floods (5 to 10 floods in that period).

In 2013 the combined treated water supply for LWB's Treatment Works was 71,000 m³/day and the total water demand was 75,000 m³/day, which resulted in a deficit of 4,000 m³/day.

The available surface water quality data for Katete River and both Kamuzu Dams shows that faecal coliforms are responsible for most of the non-compliance cases of drinking water guidelines. The mean value obtained for Katete River is 2 to 3 times higher than that for Kamuzu Dam I and II. This can be due to cattle grazing directly on the reservoir margins and in the proximity of Katete, Manuele and other settlements, where no sanitation exists.

Faecal contamination usually peaks following the first rains, when accumulated faecal matter in the fields is washed into the river. However, mean values for the monitored sites tend to be low and allow a generally safe recreational use and irrigation.

Regarding general biological issues, some problems were detected concerning iron and turbidity concentrations, especially in Kamuzu Dam I.



According to the available data, surface water nutrient enrichment, which typically comes from diffuse pollution sources such as agriculture, does not seem to be a significant issue in the region. The scarce use of chemical fertilizers and the compliance with the reservoirs' protection buffer are most likely the main reasons for this.

The study area is included in the a vast aquifer in altered formations of the crystalline basement rock of the plateau. With only a few exceptions, the fractured and unaltered basement rock is does not provide not a very productive aquifer.

The future dam reservoir area consists of Ferrallitic Soils, or Xanthic Ferralsols (under FAO soil system classification). The soils of the study area could be considered, in general, good quality soils (particularly in terms of structure and drainage), but may have potential nutrient limitations.

Local erosion factors may be problematic for agricultural and production forest use, in riverbanks upstream of the reservoir, and immediately upland of the reservoir buffer zone.

However, many major erosion factors are not detected in the study area, such as frequent steep slopes, sand/soil mining in riverbanks, soil waterproofing, agricultural land within the buffer zone and use of heavy machinery.

Baseline noise levels are fairly low and mostly due to typical rural community life. Elevations occur in the vicinity of commercial areas, such as in Malingunde/Kapininga, but the recommended limits are complied with.

Ambient air quality in the project's site should be generally good due to low relevance of atmospheric pollution sources. Human settlements adjacent to roads are particularly exposed to local elevations of traffic and dust emissions, as well as biomass combustion hotspots that can affect residential areas.

The natural and semi-natural habitats in the study area include terrestrial habitats (woodlands, forest plantation and croplands), terrestrial habitats with aquatic affinities (wetlands) and aquatic habitats (Lilongwe and Katete Rivers).

Croplands are the main habitat of the study area, occupying more than 38% of the total area. Woodlands are the second largest habitat, corresponding to



almost 30%. On the other hand, woodlands and wetlands are the most representative in the estimated new flooded area (60%).

The study area covers part of the Dzalanyama Forest Reserve, first protected in 1911 and gazetted in 1922. The Forest Reserve is also considered an Important Bird Area.

Urban and rural areas in the Lilongwe district currently face different challenges in terms of Spatial Planning. In the city, the absence of housing policies and upgrading strategies are the main challenges. As a consequence, housing development and urban sprawl is very active, including illegal and unplanned settlements without urban facilities (water supply and sewerage/ sanitation). In rural areas, the main challenge is to ensure a correct land use planning without jeopardizing sustainable development. Urban and rural areas also have common challenges, such as water management.

According to the Water Resources Act in force until 2013, human settlements or agricultural production may only be developed more than 50 metres away from the water body. The new Water Resources Act (published on the 19th of April, 2013) currently doesn't define a minimum distance from the water body to such developments.

In terms of plans and strategies, the National Physical Development Plan is the master document for land-use planning in rural areas. The Lilongwe District Development Plan covers the rural area and contains a list of proposed development projects in various traditional authorities.

The project area is included in Traditional Authorities (TA) Masula and Masumbankhunda. The villages (or group villages) that are likely to be affected by the rehabilitation and raising of Kamuzu Dam I are:

- TA Masula – Kapininga, Mbalame, Mbowela, Katopeka, Manyenje, Chaponda, Simalambo, Mamina, Chisauka and Jasoni;
- TA Masumbankhunda – Malingunde, Sinyala, Kaweche, Manuele, Bukatantha, Ntchontcho, Mafupa and Katete (along with isolated households within the Dzalanyama Forest Reserve).

In peri-urban and rural areas, most people live in informal settlements, where living conditions are undeveloped and inhabitants have little to no access to



social infrastructures or basic urban services. The use of pit latrines is very common, contributing to the pollution of underground water sources as well as to the spreading of diseases.

Most of the drinking water in the study area is abstracted from boreholes and its immediate surroundings. Nevertheless, some sporadic cases were identified where private owners (near KD1) were pumping water from the dam (in accordance with the respective water abstraction license) or isolated households near the river were using untreated river water or dug holes for drinking water.

The vast majority of the rural population in the study area and its vicinity relies heavily on subsistence agriculture, mostly with smallholder farms based on rainfed maize production and tobacco. Groundnuts are also important planted crops as well as vegetables and other subsistence and consumption products within households (like Irish and sweet potatoes, green beans, soyabeans, tomatoes, pumpkins, sugarcane, among others).

Although most of the human settlements are located upland of the river and/or reservoir boundaries, a set of infrastructures and other areas of interest to local populations are located within the study area. According to fieldwork surveys, 15 structures are included by the FSL at 1,105 masl and 89 structures are framed by the 100 m study buffer, which makes a total of 104 structures within the study area.

A field survey conducted in November 2014 revealed the presence of 40 archaeological sites within the study area and 2 sites of intangible cultural heritage. The latter are *dambwes* – meeting places of the *nyau* societies which are acknowledged under the UNESCO convention of Intangible Cultural Heritage. Due to methodological constraints it is possible that the area may even hold more archaeological sites. No historical buildings were found within the projected flood zone or its 100 m buffer.



Impact Assessment and Mitigation/ Compensation/ Enhancement Measures

Most impacts arising during the construction phase are caused by activities such as: land clearance, earthworks/excavations, operation of heavy machinery, traffic and other construction activities. These will likely cause temporary to short-term negative impacts such as soil erosion, pollution (noise, dust, possible spillages to soil and water, etc.) and a general disturbance to the local people's everyday life. The impacted area is expected to be rather contained, with the majority of impacts occurring mainly around the construction site on Kamuzu Dam I wall and embankments. Mitigation is usually possible for these kinds of impacts and, after adequate action and management has been taken, most of them could be classified as being of low significance.

Construction itself will also generate some long-term to permanent negative impacts over soil and land uses, habitats, buildings and other structures existing along the construction site needed for the dam's raising. These were evaluated overall as of low significance after mitigation, exception made to habitat alteration/loss that will be in the low to moderate range due to the value of some of the affected habitats.

Other construction phase negative impacts arise in the social and economic sphere, such as possible conflicts with migrant workers, risk of accidents and spread of sexually transmitted and communicable diseases (like HIV/AIDS). These were considered of general low significance after the application of the recommended mitigation measures' extensive set.

On the other hand, construction will create employment and new local business opportunities, which will determine positive impacts on local income, improvement of household's living, empowerment of local contractors and suppliers, among other indirect benefits. Construction will require a significant workforce, part of which should be recruited locally. It is considered an impact of moderate intensity, but facing the low rates of local employment it is rated as of moderate to high significance after enhancement, with a short-term effect.

The resulting reservoir's enlargement in the operation phase features the major identified positive impacts. Water supply availability is an important economic development factor, so in this way the expected improvements can give a beneficial boost to various sectors of Lilongwe's economy. Also, taking into



consideration the rapid population growth and increasing demand in Lilongwe City and the current water limitation and deficit, the raising of Kamuzu Dam I increases the water management capability to support the growing demand in the medium-term, until new water sources and infrastructure investments are put into operation.

A larger inundation area will represent an increment in the available aquatic habitat and thus a favourable opportunity for water-related vegetation and fauna, such as fishes, amphibians and birds. At the same time this will represent an increase in food supply to many other animal species. This promotion of ecological diversity is considered a positive impact, which significance may be increased to a moderate level if some enhancement measures are taken.

Soil and agricultural land/crops loss (as well as terrestrial habitat loss) are inevitable interconnected negative permanent impacts of the reservoir's extension to FSL. Loss of housing and human structures located within the new possible maximum water limits (MWL), variable with the project option, would be another negative effect, in this case. What these impacts have in common is the possibility of being mitigated and compensated through a properly organized and thorough resettlement plan, which can include compensation measures directed to the community or to promote alternative income sources, when direct resettlement or compensation for agricultural and infrastructural losses is possible (water infrastructures, schools and road improvements, amongst others).

The permanent loss of agricultural land is a primary impact that generates indirect impacts as the reduction of livelihood and income for local populations or the arising of latter disputes during the relocation of land for cultivation and grazing. Particularly, the loss of small scale subsistence farming (lands close-by the water reservoir, which are planted during all year and from which families rely on) is one of the major concerns, as it can result in severe indirect impacts, including possible food privation. The RAP will also address such issues.

The resettlement and compensation process can be viewed as an opportunity to improve living conditions and livelihood, through better housing, access to urban commodities like good quality drinking water, health services, etc., since local housing conditions in villages are generally very poor.



Regarding habitat loss, woodlands and wetlands should be the most affected. Both have an intrinsic ecological value, but will also represent a loss of food resources and shelter to occurring wildlife. However, while the loss of riverine and lacustrine floodplains (wetlands) will be mostly a temporary impact (new floodplains will be created), the loss of woodlands will be of greater intensity as they are quite scarce in the surrounding. Overall, a low to moderate significance impact is predicted, regardless of the project option.

The increase of the inundated area will also represent a wider physical barrier to terrestrial faunistic species, in particular considering the interruption of the terrestrial habitat's continuity, with special regard to woodlands.

Cultural heritage sites found along the new flooding area will be affected with different severities, from low to high, but none of them presents a red flag to the projected development since mitigation or rescue is possible, independently of the project option.

As the *nyau dambwes* are at the very fringe of the study area, the groves are not expected to be affected by the inundation itself. It should be ensured though that local communities retain access to the indicated *nyau* groves for burials and *nyau* activities. With more detailed design of project options in further stages, namely during the development of the Resettlement Action Plan, the rigorous assessment of the possible impact over graveyards and need to resettlement to new burial sites will be evaluated thoroughly and mitigated as adequate, with the involvement of responsible authorities and articulation with local leaders.

Lastly, no significant water quality issues are expected in the augmented reservoir, particularly the ones related to oxygen depletion, considering that current pollution sources will remain the same (and reservoir protection measures will continue to be enforced). Nonetheless, as a preventive measure towards this prediction, a previous tree and vegetation clearance in the new flood area is recommended to be done. In this context (with positive effects transversal to other environmental components), it is also proposed the establishment of a levelled protection buffer zone (with different restrictions to human activities allowed at each level) and the reestablishment of a riparian and protective vegetation buffer next to the future FSL.



The main feature that distinguishes the magnitude and significance of each option's impacts is the type and dimension of embankments.

Regarding construction's (mostly temporary) impacts, Option 2 is the least favourable option as it demands a high quantity of borrow material to construct the necessary embankments, implying maximised earthworks with larger soil needs and higher noise and dust emissions. As for Options 1 and 3, the latter would be slightly more favourable concerning soil demand – as excavation products could make up for part of the earthworks' necessities thus decreasing the need for the creation of borrow pits. In case there is a need for blasting rocky patches for the construction of the side-channel, Option 3 will then present itself as the least favourable one.

Without having a clear agreement on which option is the most favourable in the construction phase – even though Option 2 presents itself as more unfavourable, the long-term/permanent operation phase impacts are the ones that shall dictate the final verdict.

Considering that the three different maximum water levels will determine proportional increasing losses (Option 1<Option 3<Option 2), for either impacts regarding "loss of agricultural land" or "loss of buildings and other structures", Option 1 is the most favourable option. Between Options 2 and 3, Option 2 is again the most unfavourable (as it will generate the higher water level).

Nonetheless, after adequate compensation all options are equally placed, resulting in low significance negative impacts – although it should be emphasize that compensation costs will also be proportional to the MWL of each option.

Conclusions and Recommendations

Kamuzu Dam I's raising and rehabilitation Project will have limited negative construction impacts, most of which can be adequately mitigated by the recommended measures, and relevant negative operation impacts, to be tackled by the development and rigorous implementation of a thorough Resettlement and Compensation Action Plan. On the other hand, the project will generate several important positive impacts, mainly on the socio-economic sphere, actively contributing to a general development of the region, and more specifically to an improved water management and water supply capability.



Overall Option 1 is assessed as the most favourable project alternative pondering all environmental and social impacts; on the other hand, Option 2 has the highest negative effects, especially regarding the loss of agricultural and social assets. Although all options can potentially achieve a similar net result in terms of environmental and social viability (after mitigation, compensation and enhancement measures' effects are accounted for), there's an economic and social cost that always weighs in on the least favourable options, with increased risks of disrupting and negatively influencing local populations.

With the proper implementation of all the recommended measures, the proposed development is environmentally and socially viable. In fact, this ESIA anticipates that in those conditions the project may contribute with an overall environmental benefit.

Some key recommendations are highlighted to ensure an adequate provision and validity of the achieved global conclusions:

- The detail project design and decision on the preferred project option should have in account as a key factor the minimisation as feasible as possible of the maximum water level of the dam and subsequent impacts over soil, habitats, agricultural land and houses and other infrastructures losses.
- Perform a thorough inventory of the wells and boreholes directly affected by the project, ensuring their replacement.
- Villages surrounding KD1 should benefit in some extent from the new reservoir that will flood part of their land. Thus, if feasible, the project should incorporate provisions for some kind of water supply facilities, proposals to be discussed with local village leaders.
- As a preventive measure, a deforestation of the new area to be flooded shall be done according to deforestation regulatory procedures to be developed, namely through a previous demarcation of the new FSL at 1,105 masl for authorised and regulated collection and clearance of vegetation and wood by local population, according to a fair and clear set of rules to be negotiated with local traditional authorities.
- Fair compensation and resettlement shall be provided to cases that cannot be avoided, under the guidelines of the Compensation and Resettlement Action Plan that will define compensation and resettlement



measures for the affected land, socio-economical activities, housing and other household assets. Assistance and monitoring should also be ensured throughout the process.

- Roads and bridges included within the designed maximum water level must be timely replaced to assure the connection between territories and margins. If not feasible, alternative road accesses must be planned and provided, without worsening the villages' accessibility and mobility.
- Prior to inundation, archaeological excavations should be allowed. The need for rescue archaeology at other sites will depend on the exact determination of the inundation area and further testing of the site's significance (through digging of test pits).
- Enforce the maintenance and control of protection buffer zones around the reservoir (Zone 1, Zone 2 and Zone 3, with different restriction levels for permitted activities).
- Implement a riparian and protective vegetation buffer within Zone 1 and demarking it.
- Urgent preventive land use measures should be taken to avoid or stop encroachment within the study area, especially around KD1's site. Land uses should be closely monitored by the Lilongwe Water Board and some kind of legal measures should be considered to prohibit or at least control new developments in this area.
- The Environmental and Social Management Plan (ESMP), defined in the present ESIA shall be integrated as part of the Terms of Reference (ToR) for the construction's bidding process. The developer and the contractor shall thereby be contractually obliged by the ESMP to implement all the identified mitigation and monitoring measures according to the planned schedule.



I. Introduction

The present document constitutes the **Environmental and Social Impact Assessment Report** regarding the Consultancy Services for the Environmental and Social Impact Assessment for Rehabilitation and Raising of Kamuzu Dam I, conducted by NEMUS – Gestão e Requalificação Ambiental, Lda. – for the Lilongwe Water Board.

In order to manage and tackle water supply limitations and deficits, the LWB intends to increase the storage capacity of Kamuzu Dam I and cater to the current water supply deficit and growing water demand in Lilongwe City. Kamuzu Dam I is located at Traditional Authority Masumbankhunda, Lilongwe District, approximately 25 km south west of Lilongwe in Malawi (Appendix 1 – Map 1).

At this stage, the LWB envisages three preliminary project options for the raising of the dam by 5 m (to establish a new Full Supply Level of 1,105 masl), along with a set of rehabilitation actions and measures to also be undertaken:

- Raising through the use of Fusegate® System;
- Fixed raising;
- Fixed raising with side channel.

The project developer is **Lilongwe Water Board**:

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The consultant responsible for the ESIA is **NEMUS, Lda**:

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The ESIA was conducted by a team of specialists with vast experience in environmental assessment and management. The team was led by Pedro Bettencourt (Project Manager), with the support of Project Coordinators Nuno Silva and Pedro Moreira.

Table 1 – ESIA Team composition

Name	Qualifications
Pedro Bettencourt	• ISCED 7/ MSc in Geology; ISCED 7/ Post-graduation in Geologic Oceanography and Marine Sedimentology
Nuno Silva	• ISCED 7/ MSc in Environmental Engineering
Pedro Moreira	• ISCED 7/ MSc in Environmental Engineering
Pedro Afonso Fernandes	• ISCED 8/ PhD in Urbanism; ISCED 7/ MSc in Urban and Regional Planning; ISCED 7/ MSc in Economics; ISCED 7/ MSc in Economics
Henrique Coelho	• ISCED 8/ PhD in Environmental Engineering; ISCED 7/ MSc in Ecology, Management and Modeling of Marine Environment • Physics Oceanographer
Sara de Sousa	• ISCED 7/ MSc in Biology
Ângela Canas	• ISCED 8/ PhD in Environmental Engineering; ISCED 7/ MSc. in Science in Engineering and Management of Technology; ISCED 7/ MSc in Environmental Engineering
Ana Quaresma	• PhD candidate in Civil Engineering • ISCED 7/ MSc in Civil Engineering • Hydraulics and hydrology; Water and sanitation engineering
Maria Grade	• ISCED 7/ MSc in Environmental Engineering; ISCED 7/ MSc in Geographic Information Systems
Cláudia Fulgêncio	• ISCED 7/ MSc in Environmental Engineering
Sónia Alcobia	• ISCED 7/ MSc in Geology • Geology; Geomorphology; Hydrogeology
César Jesus	• ISCED 8/ PhD in Geosciences; ISCED 7/ MSc Post-graduation in Sciences of Coastal Areas; ISCED 7/ MSc in Geology and Biology
Gisela Sousa	• ISCED 7/ MSc in Biology



Name	Qualifications
Menno Welling	ISCED 8/ PhD candidate; ISCED 7/ MA in Theoretical Archaeology; ISCED 7/ MA in Cultural Anthropology
Sofia Gomes	ISCED 7/ MSc Post-graduation in Environmental Studies and Land Management; ISCED 7/ MSc in Archaeology
Ricardo Tomé	ISCED 8/ PhD candidate; ISCED 7/ MSc in Geography and Territory Management
Ana Otília Dias	ISCED 7/ MSc in Economics

In order to assess the cultural heritage reference situation for the study area of the project a team of five experienced archaeological surveyors was assembled. This team was responsible for identifying archaeological sites, heritage elements and performing the necessary research and fieldwork.

Table 2 – Cultural Heritage field work team composition

Name	Position
Menno Welling	Lead Consultant, African Heritage
Christopher Mankhokwe	Research officer, African Heritage
Moses Mkumpha	Conservator, Dept. of Antiquities
Moses Nyondo	Team member, Malawi Earlier Middle Stone Age Project
Henry Kalinga	Team member, Malawi Earlier Middle Stone Age Project

The Project's background, justification and necessity are discussed in chapter 2.

The ESIA's preparation began with the project's revision and description (Chapter 2) (at a preliminary design stage), the environmental planning and design (Chapter 3), the legislative and regulatory framework (Chapter 4), and with the compilation of available bibliographic research, map information and fieldwork surveys in order to achieve a baseline situation of the study area (Chapter 5).

Subsequently, the project's environmental and social likely impacts were identified, justified and assessed by a team of specialists according to pre-defined evaluation criteria (Chapter 6). Mitigation and monitoring needs were then listed and Environmental and Social Management and Monitoring Plans



were prepared (Chapter 7). Overall assessment and key conclusions and recommendations were dully presented in Chapter 8.

General methodology followed the assignment's Terms of Reference (ToR), the Malawian EIA guidelines (1997) and international best practices for EIA. The World Bank's (WB) Operational Policy (OP) 4.01 – Environmental Assessment – was also followed. Major methodological steps along the ESIA's preparation were:

- **Review of preliminary design and previous studies**
- **Project justification and description**
- **Environmental Planning and Design**
 - Includes a discussion of the environmental planning that has gone into the project. All the issues that have been taken into account for avoiding or minimizing impacts, for capturing potential benefits, for compensating for residual impacts, and for impact management are discussed
- **Environmental Setting / Baseline assessment:**
 - Review of existing information
 - Field surveys
 - National and international database research
 - Bibliographic and specialized papers' research
 - Contacts with stakeholders and relevant institutions
 - Mapping and aerial imagery analysis
 - Environmental modelling
 - The existing condition of the physical, biological and human environments of the project area, as well as trends and the anticipated future environmental conditions should the project not go ahead
 - Environmentally-sensitive areas of special or unique biophysical, socio-economic or cultural value
- **Environmental and social impact assessment:**
 - Identification of the environmental and social impacts associated with the project, focusing on both positive and negative impacts on bio-physical, chemical, ecological, social, economic and cultural components of the environment
 - Assessment of environmental and social impacts according to pre-determined criteria (see Chapter 6)



- Overall assessment and discussion
- **Environmental and Social Management Plan / Environmental and Social Monitoring Plan:**
 - Proposal of feasible and cost-effective measures and procedures to prevent and mitigate significant negative impacts and to enhance benefits
 - Operational and management procedures
 - Proposal of design modifications, if necessary
 - Guidelines for monitoring campaigns design
 - Responsibilities and roles for the promoter, contractor(s), public agencies and stakeholders in environmental management
- **Conclusions and Recommendations**



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2. Project Overview and Background

2.1. Project Justification

The water supply system for the Lilongwe Water Board has two earth dams on the Lilongwe River, namely Kamuzu Dams I and II upstream of the intake points of the treatment plants that compound raw water. Water stored in Kamuzu Dams I and II is discharged into the Lilongwe River and flows in its natural course up to the intake points.

In order to manage and tackle water supply limitations and deficits, the LWB intends to increase the storage capacity of Kamuzu Dam I by raising it and cater to the current water supply deficit and growing water demand in Lilongwe until the operation of the new raw water source and other water infrastructures investments.

According to Aurecon (2013b) the water available for abstraction at the Water Treatment Works in 2013 (including that from runoff below KD2), at a 1:20 year risk of failure and with an allowance of 8% of the runoff to meet EWR (Environmental Water Requirements), amounts to about 166,000 m³/day. LWB aims for a minimum target increase in yield of 30,000 m³/day. With a raise of 5 m, the estimated yield increase will be by 48,000 m³/day, ensuring LWB's objectives.

When Kamuzu Dam I was originally designed and constructed, it was envisaged that a 5 m raising might be implemented in the future, and the earthfill flank embankments were build wide enough to accommodate this. It is therefore feasible to raise the Full Supply Level of the dam by 5 m, without the need to draw down the reservoir level.

The practicality and options of raising the Kamuzu Dam I are seriously constrained by some limitations:

- High tailwater level of Kamuzu Dam II immediately downstream of Kamuzu Dam I – tailwater from the Kamuzu Dam II reservoir floods the toe to a depth of 9 m;



- Insufficient capacity of the Kamuzu Dam I outer works – outer works are not able to either draw down the stored water rapidly, or to pass flow during the period of reconstruction;
- Both situations imply that a possible raising of the dam by working on the downstream side only means carrying out the work with the Kamuzu Dam I reservoir drawn down by at least 8 m (allowing for a low cofferdam on the downstream side). This degree of drawdown represents virtually the entire live capacity of Kamuzu Dam II, and could only be affected after additional equivalent storage has been provided to supply the Lilongwe waterworks, i.e., a new reservoir at the Lilongwe 3 site or on the Likuni River. Moreover, the raising would have to be implemented before the demand exceeded the potential yield of the new source, without the contribution from Kamuzu Dam II and Kamuzu Dam I;
- The current spillway of the dam cannot accommodate the SEF, which means that the NOC would be slightly overtopped. When the SEF is routed through the existing reservoir, it is estimated that the overtopping of the NOC would only last for a total of four hours, starting at zero, rising to 400 mm, and then dropping to zero again. Regardless, the freeboard of the dam is adequate for the RDF, but just not so for the SEF¹.

Lastly, Kamuzu Dam I has an overdue economic life expectancy of 50 years of the dam coupled with deteriorating concrete structures of more than 50 years of economic life expectancy.

LWB envisages the raising of the dam by 5 m to establish a new Full Supply Level of 1,105 masl (ensuring an acceptable raw water reservoir to respond to increasing water supply demand), along with a set of rehabilitation actions and measures to also be undertaken.

Preliminary project alternatives designed to achieve such purposes are described in the following section.

¹ The SEF is the flood that should be contained within the spillway to the extent that, while limited damage would be acceptable during such a flood, there should not be a catastrophic failure of the dam.

The Recommended Design Flood (RDF) should be the 1:200 year flood. The RDF should pass through the spillway with sufficient freeboard to also accommodate wave action and wind setup. No significant damage should occur during the RDF.



2.2. Project Description

2.2.1. General description of Kamuzu Dam I at current conditions

Kamuzu Dam I, located at Traditional Authority Masumbankhunda, Lilongwe District, is a composite concrete and earth embankment on-channel dam across the Lilongwe River, approximately 25 km south west of Lilongwe in Malawi (see Appendix 1 – Map 1). The dam has a maximum height of 21 m, has a 400 m overall crest length and a water capacity of 5 hm³. It serves as a bulk water storage dam for the city of Lilongwe.

The following table states its main features.

Table 3 – Main features of Kamuzu Dam I

Type of dam	Mass concrete spillway in main river channel, with mass concrete abutments and earthfill embankment flanks.
Owner	Lilongwe Water Board
Completion Date	1966
NOC raised by 1.2 m	1987
Location	14°10'27" S 33°38'30" E
Nearest towns	Malingunde – 5 km north east, and Lilongwe – 25 km north east
Purpose	Bulk Water Storage for municipal use
Gross storage capacity	5,126,000 m ³ (based on a 2001 survey)
Net storage capacity	4,456,000 m ³ (based on a 2001 survey)
Surface area at FSL	140 ha
River	Lilongwe
Catchment area	757 km ²
Mean Annual Precipitation (MAP)	960 mm
Recommended Design Flood (RDF) (1:200 year)	900 m ³ /s
Safety Evaluation Flood (SEF) (PMF)	3,500 m ³ /s
RDF water level	RL 1,102.3 m
SEF water level	RL 1,106.3 m



Foundation	Hard unweathered rock, composed of pyritic micaceous gneiss
Maximum wall height from river bed level to non-overspill crest	21 m
Non-overspill crest level (NOC level)	RL 1,105.7 m
Full Supply Level (FSL)	RL 1,100.0 m
River Bed Level (RBL) Maximum wall	RL 1,084.7 m
Embankment crest length	Left 205 m and right 90 m
Embankment crest width	Left 20 m and right 5 m
Upstream face slope	±1V:3H
Downstream face slope	±1V:2.5H
Mass concrete NOC length left abutment	30 m
Mass concrete NOC length right abutment	14 m
Mass concrete NOC width	3 m
Concrete upstream face slope (NOC and spillway sections)	Vertical
Concrete downstream face slope	1V:0.78H
Type of spillway	Concrete ogee overflow weir across river bed
Spillway crest length	97.6 m
Post tensioned cables to stabilise concrete sections	Eighteen cable anchors installed in Blocks 1 to 5, and passive anchors in Blocks 6 to 8.
Freeboard above FSL	5.7 m
Spillway capacity with zero freeboard	2,900 m ³ /s



Outlet works	The outlet works comprises firstly what appears to be a 610 mm diameter scour pipe with a control valve at its downstream end, which discharges into a gallery within the dam, with its invert at RL 1,086.2 m, which in turn discharges at the downstream toe. However, the inlet is covered with a layer of silt up to RL 1,090 m, and the discharge is permanently inundated by the KD2 reservoir. Secondly the outlet works comprises a 610 mm diameter vertical outlet pipe in an outlet tower, fed by two screened inlets controlled by gate valves. The vertical pipe tees into a horizontal one at the lower inlet and runs downstream to discharge into the KD2 reservoir via a flow-measuring chamber and controlled by a butterfly valve at the downstream end.
Drainage systems	Numerous drain holes have been drilled into the foundations to relieve water pressure in the rock.

Source: Aurecon (2013b)

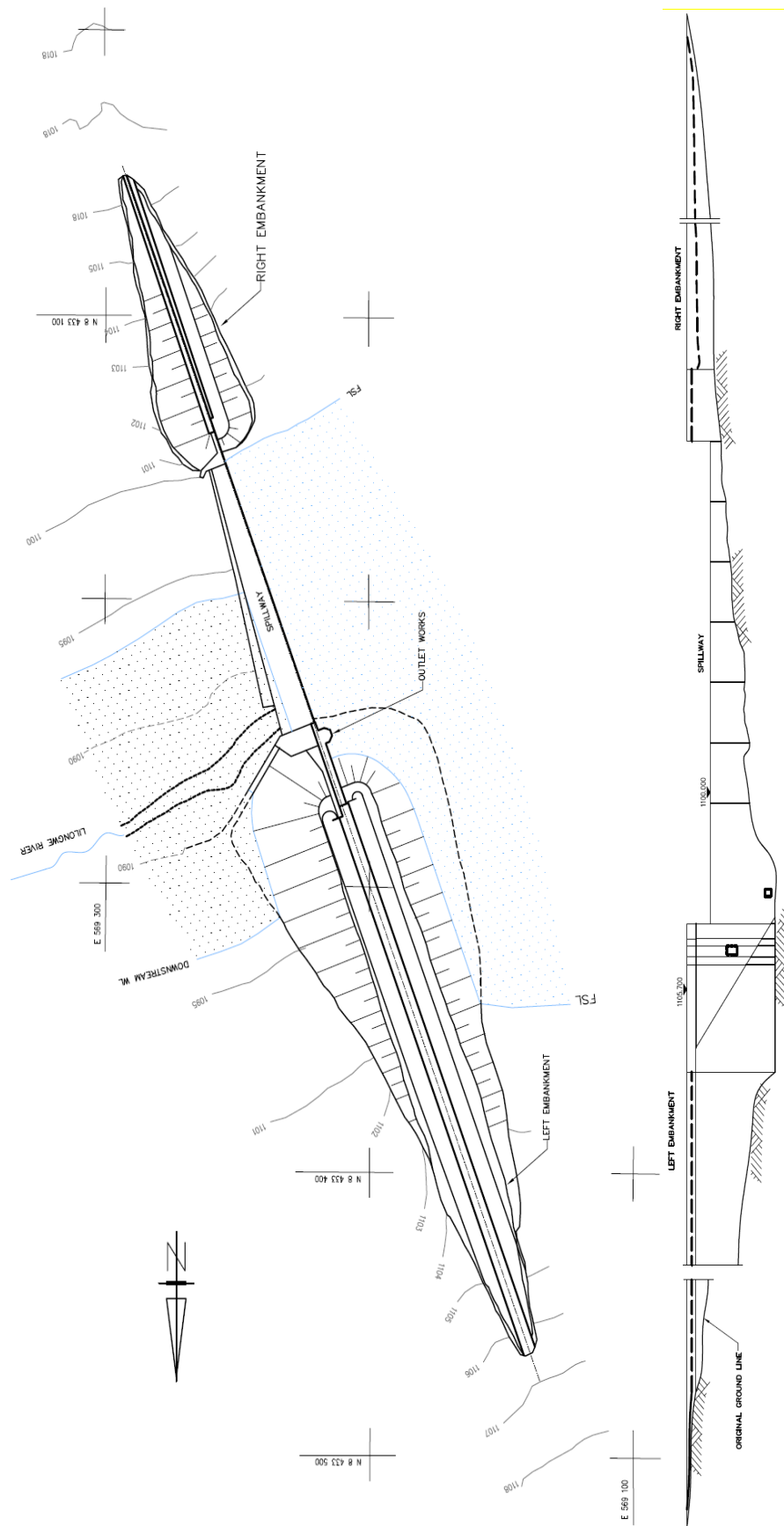
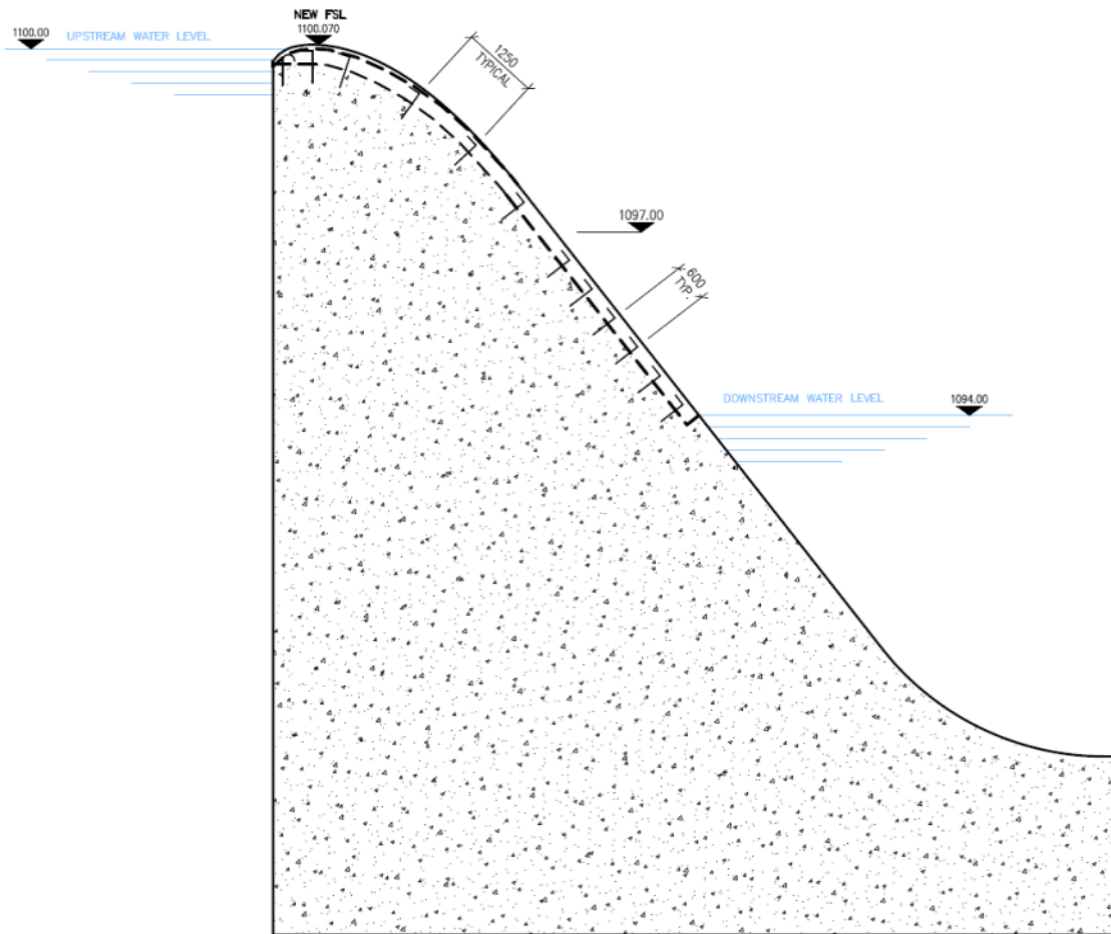


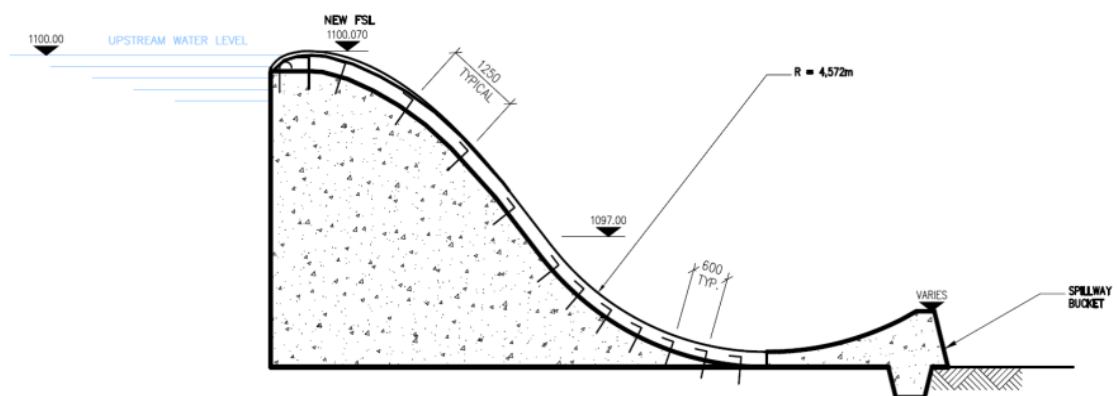
Figure 1 – Kamuzu Dam I: Plan and cross-section views

Source: POSCH&Chapita (2008)



Source: POSCH&Chapita (2008)

Figure 2 – Section view through higher part of spillway



Source: POSCH&Chapita (2008)

Figure 3 – Section view through lower part of spillway



2.2.2. Rehabilitation Project

Based on previous inspections and rehabilitation proposals, Aurecon (2013a) proposes the following rehabilitation/maintenance works/measures to be undertaken:

- Remove and backfill any ant nests or animal burrows;
- Remove trees from the embankments, particularly on the right abutment;
- Repair any erosion of the embankments due to traffic, particularly on the right abutment;
- Inspect rip-rap protection of the upstream and downstream faces of the embankment and reinstate as necessary;
- Check condition of retaining walls in detail and repair cracks;
- Rehabilitate the spillway concrete by providing a new concrete skin;
- Seal any leaks into the outlet tower;
- Seal the scour pipe and gallery with concrete, but take care not to block any of the pressure relief holes;
- Rehabilitate all the pipework (including valves) and metalwork, and replace some components if necessary;
- Repair or replace faulty hand railing on non-overspill concrete abutments as necessary;
- Ensure that hand railings and ladders (safety hoops) comply with relevant safety legislation;
- Provide a watertight bulkhead to seal the outlet works from KD2 tailwater inundation;
- Inspect the rock downstream of the spillway toe to check for erosion;
- Arrange for a dam break analysis to be undertaken to determine resultant floodlines down to Lilongwe.

Considering the cumulative works regarding the rehabilitation and raising of the dam, the rehabilitation work should fit in the raising work plan and budget (see sections 2.2.7 and 2.2.8).



2.2.3. Dam Raising Initial Alternative Projects

As previously mentioned, a 5 m raising of the current Full Supply Level to 1,105 masl of Kamuzu Dam I reservoir would ensure LWB's goals regarding raw water supply. To achieve such FSL, Aurecon's report (2013a) proposes three (3) project options:

- Raising through the use of Fusegate® System;
- Fixed raising;
- Fixed raising with side channel.

The augmented Kamuzu Dam I reservoir capacity, regardless of the project alternative developed to Detail Design, will increase the upstream flooded area of the dam. Although no rigorous estimate is available, an approximation of current and predicted full supply levels is presented in Map 2 (Appendix 1)².

It must be mentioned that all options represent preliminary alternative projects, not supported by detailed design and extensive studies (such as geological, topographic, among others). At this stage, no project alternative was selected.

Thus, due to existent project gaps, no key information/ estimates from the Detailed Design Consultant are available, such as:

- Construction activities, methods and materials;
- Rigorous topographic projection of dam structures;
- Topographic survey and estimates on Full Supply Levels and Maximum Water Levels for each alternative;
- Location of construction yard, other work areas and borrow areas location;
- Earthworks detailed estimation.

² The estimation of flooded areas that result from FSL at 1,105 masl was obtained through the newly-available SRTM 1 Arc Second Global. The available resolution at project latitude is about 30 m (29.9721 m). The resulting DTM (Digital Terrain Model) was reclassified in two sets, according with the targeted elevation (eg, first set from value 1 to 1,105 and second set from value 1,105 to 2,010). The first set layer was cut by the dam-axis line e transformed in shapefile without any simplification (in order to avoid distortion of source data).



In the following sections a brief description of the preliminary project options is presented, including construction activities, processes and methods.

2.2.3.1. Option I – Raising through the use of Fusegate® System

The application of the Fusegate® System at Kamuzu Dam I allows the necessary 5 m raising while providing for a progressive and controlled release of the flows for exceptional flood conditions and ultimately prevents the dam from being overtopped (Hydroplus, 2013, *in* Aurecon, 2013a).



Source: NEMUS

Figure 4 – 5 m Fusegates system used in Kamuzu Dam II raising

The preliminary project design was based on the following assumptions (Aurecon, 2013a):

- Raising the FSL by 5 m;
- The SEF (ie PMF) outflow between 2,500 and 3,000 m³/s;
- The RDF (ie 1:200 year) outflow about 800 to 900 m³/s;
- No lowering of the existing crest level in order not to risk damaging the strengthening cables;
- No Fusegate tip off for floods prior to the RDF (1 in 200 year flood);
- The SEF is passed below the NOC;
- Minimal raising of the NOC that meets the above premises.



The preliminary design solution is represented in Figure 5 and Figure 6.

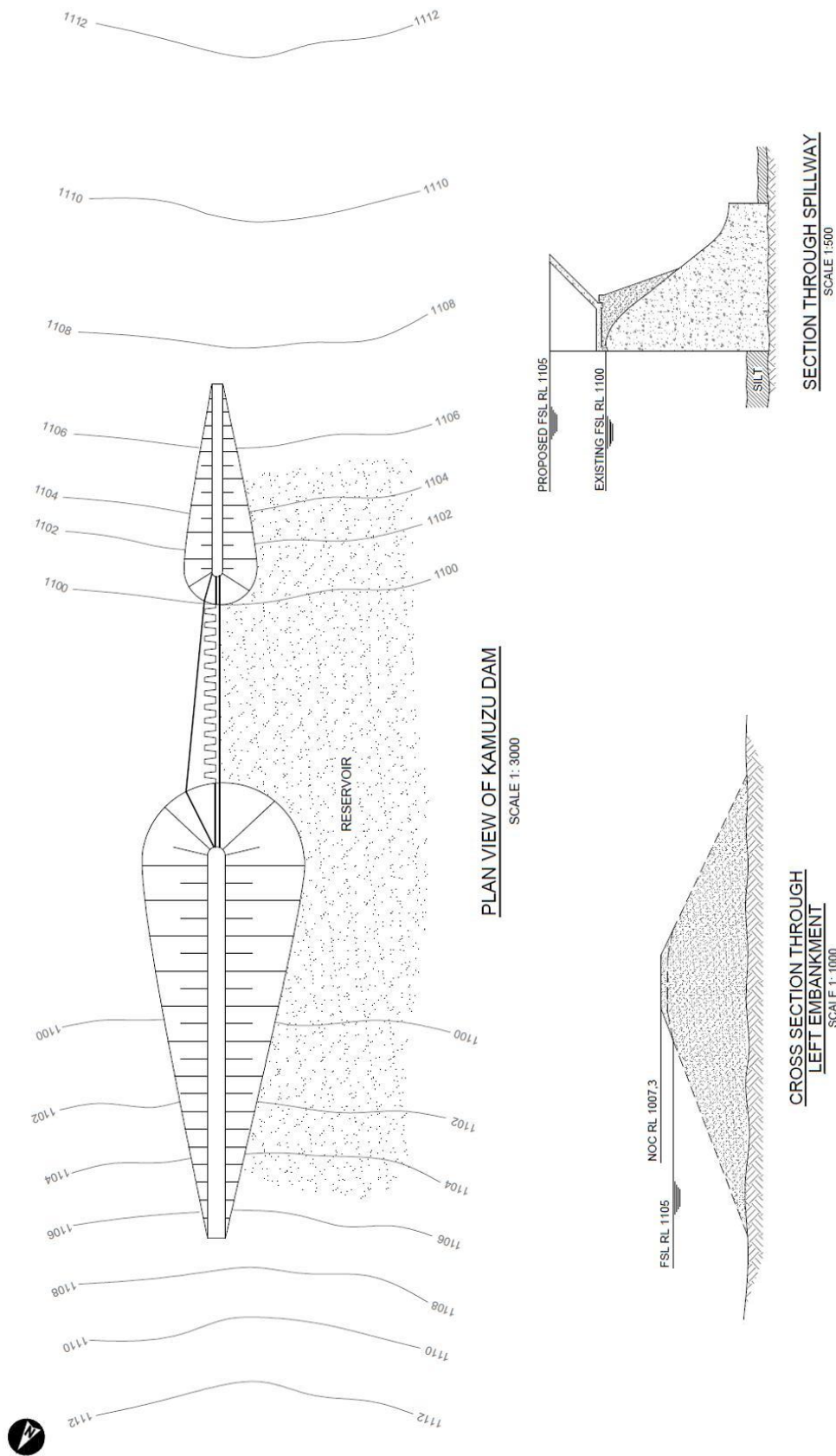
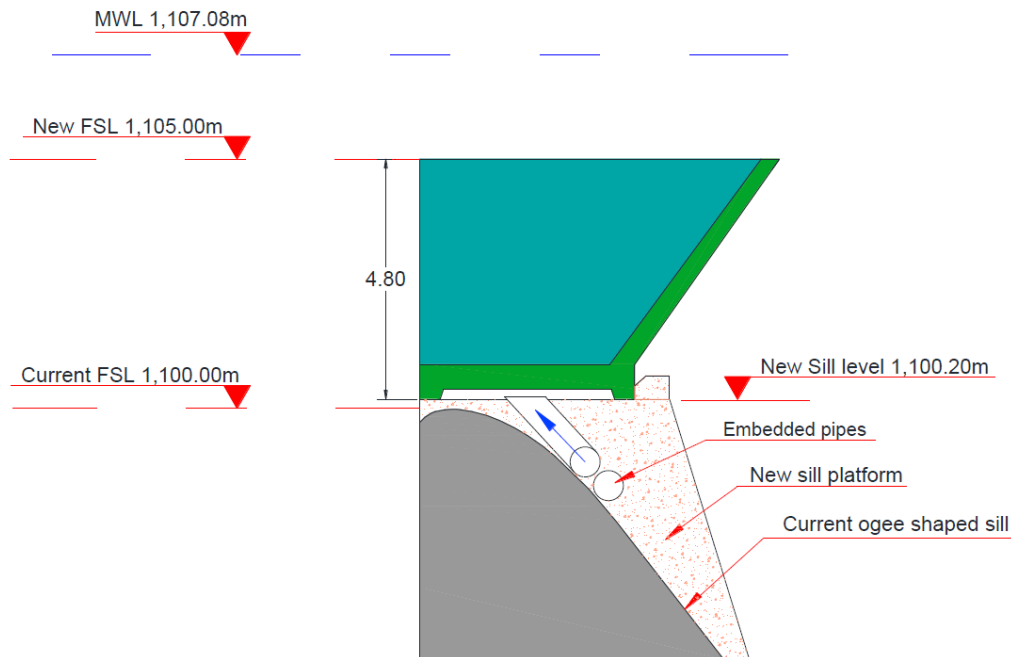


Figure 5 – Raising Option 1 (fusegates): Plan and cross-section views

Source: Aurecon (2013a)



Source: Hydroplus (2013) in Aurecon (2013)

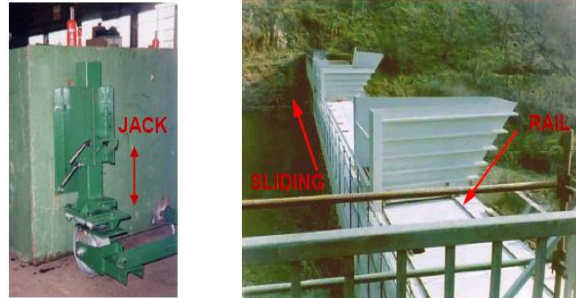
Figure 6 – Raising Option 1 (fusegates): Section view through spillway

According to Aurecon report (2013a) the dam raising project will be materialised by (Aurecon, 2013a):

- Preparation works, which include:
 - construction of a ramp up to the right abutment of the spillway crest from upstream, or a berm against the downstream face of the dam, in order to ensure a suitable access to the crest of the spillway (partially flooded by the tailwater of KD2);
 - placement of a construction yard on the right side of the spillway;
 - construction of a concrete platform on top of the spillway crest;
 - placement of additional re-stressable post-tensioned cable anchors along the higher blocks of the spillway.
- Construction/installation of 5 m high fusegates, involving:
 - erection of the Fusegate base on the right side of spillway. It is equipped with sockets and especially designed for the quickly installation of walls formworks and the sliding system;
 - on site construction of the Fusegate labyrinth walls. Formworks shall be fixed to the current base;
 - remove the formworks and installation of the sliding system;

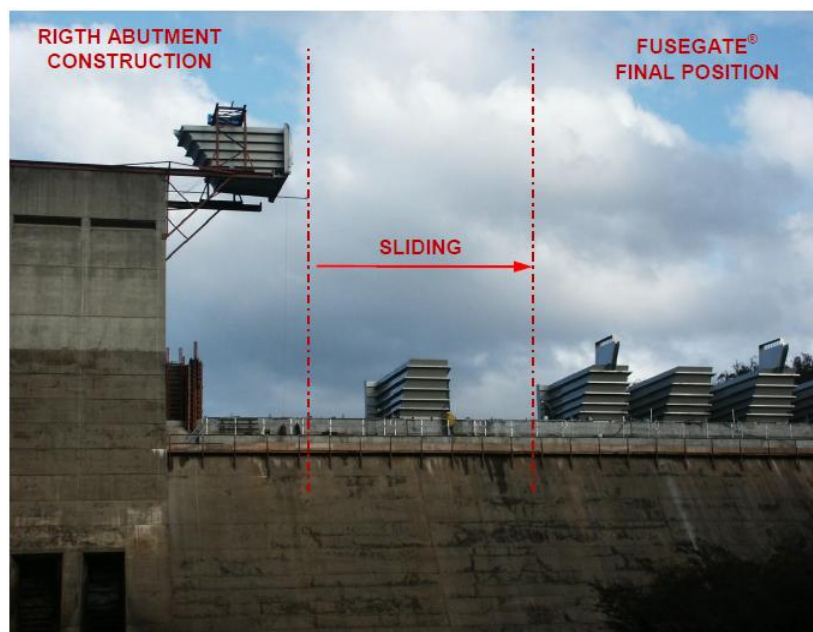


- sliding of thirteen (13) 4.8 m height and 7.51 m width Fusegates along two rails embedded on the spillway.



Source: Hydroplus (2013) in Aurecon (2013a)

Figure 7 – Temporary telescopic wheels



Source: Hydroplus (2013) in Aurecon (2013a)

Figure 8 – “On wheels” method at Dartmouth dam (Australia)

- Raising of the Non-Overspill Crest by 1,30 m (considering a Maximum Water Level at 1,107.08 masl, through the raising of the left and right embankments, construction of the raising of abutments and training walls/retaining walls on the spillway abutments;
- Outlet works, with the raise of the outlet tower to the level of the new NOC and a new outlet provided at a higher level. Consideration should be given to modifying the outlet arrangements to suit operating requirements, including the provision of a scour facility, and taking into account the tailwater from the KD2 reservoir.



2.2.3.2. Option 2 – Fixed Raising

The fixed raising will comprise the vertical 5 m raise of the spillway over a width of about 7 m, providing an ogee profile at the top so as to achieve the highest possible spillway discharge coefficient. The width of about 7 m is determined by the extent that the KD2 reservoir pushes back, i.e. to about 6 m below the existing FSL of KD1.

Access to the crest of the spillway for intervention has to be provided, as for Option 1, through the construction of a ramp up to the right abutment of the spillway crest from upstream, or a berm against the downstream face of the dam.

Post-tensioned cables would be required along the higher blocks. If 300 t cables were used, they would need to be spaced at 1.5 m for the highest block, with wider spacing as the blocks get lower.

The remainder of the spillway could be raised in a similar fashion, either with cables at a wider spacing, or with mass concrete against the downstream face down to the downstream toe, once access become possible (these lower blocks are not inundated by the KD2 reservoir during the dry season when it is not overflowing, and suitable access for construction could be provided from the right flank).

All of the above will require a corresponding raising of the NOC by 5.5 m. This could be achieved by raising and extending the existing embankment flanks and a corresponding raising of the concrete abutments, including the training/retaining walls. The raising and cabling of the abutments should be easier than the spillway section due to the easy access. However, raising the training/retaining walls will present more of a challenge, especially on the right flank, to accommodate the wrap-around of the raised embankment, and to preserve (or relocate) the pump house.

The preliminary design solution is represented in Figure 9.

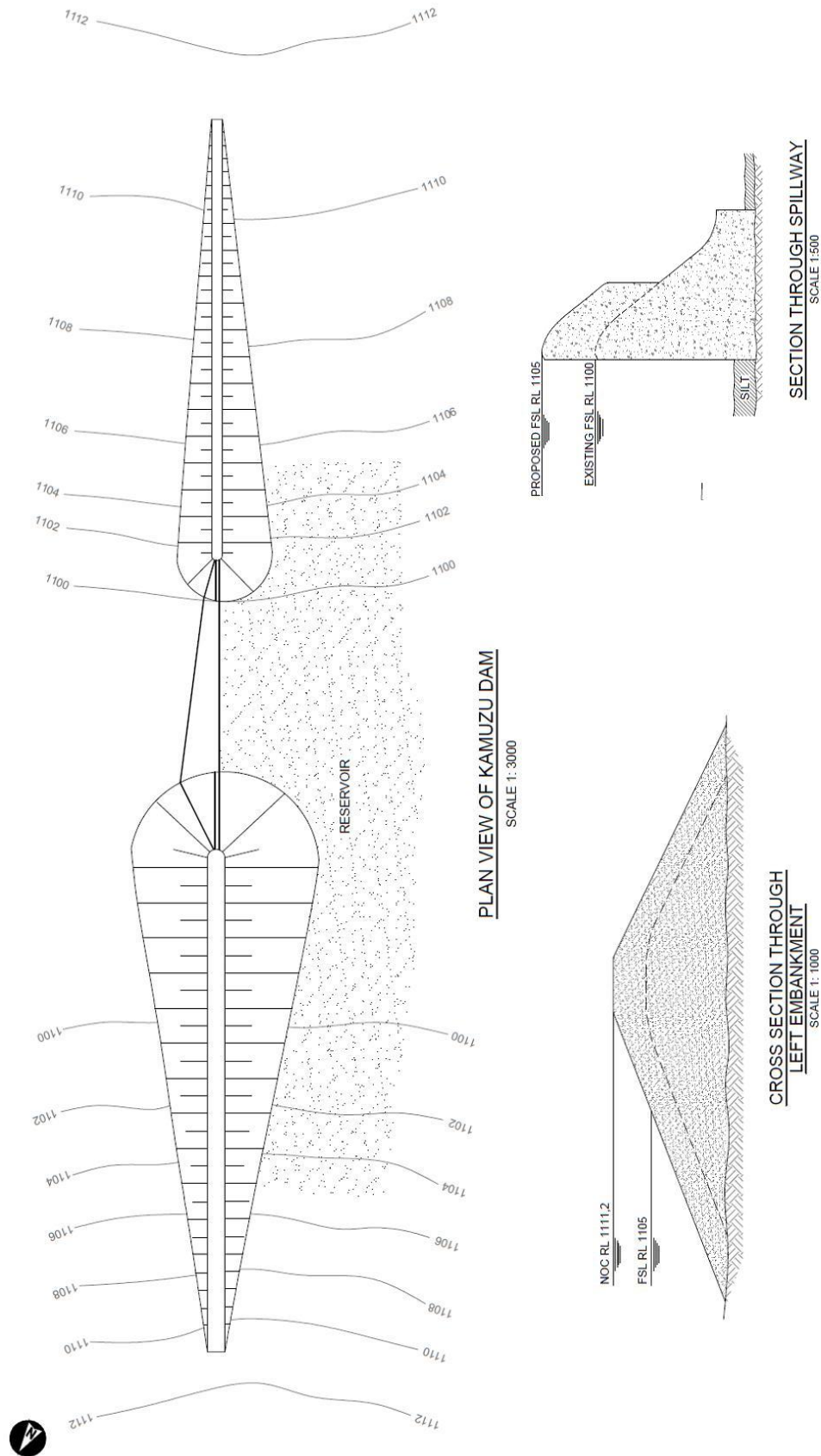


Figure 9 – Raising Option 2 (fixed raising): Plan and cross-section views

Source: Aurecon (2013a)



2.2.3.3. Option 3 – Fixed Raising with Side Channel

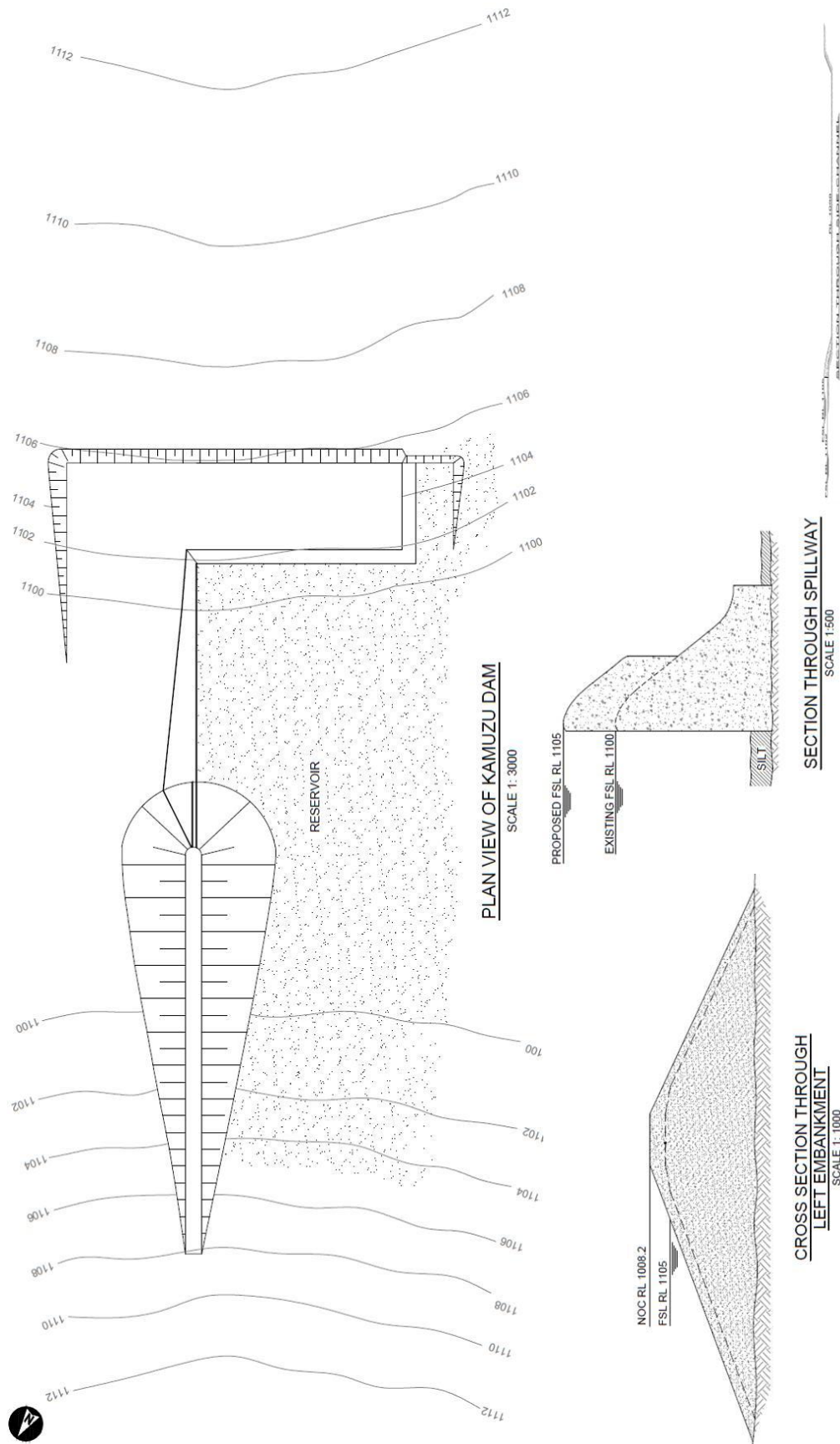
The present project alternative is based on Option 2, with a similar fixed raising of the spillway, but including as premise the limitation of the NOC raising in order to minimise the Maximum Water Level and limit the flooding of downstream areas.

For that purpose, Option 3 includes the construction of a side-channel around the right flank. Considering that structure, it is possible to have a total spillway length of about 300 m, allowing the SEF to pass over the spillway with a head of only 3.2 m (Option 2 requires a head of 6.2 m).

This would require a corresponding raising of the NOC by 2.5 m (versus 5.5 m of Option 2). This could be achieved by raising and extending the existing left embankment flank and a corresponding raising of the concrete abutments, including the training/retaining walls. It would not be necessary to extend the right embankment flank.

Post-tensioned cables would still be required as for Option 2.

The preliminary design solution is represented in Figure 10.



Source: Aurecon (2013a)

Figure 10 – Raising Option 3 (fixed raising with side channel): Plan and cross-section views



2.2.4. Construction equipment and machinery

A project of such magnitude requires the use of different types of equipment and machinery during the construction phase like earth moving equipment, compactors, other lighter equipment and heavy excavators (for project options that include excavation). It is expected the presence of the following equipment, among others:

- Graders;
- Compaction machines (like vibrating rollers, vibratory plates, vibratory rammers);
- Dozers, loaders and excavator-loaders;
- Dumpers;
- Lift trucks;
- Mixers;
- Mobile cranes and construction winches;
- Paver-finishers;
- Diesel and water bowsers;
- Hand-held concrete-breakers and picks;
- Welding and power generators;
- Compressors;
- Motor hoes, lawnmowers, lawn trimmers/lawn-edge trimmers
- Primary and secondary crushers;
- Water pumps and tanks;
- Light and heavy vehicles and tractors;
- Concrete plant;
- Sliding mechanisms (Option 1);
- Excavators (Option 3).

2.2.5. Construction yard and support sites

At this there is not information regarding the construction yard, campsite or other support sites (borrow sites, soil/ waste disposal locations, material/ equipment's temporary storage, etc.). Guidelines for site selection are recommended in ESMP.



2.2.6. Inputs and outputs

2.2.6.1. Construction materials

The project will require various materials for the construction of the infrastructures, such as:

- Soil/rock (and different grain sizes or by-products);
- Concrete;
- Steel;
- Post-tensioned cables;
- PVC pipe and hydraulic elements;
- Cast iron pipe;
- Other hydraulic elements – valves, joints, adapters;
- Wood;
- Paints and solvents.

As mentioned no information is given regarding material sources – especially of soil/rock/gravel needs and requirements and possibility of reuse of excavated material (when applicable). However, and considering preliminary cost estimations (Aurecon, 2013a), it is possible to present an estimated balance and magnitude of the proposed earthworks by project option. Regarding steel and concrete needs, they are estimated in 2,400 t of steel and 270 m³ of concrete (valid for the three options).

Table 4 – Earthworks Estimation

Project alternative		Earthworks (m ³)		Surplus (m ³)
		Embankment	Excavation	
Option 1	Fusegates	20,000	—	(20,000)
Option 2	Fixed raising	130,000	—	(130,000)
Option 3	Fixed raising with side channel	8,000	45,000 ¹	37,000

Source: Aurecon (2013a)

¹ Estimated 87% rock.



From the table analysis arises that Options 1 and 2 will require borrow material. For Option 3, there's a theoretical opportunity for 13% of excavated material might be reused as input for embankments, if assured the technical requirements for its use. Hence, the soil needs for embankment could be totally assured without recurring to borrow material for Option 3.

2.2.6.2. Water and energy

Water supply needs and origins during the construction phase are not yet defined, although it is expectable the use of surface water from Kamuzu Dam I reservoir.

Electric energy is necessary for equipment and machinery operation, along with the normal day-to-day activity in construction yard – social areas, illumination, office and storage areas, among others. If available, the use of the public electric grid could be requested to authorities. Diesel generators should be a standard option in construction sites.

2.2.6.3. Emissions and wastes

Regarding liquid wastes, production is expected from construction sites and yard, vehicles and machinery parking/maintenance areas and campsites/social areas for workers, all together representing a source of organic matter and suspended solids. A solution should be designed to contain runoff or disposal into water or soil, and/or for the collection of wastewaters – septic tank, portable chemical toilets or other. Disposal of collected liquid wastes should be done in accordance with local laws and regulations.



The construction phase is usually intense regarding solid waste production. Considering the type of project at hand, the main expected residues are demolition wastes (especially the materials resulting from the demolition of houses to resettle and annex structures), organic residues from ground clearance operations and construction yard wastes. For Option 3, excavated materials should also be considered as a by-product, since at least 37,000 m³ will require proper management and final destination. Reuse options and disposal site selection guidelines are presented in Chapter 0.

Construction yard operation and management will generate several types of residues such as metal, wood, used oil, lubricants and other oil derivatives, tyres, plastic, paper and cardboards, glass and organic waste. Construction machinery requires periodical mechanic maintenance, as well as fuel supply. These operations, if performed at construction yard and sites, will generate mainly hazardous waste. Finally, particularly in social areas and campsites, residues equated to urban solid waste are also expected.

A waste management area should be designated in the construction yard – a temporary storage park – and equipped with a set of containers to sort the different types of wastes.

In synthesis, during the construction phase a multiplicity of solid wastes will be produced, including the following most likely categories:

- Hydraulic oils and lubricants used in machinery maintenance;
- Packages/wrappers of paper, cardboard, plastic, wood, metal, glass, composite or mixture;
- Package residues contaminated by hazardous substances;
- Contaminated wastes and oil filters;
- Used tyres;
- Metal scrap;
- Lead accumulators;
- Residues of Construction and Demolition:
 - Non-contaminated surplus soil and rock (inert material);
 - Plant residues;
 - Concrete, bricks, ceramic materials and other demolition material;
 - Wood, glass and plastic;
 - Metals and alloys;



- Solid urban waste mixture and similar.

The waste management options should be discussed with local and district authorities, regarding licensed waste management entities, suppliers (and possibility of recapture the products' residues), public management systems and final destination options (recovery of quarries, gullies or other degraded sites, or landfill).

Other emissions and by-products typical of construction activities concern noise emissions from construction machinery and equipment's operation and circulation of construction vehicles and machinery, and air pollutants, especially exhaust gases from trucks and machinery– nitrogen oxides, carbon monoxide and volatile organic compounds – and particulate matter emitted or re-suspended from bare soils or dirt roads.

2.2.7. Cost Estimation

The cost estimate for the rehabilitation and raising of Kamuzu Dam I for the three projects alternatives is as follows.

Table 5 – Project Cost Estimation

Project alternative		Concrete works (USD)	Earth works (USD)	Total Cost (USD)
Option 1	Fusegates	748,000	500,000	12,600,000
Option 2	Fixed raising	1,700,000	3,250,000	9,800,000
Option 3	Fixed raising with side channel	4,000,000	200,000	10,700,000

Source: Aurecon (2013a)

The proposed budget will be refined in the detail engineering design stage.



2.2.8. Design and construction programme

According to Aurecon (2013a), the total period for project implementation is estimated in 24 months – 2 years – of which 10 months are estimated for construction.

Construction schedule and work plan will be refined in the detail engineering design stage.

2.2.9. Operation phase activities

Two major activities characterise the operation phase of the project:

- Raw water abstraction and reservoir;
- Maintenance interventions.

The normal operation of the dam encloses the following activities:

- Free water flow over the spillway (with water level control given by the spillway crest, or by the non-overspill crest for flood events);
- Abstraction of raw water for local uses near the dam.

Other activities concern the necessary maintenance operations, either periodical maintenance actions – prevention of siltation, substitution of hydraulic elements, as joints and valves, vegetation and trees clearance in embankments – or emergency interventions – such as repair/substitution of spillway, pipes or elements in case of accidental occurrences or ruptures. For Option 1, the tipping and replacement of fusegates are considered as maintenance operation.

No estimation for the decommissioning of the project is detailed. The future decommission of the project is dependable of future water sources options and demand dynamics – either a complementary source is guaranteed and the project is limited by the infrastructure longevity, either a new and alternative water supply system and/or source is foreseen, and the project will be limited by the feasibility and materialisation of such alternative.



2.2.10. Selected Project Alternative – Option E

As mentioned, in the stage that the ESIA was developed, no project option was yet reviewed by the hired Detailed Design Consultant (SMEC), and no decision existed. Therefore, the ESIA assessed the three initial preliminary project alternatives proposed by Aurecon (2013a) in its initial investigations for the raising project - present in sections 2.2.3.1, 2.2.3.2 and 2.2.3.3 – and considered a broader study area in order to accommodate future changes.

Further developments by the Design Team (SMEC) following technical and economic feasibility assumptions, as well as the indications and conclusions of the draft ESIA, resulted in an additional preliminary project option for the raising and rehabilitation of Kamuzu Dam I, recurring to a fixed raising without the use of stressed anchors, with a 70 m extension of the spillway – Option E.

The LWB's decision to develop the preliminary Option E to the detailed engineering project design phase justifies including the following in the ESIA's adequate sections:

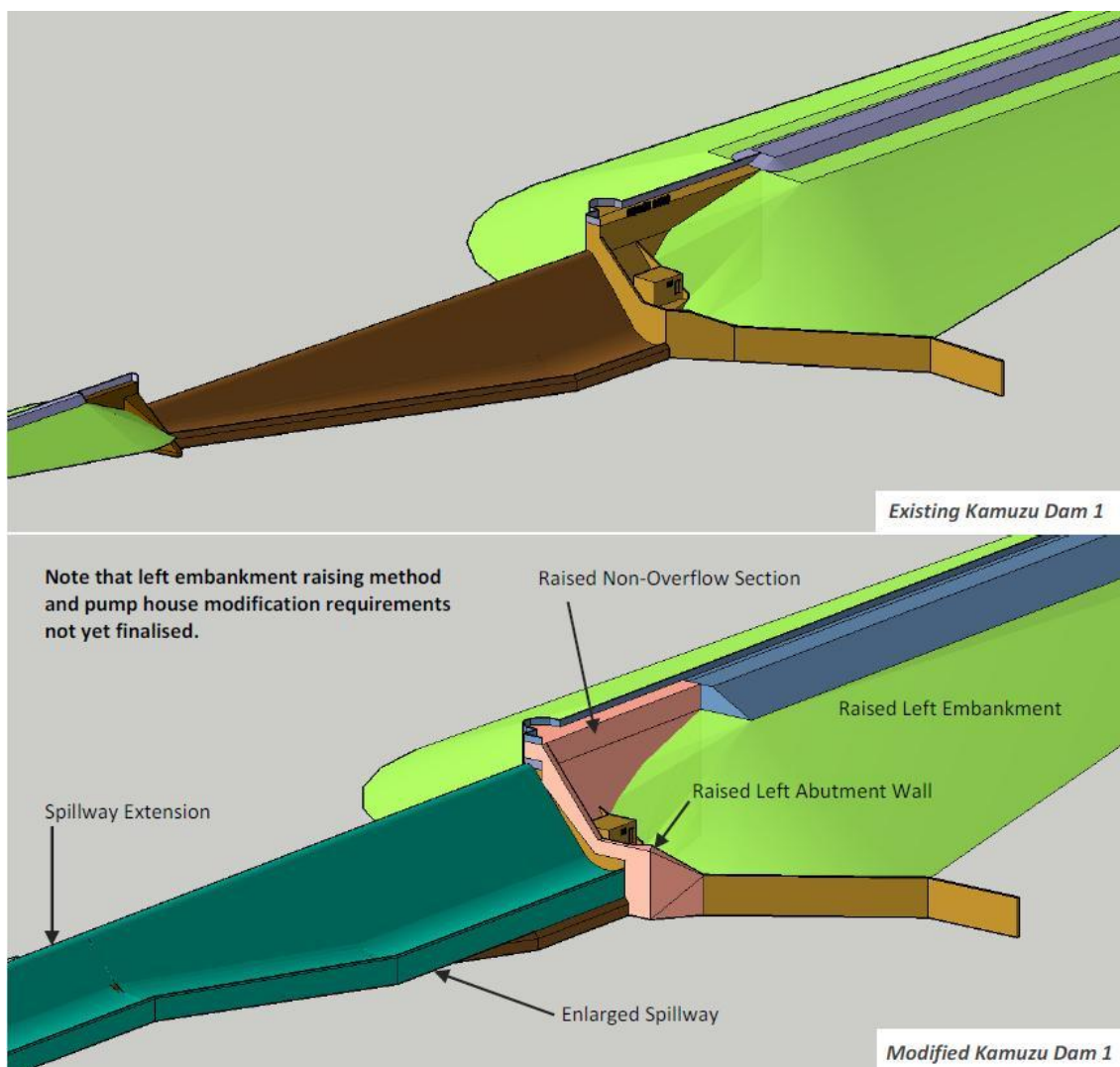
- Description of the preferred project option (section 2.2.10);
- Evaluation of increased or decreased impacts that result from the new project option in comparison with the draft ESIA Report's impact assessment (6.13);
- Update of the overall impact assessment matrix (6.13);
- Adjustment of mitigation measures and monitoring programmes and proposal of new ones if necessary (section 0).

It must be mentioned that the work developed in the ESIA Report remains globally valid, as the new information will frame the new preferred project option among the baseline and set of impacts identified in it.

The spatial assessment scope for Option E is presented in Appendix 1 (Map 8).

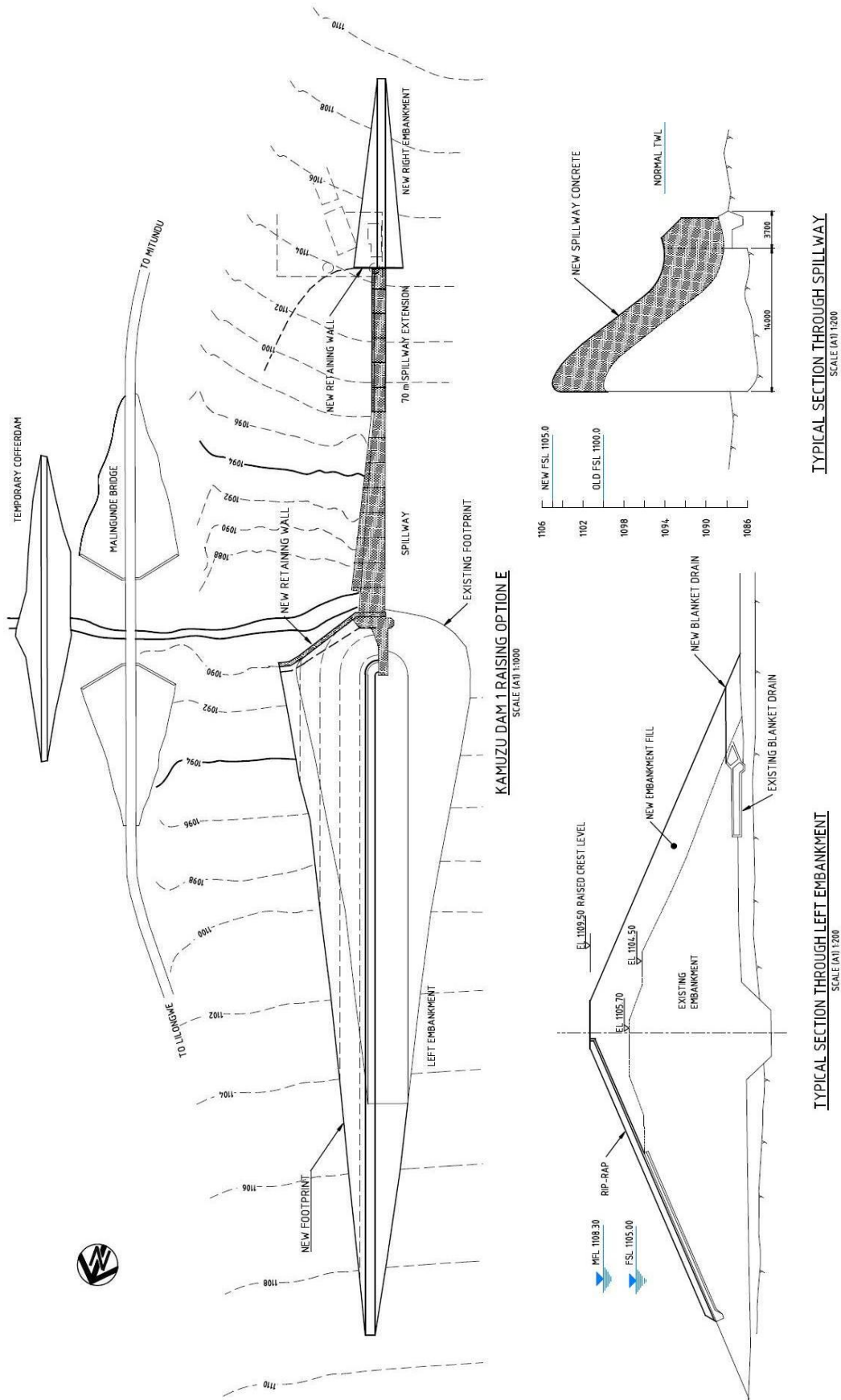
2.2.10.1. Overall Project Description – Option E

To achieve the 5 m raise of Kamuzu's Dam I, considering all existing constraints and without the use of stressed anchors for stability, the preferred Project Option E comprises a fixed 5 m raise to the existing spillway crest and an additional spillway length of 70 m located on the right abutment, using mass concrete to ensure appropriate hydraulic performance and stability. Finally, the left embankment will be raised to the level 1,109.5 masl (Figure 12 and Figure 11).



Source: SMEC (2015)

Figure 11 – Kamuzu Dam I raising: 3D view of existing and modified dam



Source: SMEC (2015)

Figure 12 – Raising Option E: general arrangement



The raising is assumed to comprise sufficient concrete to provide appropriate hydraulic conditions and to negate the requirement for stressed anchors.

The 70 m extension at this location is proposed considering the following:

- Favourable and appropriate combination of maximising the spillway length, whilst not spillway too far from the river channel;
- Flattening of the rock surface, which may complicate the hydraulic regime downstream of the weir.

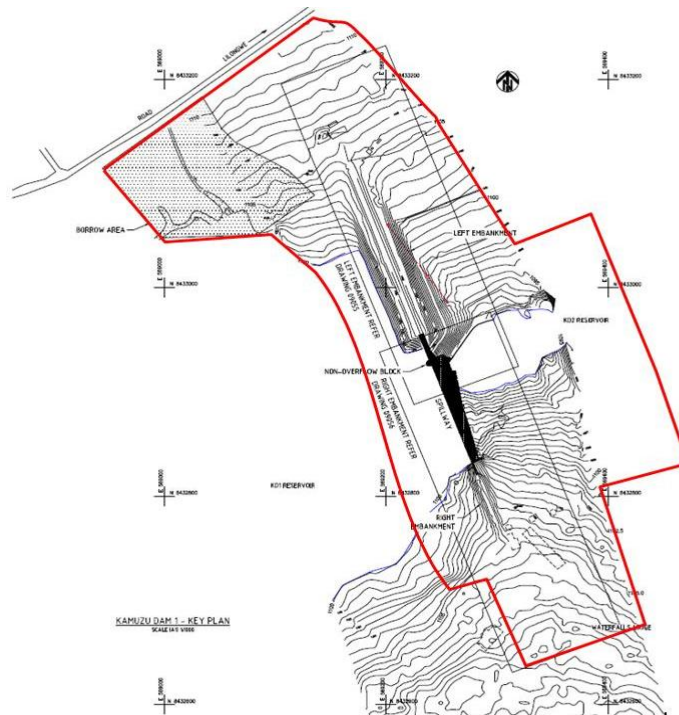
Other interventions are required:

- Construction of a training/retaining wall to both sides of the spillway;
- Modification to the existing intake, bottom outlet and pump house;
- Construction of a small embankment at the right abutment;
- Installation of internal drainage and filters in the left embankment.

2.2.10.2. Construction yard and support sites

At this moment there is not detailed and final information regarding the construction yard, campsite or other support sites (borrow sites, soil/ waste disposal locations, material/ equipment's temporary storage, etc.).

According to the Design Team, two construction yards will be placed downstream of left and right embankments, as well as a borrow area proposed north of the left embankment (near the road T364). The construction of a temporary cofferdam downstream Kamuzu Dam I and Malingunde's bridge will also be required. The work area is estimated in the following figure.



Source: SMEC (2015)

Figure 13 – Estimated work and borrow areas (SMEC, 2015)

The possibility of the construction of an alternative flow diversion channel may arise, pending decision of the Contractor (responsible for river management during construction phase), as mentioned by the Design Team.

2.2.10.3. Construction materials' inputs

The project will require various materials for the construction of the infrastructures, such as:

- Soil/rock (and different grain sizes or by-products);
- Concrete;
- Steel;
- Post-tensioned cables;
- PVC pipe and hydraulic elements;
- Cast iron pipe;
- Other hydraulic elements – valves, joints, adapters;
- Wood;
- Paints and solvents.



Considering preliminary cost estimations (SMEC, 2015), it is possible to present an estimated balance and magnitude of the proposed earthworks – 43,400 m³ of filling (for embankments), plus 15,000 m³ necessary to place the temporary cofferdam. Overall, the total earthworks, exclusively embankment activities, are estimated in 58,400 m³.

Borrow material will be required to fulfil soil and rock needs for embankment. Considering the temporary nature of the cofferdam, when dismantled it represents the theoretical opportunity of reuse of such soil and rock quantity as input for embankments. Looking at the construction programme (see section 2.2.10.5), it can be reused on both embankments. Assuming that all 15,000 m³ used in the cofferdam's filling can be entirely reused in the left and right embankments, the total borrow material need will be of 43,400 m³.

Regarding steel and concrete needs, they are estimated in 2,400 t of steel and 1,080 m³ of concrete.

2.2.10.4. Cost Estimation

The global cost estimation for the rehabilitation and raising of Kamuzu Dam I for the preferred project Option E is around 7,700,000 USD. The proposed budget will be refined in the detail engineering design stage.

2.2.10.5. Construction programme

Prior to the construction phase, the preferred preliminary Option E will be developed in the detail engineering design stage. In it, the full construction work plan and programme will be refined.

At this project phase, the Design Team foresees as the total period for project implementation an estimation of 21 months. Such period will be divided into 4 (four) development stages, determined by the hydrological regime of KD1 and KD2 (drawdown of reservoirs between July and late November), according to the following sections (SMEC, 2015) and the construction schedule presented in Table 6



Table 6 – Construction schedule

Phases	Year One												Year Two											
	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
Stage 1																								
Stage 2																								
Stage 3																								
Stage 4																								

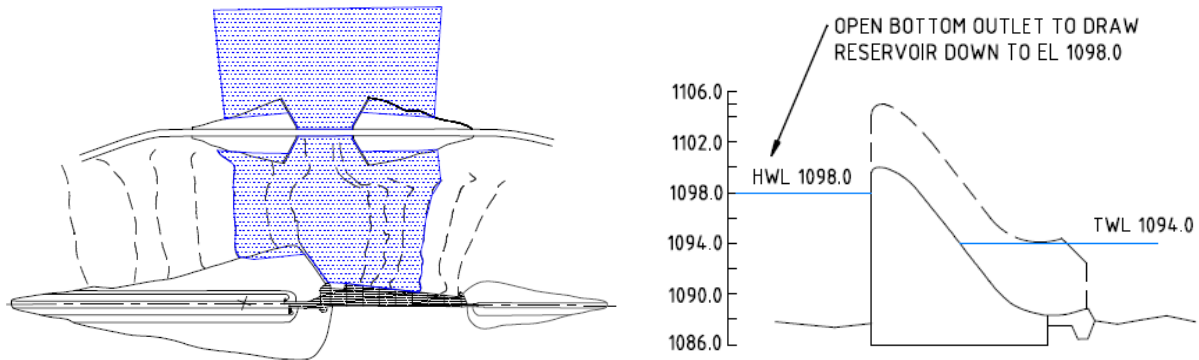
Stage I – April to end of August

In the first stage, the drawdown of KD1 will occurs through the opening of the bottom outlet to the maximum possible extent. The drawdown is believed to be possible to the EL 1,098 (approximate rock level at the right abutment), by the end of August.

The dewatering of the river bed immediately downstream KD1 spillway is required in order to:

- inspect the condition of the rock surface in the river bed immediately downstream of the spillway flip bucket;
- inspect the low level outlet which is located in the first spillway block and to backfill with concrete if required;
- clean and prepare the foundation rock and existing spillway surface prior to placement of new concrete;
- enable completion of the left embankment works below EL 1,094; and
- To enable placement of new concrete for the raised spillway in dry conditions.

When the target reservoir level is reached, the bottom outlet will be closed and the right embankment and downstream in-river works will commence.



STAGE 1 – APRIL TO END AUGUST

1. OPEN BOTTOM OUTLET IN JULY AND DRAW RESERVOIR DOWN TO EL 1098.0.

SMEC (2015)

Figure 14 – Construction works: stage 1

Stage 2 – September to mid January (dry season)

At this stage a temporary cofferdam is required, allowing that in-river works can be developed. The cofferdam will be approximately 100 m long, 5 m high and with a total fill volume of 4,500 m³, with upstream and downstream shoulders built from fine grained material and rockfill, respectively.

Regarding the right embankment, during stage 2 it will be removed and replaced with the concrete weir extension. This work can continue through the wet season until the spillway weir is complete to the new FSL.

The in-river works can begin after the construction of the cofferdam and dewatering of the ponded area between KD1 and the cofferdam through the use of pumps. Assuming that these works are completed in early September, the foundation and concreting works will have over 4 months (until the middle of January) to be completed prior to the spilling of Kamuzu Dam 1 in the subsequent wet season.

The concrete in the new spillway will be completed at least to a level above the FSL of KD2 (EL 1,094) as this will enable the works to recommence as soon as KD1 stops spilling at the end of the wet season. All required works to the left embankment below EL 1,094 will also be completed during this phase.

Once the spillway concrete and left embankment filling is raised above the water level in the KD2 reservoir, the temporary cofferdam can be removed and the bottom outlet can be opened to start filling the KD2 reservoir and to keep the KD1 reservoir as low as possible into the wet season.

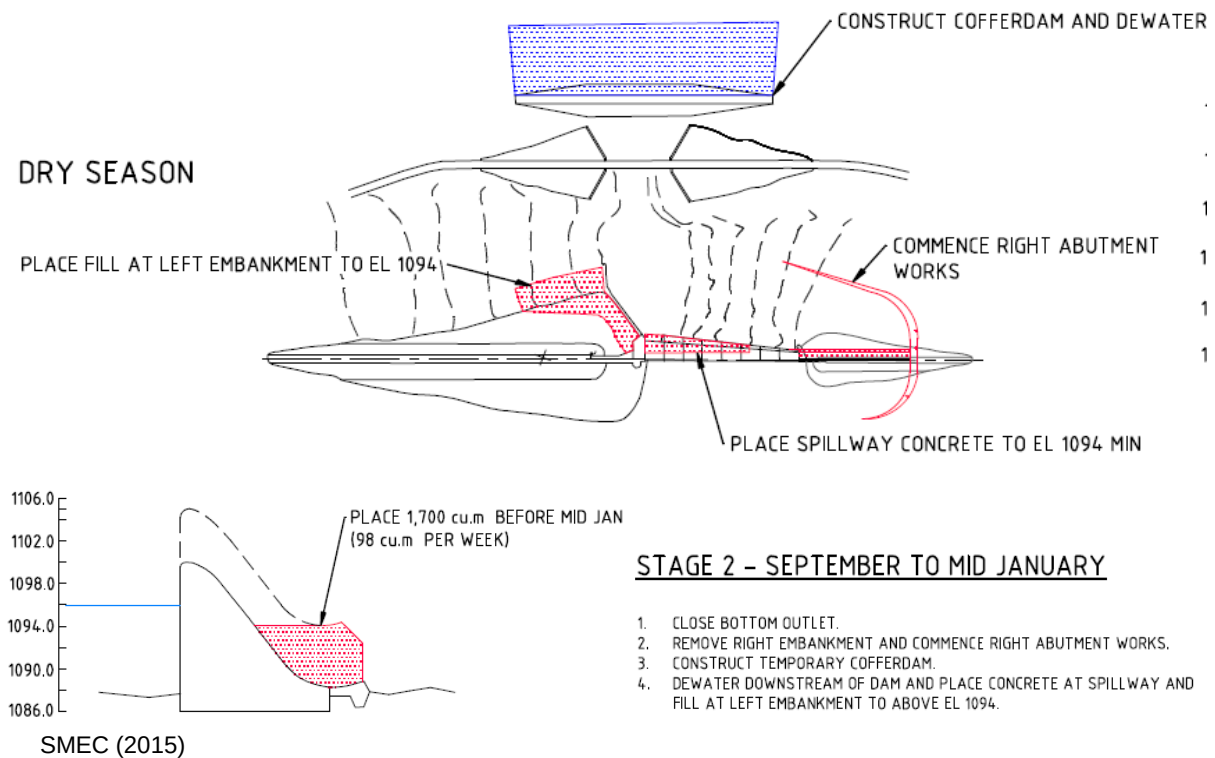


Figure 15 – Construction works: stage 2

At the end of Stage 2, the following works should be completed:

- Left embankment works complete below EL 1,094;
- Right weir extension complete;
- Temporary cofferdam removed; and
- Centre spillway concrete complete to at least EL 1,094, and possibly higher.

Stage 3 – Mid January to July

This stage represents the completion of concrete spillway raising works, to occur during the wet season.



Considering that the new concrete at the existing spillway will be at least at EL 1,094 across the full width and that the left embankment crest is completed, in this stage the existing spillway can be raised above the current FSL (1,100 masl) with no risk of overtopping the dam during an unexpected flood.

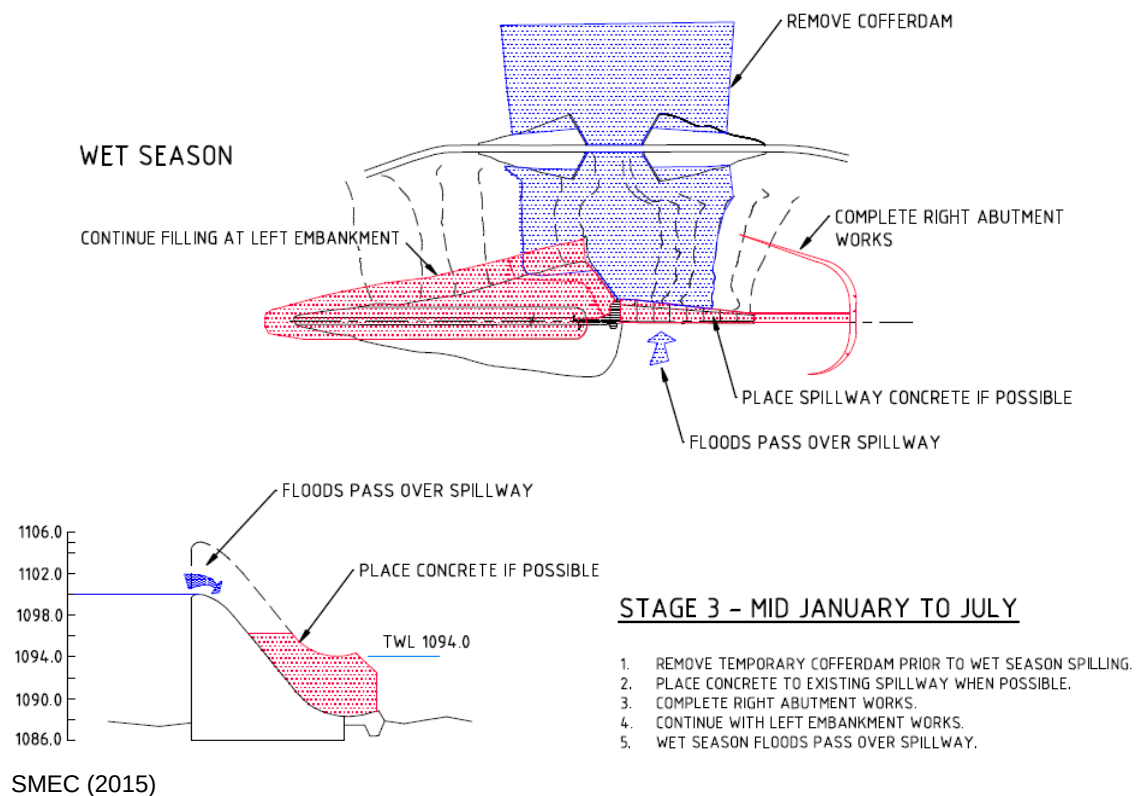
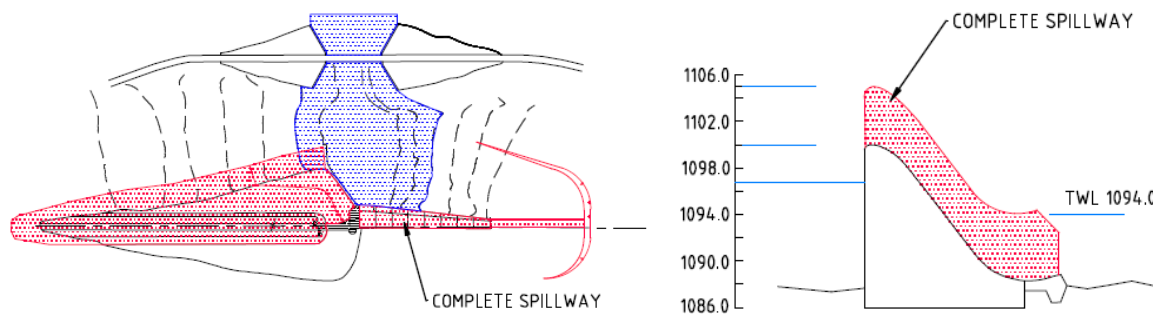


Figure 16 – Construction works: stage 3



Stage 4 – August to December

The final stage, all concreting works can resume unhindered by possible spill flows, and the spillway completed to the new FSL of EL 1,105.00.



STAGE 4 – JULY TO DECEMBER:

1. COMPLETE ALL REMAINING WORKS.

SMEC (2015)

Figure 17 – Construction works: stage 4

2.2.11. Project alternative's comparison

In the following table, a synthesis on the preferred option – Option E – and alternative solutions – Options A, B and C, globally corresponding to the initial Alternatives 1, 2 e 3 considered on the ESIA – main financial and technical characteristics is presented, justifying the decision of advance to the project detailed design phase of the preliminary project Option E.

One main justification is that Option E does not rely on stressed anchors for stability. According to the Design Team (referring USACE; 1999), “*stressed anchors should generally not be used in the design of new gravity dams and should only be used for the raising of existing dams when no suitable alternatives are available*”, and therefore Options A, B and C should not be considered as viable technical alternatives for Kamuzu Dam I's raising.

Also, Option E provides additional benefits when compared to the three alternatives, namely:

- lowest estimated cost;
- simplest construction;



- improved hydraulic conditions;
- 100% local supply;
- low foundation demands;
- low durability and maintenance demands; and
- simplified contractual arrangements.

If Option E presents itself as the most favourable solution regarding technical and economic viability, in the environmental and local resources' context it's expected an intermediate positioning considering all options. Assuming that the 100-year estimates (SMEC, 2015) for each project option determines the extension of territorial impacts of the dam's raising, Option A and C are the most favourable options and Option B the option with more extent impacts.



Table 7 – Comparison between preferred project option (E) and alternative project solutions

Parameter	Option A	Option B	Option C	Option E
Technical characteristics				
Raise Method	Hydroplus Fusegates	Fixed		
Stressed anchors	Yes			No
Spillway Extension	None		180 m	70 m
Maximum Inflow (m ³ /s)	2,500.0			
Maximum Flood Level (PMF) (masl)	1,107.0	1,109.4	1,107.5	1,108.3
Full Supply Level	1,105.0			
100-year flood level estimate (masl)	1,106.1	1,107.0	1,106.0	1,106.4
Constructability and complexity	Fusegate solution requires complex reinforced concrete construction and hydromechanical components (gate seals). Installation of stressed anchors requires a high standard of workmanship and quality control to ensure long term durability. Cofferdam not required.	Installation of stressed anchors requires a high standard of workmanship and quality control to ensure long term durability. Cofferdam not required.		Comprises mass concrete placement and embankment work items which are relatively simple and straightforward. Cofferdam is required.



Parameter	Option A	Option B	Option C	Option E
Inspection of existing rock surface downstream of spillway	Not possible			Possible due to cofferdam
Foundation requirements	Higher foundation requirements due to anchor loading when compared to Option E			Lower foundation requirements when compared with Option A to C
Stability	This solution requires that anchors are required to ensure stability for all load cases when resisting toppling, sliding and overturning forces. This is contrary to current design standards.			Enlarged spillway provides a gravity structure which is stable under all load cases without relying on anchors. This is in line with current design practise.
Spillway hydraulics	No special hydraulic considerations are incorporated in the design. Flows will impact existing spillway from height which may cause erosion problems.			Spillway profile will be specifically shaped to meet all hydraulic design requirements especially with regards to the terminal structure (flip bucket).
	Fusing of gates during floods will result in loss of water.	—	Side channel spillway will cause concentration of flow at right abutment leading to potential erosion problem.	
Future raising with no modification to embankments	Difficult			Possible using rubber dam



Parameter	Option A	Option B	Option C	Option E
Durability/maintenance	Potential future maintenance issues with regards to fusegate seals, replacement of breached sections and stressed anchors. Stressed anchors have a finite design life.	Potential future maintenance with regards to stressed anchors. Stressed anchors have a finite design life.		No significant long term maintenance issues with mass concrete spillway block.
Earthworks estimations (m³)				
Embankment	22,000	77,000	34,000	43,400 + 15,000 ¹
Excavations	—	—	45,000	—
Surplus	(22,000)	(77,000)	11,000	(43,400) ²
Cost estimates (USD)				
Concrete works	1,180,000	2,606,000	3,819,000	3,040,000
Earthworks	550,000	1,925,000	1,495,000	1,385,000
Total cost	13,100,000	9,450,000	10,350,000	7,700,000
Environmental issues				
Due to work area	Lower work area than Option E (no cofferdam). A similar work area is expected for Option A to C.			Higher work area than Option A to C (cofferdam)
Due to raised 100-year flood estimates	Impacts are proportional to water levels rising. Lowest of all options.	Impacts are proportional to water levels rising. Highest of all options.	Impacts are proportional to water levels rising. Lowest of all options.	Impacts are proportional to water levels rising. Intermediate option.

Source: SMEC (2015)

¹ Temporary cofferdam; ² Assuming that all 15,000 m³ of cofferdam's filling can be reused in the left and right embankments



3. Environmental Planning and Design

The Environmental and Social Impact Assessment condensed in the current ESIA Report concerns a preliminary stage where three project alternatives are under consideration. Such alternatives were initially design taking into consideration key concept (5 m raising of the current FSL) and some general project guidelines, with further features and specifications to be detailed in the subsequent project phases, namely the Project Detail Design.

Hence, the above described alternatives and project drawings confirm the early development of project solutions, namely the absence of topographic and geological surveys, rigorous hydrological studies, estimates on flooded areas and dam structures alignment (especially embankments), definition of construction yards and sites, estimation of rigorous soil needs (including borrow or landfill areas), processes and methods to be used, and the construction management options and solutions to undertake to minimise the predictable environmental and social impacts.

In face of the above, environmental design features are not yet defined. Still, some premises can be identified considering the project concept:

- Search and weighting of alternative raising solutions to fixed raising, aiming the minimisation of the NOC increase, that is, limiting as feasible the expansion of the reservoir area (a larger reservoir area would have negative impacts proportional to the increment of the flooded area). Although fixed raising represents the least-cost solution, options 1 and 3 intends to limit the potential social and environmental impacts, namely the need for resettlement and compensation of affected population;
- Resettlement and compensation of affected communities/individuals.

In which concerns environmental planning and construction works management, as pointed out, at this stage scarce detailed information is given.



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4. Legal and Regulatory Framework

4.1. Introduction

Environmental protection is a constitutional precept in Malawi, as inscribed in Section 13 (d) of the Constitution of Malawi, which states “*To manage the environment responsibly in order to:*

- i. prevent the degradation of the environment;
- ii. provide a healthy living and working environment for the people of Malawi;
- iii. accord full recognition to the rights of future generations by means of environmental protection;
- iv. conserve and enhance the biological diversity of Malawi.”

The commitment to the environment and sustainable development is also marked by the adherence to internationally accepted principles given by the Stockholm Declaration (1972), Rio Declaration (1992) and Water, Energy, Health, Agriculture and Biodiversity initiative emerged at the World Summit on Sustainable Development (2002), as well as a signatory of a number of international and regional environmental conventions and protocols.

The national legal framework is set by two key documents – National Environmental Policy (NEP, 1996, revised in 2003) and Environmental Management Act (EMA; No.23 of 1996). The Environmental Management Act states that Water Resources Development projects such as “construction or expansion of dams with a height of 4.5 m or higher” requires an Environmental Impact Assessment.

These documents are supported by a number of sectoral policies, acts, regulations and requirements, embracing the transversality of environmental issues.



4.2. Sectoral legislation

As environmental issues cut across a wide variety of sectors, a number of legal documents assume an important role in environmental protection. Table 8 summarizes some of the most relevant sectoral plans, projects and legislation considering the context of the project, impact and construction activities.

Table 8 – Sectoral documents

Legal document	Brief description
LAND RESOURCES	
Land Act (CAP 57.01, 1965)	Customary, public and private land, use of land, trespass and encroachment.
Registered Land Act (CAP 58.01, 1967)	Registration of title, land and dwellings on registered land.
Land Acquisition Act (CAP 58.04, 1971)	Acquisition under public interest and market value for the land assessment and retribution.
Customary Land (Development) Act (CAP 59.01, 1967)	Rights and interests in customary land including land allocation; aim to promote better land development.
Lilongwe Agricultural Development Area Boarder	Customary land boarders in Lilongwe.
Lilongwe District Development Plan	Projects to develop in Lilongwe rural areas.
WATER RESOURCES	
Second National Water Development Project (NWDP II) 2007-2015	World Bank funded-program aiming the increase access to sustainable water supply and sanitation services and improve of water resources management at national level. The project will also contribute to building sector capacity through improved monitoring, regulation, incentive structures, public private partnerships, and coordination among the sector stakeholders.
Water Resources Investment Strategy (WRIS)	Framework and catalyst for water sector investment.
Water Resources Act (No. 2 of 2013)	Management, conservation, use and control of water resources; Acquisition and regulation of rights to use water.
Water Regulations (G.N. 230/1969)	Regulation of water abstraction.



Legal document	Brief description
Water (Water Pollution Control) Regulations (G.N. 31/1978)	Construction regulations of septic tank or pit-latrine, boreholes and wells; Control of water pollution discharge of effluent into public water: analysis of water and effluent.
Water Works Act (No. 17 of 1995)	Establishment of Water Boards water-areas and for the administration of such water-areas for the development, operation and maintenance of waterworks and water-borne sewerage sanitation systems.
ECOLOGY, FLORA AND FAUNA	
National Parks and Wildlife Act (No. 11 of 1992)	Establishment of national parks, preservation of animals, vegetation and objects of special interest in parks and wildlife management.
National Parks and Wildlife (Protected Areas) Regulations (G.N. 87/1994)	Regulation of protected areas.
National Parks and Wildlife (Protected Species) (Declaration) Order (G.N. 89/1994)	Declaration of protected wild plants and wild animals species
Forestry Act (No. 11 of 1997)	Participatory forestry, forest management, forestry research, forestry education, forest industries, protection and rehabilitation of environmentally fragile areas and international co-operation in forestry.
Forest Rules	Regulations in forest areas reforestation, felling, etc
Fisheries Conservation and Management Act (Cap 66.05, 1997)	Regulation, conservation and management of the fisheries of Malawi.
Fisheries Conservation and Management Regulations (G.N. 32/2000)	Includes conservation measures.
MINERALS, CHEMICALS AND POLLUTION	
Mines and Minerals Act (CAP 61.01, 1981)	Regulates the search for and the mining of minerals, ensuring the protection of the environment and natural resources.
Explosives Act (CAP 14.09)	Storage, handling, mixing, preparation and use of explosives for blasting.
Fertilizers, Farm Feeds and	Registration, regulation and restriction of fertilizers,



Legal document	Brief description
Remedies Act (CAP 67.04, 1989)	farm feeds and remedies.
Fertilizer Regulations (of 2003)	Includes environmental issues associated to fertilizers, imposing heavy metal limits for fertilizer products.
Pesticides Act (CAP 35.03, 2000)	Control and management of the import, export, manufacture, distribution, storage, disposal and use of pesticides.
Pesticides Regulations (G.N. 5/2002)	Among other provides regulations concerning storage and application of pesticides.
OTHER ACTS	
Monuments and Relics Act (CAP 29.01, 1990)	Conservation, preservation and study of cultural heritage including places of distinctive natural beauty and of sites, buildings and objects of archaeological, paleontological, geological, anthropological, ethnological, historical, prehistorical and other interests; procedure to be followed in relation to the discovery, excavation, removal, sale, exportation and importation of monuments, relics and collections of cultural heritage.
Public Roads Act (CAP 69.02, 1962)	Provides information on matters relating to public roads, construction and maintenance including compensation for land taken under roads construction.
Public Health Act (CAP 34.01, 1968)	Preservation of public health: prevention of infectious diseases, sanitation and housing, sewerage and drainage.
Occupation Safety, Health and Welfare Act (CAP 55.07, 1997)	Regulation of the employment conditions in workplaces in regards to safety, health and welfare of employees therein; for the inspection of certain plants and machinery, and the prevention and regulation of accidents occurring to employees or authorized personnel in the workplaces



4.3. Environmental standards

Infrastructure construction activities, ESIA preparation (e.g. sample collection, tolerance and threshold limits) as well as actions that derive from it – mitigation measures and recommendations, environmental and social management plans and environmental monitoring – require knowledge and application of specific standards in environmental and social issues.

The following table summarizes the key Malawi standards to the assessment.

Table 9 – Key Malawi Standards

03. SOCIOLOGY. SERVICES. COMPANY ORGANISATION AND MANAGEMENT. ADMINISTRATION. TRANSPORT.	
03.020	Sociology. Demography
MS 700	Social responsibility – Requirements for combating child labour
13. ENVIRONMENT HEALTH PROTECTION. SAFETY	
13.020	Environmental protection
13.020.10	Environmental management
MS-ISO 14001	Environmental management systems – Specification with guidance for use
MS-ISO 14004	Environmental management systems – General guidelines on principles, systems and support techniques
MS-ISO 14010	Guidelines for environmental auditing – General principles
MS-ISO 14011	Guidelines for environmental auditing – Audit procedures – Auditing of environmental management systems
MS-ISO 14012:1	Guidelines for environmental auditing – Qualification criteria for environmental auditors
MS-ISO 14015	Environmental management systems – General guidelines on principles and support techniques
MS-ISO 14020	Environmental labels and declarations – General principles
MS-ISO 14031	Environmental management Environmental performance evaluation – Guidelines
MS-ISO 14032	Environmental management – Examples of environmental performance evaluation (EPE)
MS-ISO 14040	Environmental management – Life cycle assessment principles and framework
MS-ISO 14041	Environmental management – Life cycle assessment Goal and scope definition and inventory analysis



MS-ISO 14042	Environmental management – Life cycle assessment life cycle impact assessment
MS-ISO 19011	Guidelines for quality and/or environmental management systems auditing
13.020.40	<i>Pollution, pollution control and conservation</i>
MS 539	Industrial effluents – Tolerance limits for discharge into inland surface waters
MS 691	Tolerance limits for domestic sewage effluents discharged into in land surface waters – specification
13.030	<i>Wastes</i>
MS 59	Solid waste – Handling, transportation and disposal – Code of practice
13.030.10	<i>Solid Wastes</i>
MS 713	Plastic products – Guidelines for safe management and disposal
13.030.30	<i>Special wastes</i>
MS 675	Safety procedures for the disposal of surplus pesticides and associated toxic waste – code of practice
13.030.40	<i>Installations and equipment for waste disposal and treatment</i>
MS 730	Solid waste disposal sites, guidelines for design – code of practice
MS 731	Solid waste disposal sites: Guidelines for safe management – code of practice
MS 732	Effluent treatment plants – operating conditions (code of practice)
13.060	<i>Water quality</i>
13.060.10	<i>Water of natural resources</i>
MS 733	Borehole and shallow well water quality – Specification
13.060.20	<i>Drinking water</i>
MS 214	Drinking water – Specification
MS 678	Drinking water quality - control and surveillance of water in public supply net works
MS 699	Bottled drinking water other than mineral water
13.060.01	<i>Water quality in general</i>
MS 682-1	Water quality – Sampling Part 1: Guidance on the design of sampling programmes and sampling techniques
MS 682-3	Water quality – Sampling Part 3: Guidance on the preservation and handling of water samples
MS 682-4	Water quality – Sampling Part 4: Guidance on sampling from lakes, natural and man made
MS 682-6	Water quality – Sampling Part 6: Guidance on sampling of rivers and streams



13.100	Occupational safety. Industrial hygiene
MS 714	Occupational safety and health management systems – Specification
13.140	Noise with respect to human beings
MS 712-1	Acoustics – Recommended practice for the design of low noise at workplaces containing machinery Part 1: Noise control strategies
MS 712-2	Acoustics – Recommended practice for the design of low noise at workplaces containing machinery Part 2: Noise control measure
MS 712-3	Acoustics – Recommended practice for the design of low noise at workplaces containing machinery Part 3: Sound propagation and noise prediction in workrooms
17. METROLOGY AND MEASUREMENT. PHYSICAL PHENOMENA	
17.140	Acoustics and acoustic measurements
MS 173	Acoustics Noise pollution – Tolerance limits
17.140.01	<i>Acoustic measurements and noise abatement in general</i>
MS 697	Industrial noise affecting mixed residential and industrial area – Method for rating
65. AGRICULTURE	
65.080	Fertilizers
MS 167	Fertilizers and soil conditioners – Vocabulary
MS 265	Bagged fertilizers, handling and storage – Code of practice
65.100	Pesticides and other agrochemicals
65.100.01	<i>Pesticides and other agrochemicals in general</i>
MS 89	Pesticides – Handling, storage and disposal – Code of practice
MS 120	General requirements for pesticides – Specification
91. CONSTRUCTION MATERIALS AND BUILDING	
91.100	Construction materials
91.100.15	<i>Mineral Materials and Products</i>
MS 6	Burnt clay bricks – Specification (First revision)
MS 175	Burnt clay bricks – Code of practice for moulding and firing
91.140	Installations in buildings
91.140.60	<i>Water supply systems</i>
MS 532	Borehole construction – Code of practice

Coding according with Catalogue of Malawi Standards (online available version of 2013).

Source: <http://www.mbsmw.org/index.php/mbs-publications/18-malawi-standards-catalogue-2013/file>

Some environmental factors are still being developed by the Malawi Bureau of Standards. In the absence of specific standards, World Bank (WB), World Health Organization (WHO) and International Finance Corporation (IFC) standards, as well as other international regulatory documents are applicable to the Malawian territory.



4.4. International Standards and Guidelines

A general overview of the main international standards and guidelines of the World Bank (WB), the International Finance Corporation (IFC) and the World Health Organization (WHO), in relation to the main issues of the project, is listed next.

Table 10 – Applicable International Policies, Standards and Guidelines

Institutions	Applicable Policies, Standards and Guidelines
World Bank	Overview: The World Bank frames its lending-operations in a set of established policies and procedures, ensuring that support projects are socially and environmentally sound. Such policies and procedures provide not only guidelines of mandatory compliance, but also fosters environmentally sustainable and social development opportunities, while clearly states the principles, measures and impacts that are not acceptable.
	• OP 4.01 – Environmental Assessment
	• OP 4.04 – Natural Habitats
	• OP 4.07 – Water resources Management
	• OP 4.11 – Physical Cultural Resources
	• OP 4.12 – Involuntary Resettlement
	• OP 4.36 – Forests • OP 4.37 – Safety of dams
International Finance Corporation	Overview: As a member of the WB, responsible for the coordination of its activities with the other institutions of the World Bank Group, the IFC published the Environmental, Health, and Safety (EHS) Guidelines to be applicable in projects within such Group. The EHS Guidelines are technical reference documents with general and industry-specific examples of Good International Industry Practice with performance levels and measures that are generally considered to be achievable at reasonable costs.
	• 1 – Environmental Guidelines/ 1.1 – Air Emissions and Ambient Air Quality
	• 1 – Environmental Guidelines/ 1.4 – Water Conservation
	• 1 – Environmental Guidelines / 1.7 – Noise



Institutions	Applicable Policies, Standards and Guidelines
International Finance Corporation (cont.)	• 2 – Occupational health and safety Guidelines
	• 3 – Community health and safety Guidelines
	• 4 – Construction and Decommissioning Guidelines/ 4.1 – Environment
	• 4 – Construction and Decommissioning Guidelines/ 4.2 – Occupational Health & Safety
	• 4 – Construction and Decommissioning Guidelines/ 4.3 – Community Health and Safety
World Health Organization	Overview: World Health Organization Guidelines are addressed primarily to water and health regulators, policymakers and their advisors, to assist in the development of national standards. The Guidelines and associated documents are also used by many others as a source of information on water quality and health and on effective management approaches.
	• Air quality guidelines
	• Noise guidelines
	• Drinking-water Quality

4.5. Cultural Heritage

Before any land altering development activity is undertaken, archaeological impact assessment is required by Malawi law. Section 29 of the Monuments & Relics Act of 1990 (Cap. 29:01 Laws of Malawi) reads:

- (1) “A person in charge of any survey, excavation, exploration, construction or new development shall, at the earliest stages of planning for such activities, give notice to the Minister to enable, where necessary, rescue archaeology to be carried out (...)”
- (2) “(...) the cost of such work shall ... be borne by the person in charge of any survey, excavation, exploration, construction or other development.”

Besides these domestic legal requirements, project donors may have their own safeguarding policies to adhere to. World Bank and IDA funded projects have to go by their safeguard operational policy 4.11 on physical cultural resources, and



operational policy 4.10 on indigenous people³. The latter is particularly relevant with regard to intangible cultural heritage such as shrines and other spiritual places.

Also the European Union has acknowledged the value of archaeology and the critical role of the archaeologist in development projects in its Malta Convention (1992) which followed the ICOMOS charter on Archaeological Heritage Management (1990).

Malawi is further signatory to the 1970 UNESCO World Heritage Convention and the 2003 UNESCO Convention on Intangible Cultural Heritage. Malawi thus has an international obligation to preserve its heritage.

Heritage impact assessment can be done by private companies but requires permission and participation of officials of the Department of Antiquities which is the regulatory body.

³ The World Bank safeguard policies are available at <http://go.worldbank.org/MTA1ODE7T0>. They are currently under revision.



5. Description of the Environmental and Social Setting

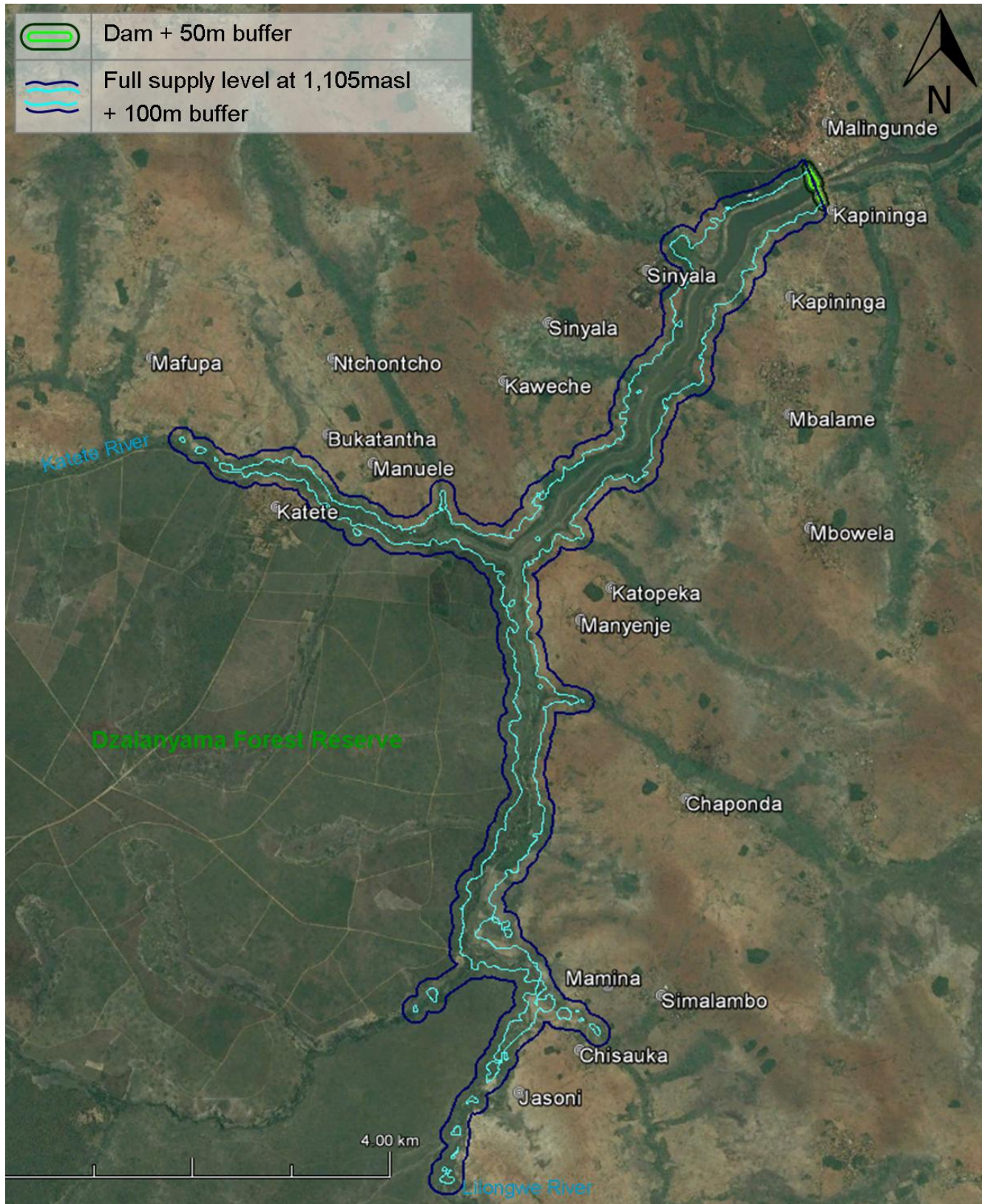
5.1. Introduction

This chapter sets the spatial and temporal boundaries within which the environmental and social setting was considered. Its goals are describing the pre-existing conditions of the physical, biological and human environments of the likely affected area of the project, both directly and indirectly. Environmentally-sensitive areas of special or unique biophysical, socio-economic or cultural value will also be located and described along the region that might be affected by the project's activities.

The following biophysical and socio-economic issues were screened according to the type of project and region it crosses, as defined in the assignment ToR:

- Geology and topography;
- Hydrogeology;
- Soils;
- Hydrology;
- Surface Water Quality;
- Noise;
- Air Quality;
- Aquatic and Terrestrial Ecology (Flora and Fauna);
- Land Use and Spatial Planning;
- Socio-Economics and Public Health;
- Cultural Heritage.

The Environmental and Social Setting reports to a study area that comprises the project and intervention areas available at this stage, as well as their immediate surroundings – 100 m study area around the new Full Supply Level (1,105 masl), and 50 m buffer area around the current dam structures (spillway and embankments). Nevertheless, for some studies, the analysis scale could be larger (regional or national scale), as far as certain socio-economic topics are concerned for instance.



Source: aerial image from Google Earth (December, 2013)

Figure 18 – ESIA Study area



5.2. Geology and Topography

5.2.1. Introduction

The characterisation of the current geomorphological and geological setting is the baseline reference for the assessment of impacts in this study.

Since the potential impacts on geology and topography are localised, i.e. not reflected in areas distant from the project site, the study area here considered refers to the area being flooded by the dam's raising and its immediate surroundings (100 m study area), except for those aspects of regional coverage needed to understand the study area (e.g. seismic hazard).

The present description of the geomorphological and geological aspects is based on the sheet 23 of the geological map of Malawi at 1:100,000 (Thatcher & Walter, 1968). However, other sources of information include fieldwork in the study area and specific studies such as those related to seismic hazard.

This characterisation includes descriptions for the area of the following topics:

- Geomorphology;
- Geology;
- Geohazards;
- Geologic resources with economic and conservation interest.

5.2.2. Regional geomorphology

5.2.2.1. Regional aspects

The study area is located in the gently undulating South Lilongwe Plain. Three major erosion surfaces have been recognised in this area: post-Gondwana residuals, African erosion surface and post-African erosion. The oldest of the three, the post-Gondwana surface of the early and mid-Cretaceous age is now merely represented by residuals (inselbergs) which rise above the level of the surrounding plain.



The African cycle of erosion, which occurred in the late Cretaceous – early Miocene formed an extensive plain in the Central Region of Malawi of which the South Lilongwe Plain is but a part. This surface reached a state of extreme old age, characterised by its monotonous flatness, before the post-African cycle of erosion was initiated in late-Miocene times.

The mature African surface is slightly downwarped in the vicinity of Lilongwe, this feature possibly being associated with Rift Valley faulting in the area to the east. Incipient post-African erosion has penetrated along the floor of the major river valleys and in places a composite surface results, the African and post-African surfaces merging gently and indiscernibly on the interfluves.

The level of the plain shows a gentle southward rise over a distance of 56.3 km from an elevation of 1,143 m at Lilongwe to 1,295 m on the Mozambique border. Slight rises also occur towards the eastern and western margins of the plain. Inselbergs rise from the surface of the plain along interfluves. Towards the east these tend to be more prominent and surrounded by lower hills at 1,250 – 1,280 m above sea level (Thatcher & Walter, 1968).

The Lilongwe river is one the three main river systems draining the South Lilongwe Plain. This river is composed of five main tributaries, Likuni, Katete, Lisungwe, Nanjiri and Nathenje. The headwaters of these rivers form a complex network of deeply dissected valleys which frequently follow joint directions, shear zones and foliation within Dzalanyama Granite. Small dambo⁴ lie at the source of each tributary stream and rarely dry up as all but the smallest streams in the Dzalanyama continue to flow throughout the year.

5.2.2.2. Study area

The study area corresponds to the future water reservoir and a 100 m buffer around it, as well as a 50 m buffer around the new structures to be implemented (weir and adjacent slopes). This area includes the Lilongwe River across slightly more than 12 km and the Katete River (a tributary of the Lilongwe River) across more than 3.1 km.

⁴ Dambo – broad, grass covered, swamp valley(s)



Considering the area to be occupied by the water reservoir created by the raised dam and the 100 m buffer around it, the hypsometry ranges from 1,090 m and 1,109 m in the downstream and upstream limits of the study area, respectively (see Appendix 1 – Map 3).

In this section of the Lilongwe River, pot-holed areas are common. Generally this stretch of the river is characterised by gently sloping margins. Considering the 100 m buffer and also the area occupied by the future water reservoir, slopes only exceptionally exceed 20% (see Appendix 1 – Map 4).

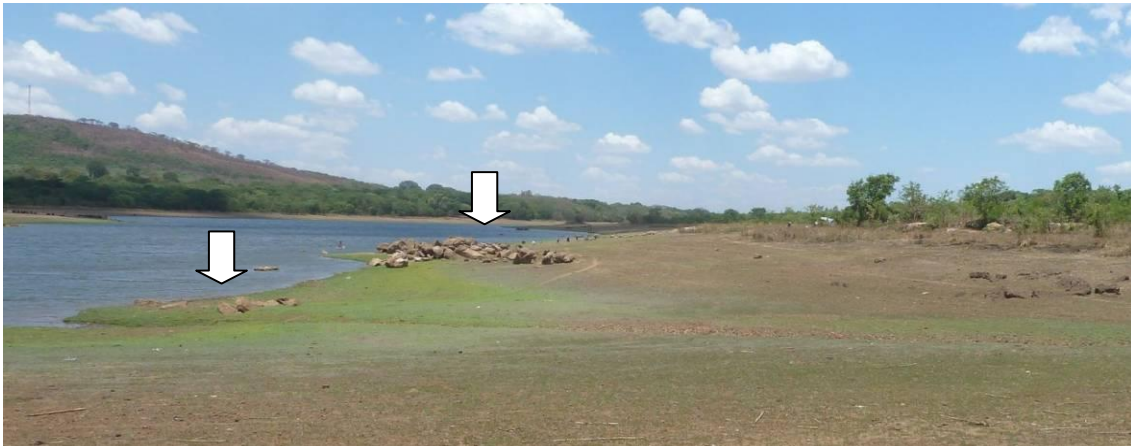
5.2.3. Geology

The South Lilongwe Plain and Dzalanyama Range are largely underlain by granulites, gneisses and schists of the Precambrian Basement Complex; on the plain this basement complex is, for the most part, obscured by thick superficial deposits which include residual soils, alluvium and colluvium.

5.2.3.1. Basement complex: charnockitic granulites, paragneisses and schists

Charnockitic granulites⁵, paragneisses and schists are very widespread in the South Lilongwe Plain and Dzalanyama Range, particularly in the central part of the area where they are overlain by thick superficial deposits. According to Thatcher & Walter (1968) the basement complex in the study area is mostly composed of paragneisses in depth and expressed in the surface by a series of small outcrops in the river and margins (Figure 19). Through the 1:100,000 geological map, ten (10) rock outcrops are identified in these areas, spanning from biotite-gneiss, muscovite-schist, quartzofeldspathic granulite, amphibolite to granite (see Appendix 1 – Map 5).

⁵ Granulites in this case refer to rocks with granulose texture not necessarily belonging to the granulite facies.



Source: NEMUS (2014)

Figure 19 – Biotite-gneiss outcrops in Kamuzu Dam I reservoir

5.2.3.2. Superficial deposits

Thick superficial deposits comprising various types of residual soils, river alluvium and dambo soils cover much of the South Lilongwe Plain. Brown and Young (1965) have classified the soils as latosols which vary from highly ferruginous to sandy ferallitic types. The various types of these soils frequently grade into one another. The depth of weathering is very variable in this area; wells drilled for rural water supplies have in places penetrated as much as 45 m of weathered rocks (Thatcher & Walter, 1968). Considering the information from the boreholes close to the study area (Appendix 1 – Map 5), weathered rocks reach around 43 m in depth.

According to the geological map (1:100,000), red-brown sandy clay soils (Qr) dominate the study area (see Appendix 1 – Map 5 and Figure 20 below). Their colour depends on the degree of cultivation and the percentage of humus present. These soils are probably derived largely from the micaceous rocks and, to a lesser extent, from pyretic and hornblendic rocks, including metagabbros. A surface float of quartz, kyanite and, less commonly, tourmaline is typically developed over these soils which broadly may be correlated with the ferruginous soils of Brown and Young's (1965) classification.



Source: NEMUS (2014)

Figure 20 – Brown sandy clay soil in the margin of the Lilongwe River

In the Lilongwe River, the 2.5 km stretch in the upstream limit of the study area is occupied by dambo soil (Thatcher & Walter, 1968). This area of impeded drainage is occupied by hydromorphic soils; dark grey, black and mottled soils mainly composed of clay minerals. The thin humus of the A-horizon supports only shallow rooted plants like grasses (Figure 21). The low permeability of clays combined with the poor site drainage produce a waterlogged soil liable to seasonal flooding.



Source: NEMUS (2014)

Figure 21 – Dambo soil in an upstream location of the study area



5.2.4. Geohazards

5.2.4.1. Neotectonics and seismicity

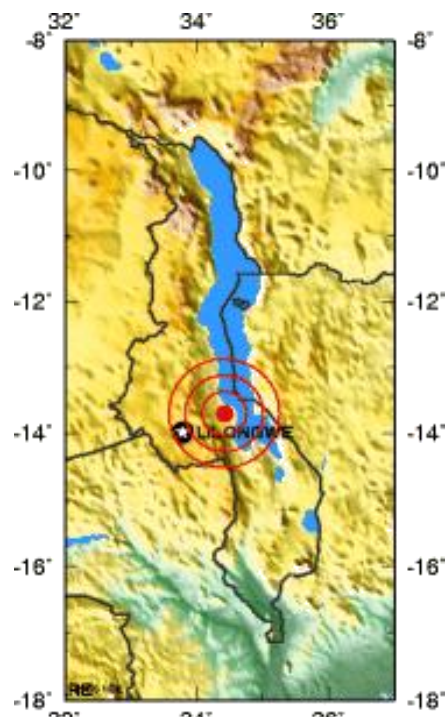
Malawi is within the most seismically active belt of the East African Rift System (EARS). The EARS extends from the Red Sea/Gulf of Aden to Malawi and it is seismically active beyond. In its actual configuration it presents two main rift branches, the Western and the Eastern Rifts (Figure 22). The Western Rift of deep lakes and few volcanoes bends about the eastern edge of the Kenya dome from Uganda to Tanzania continuing south to Malawi (Figure 22).

The Western Rift is characterised by moderate magnitude earthquakes ($M \leq 6.0$). Historical records show strongly felt earthquakes reported in various parts of Malawi, but no damage to property or loss of life has been recorded until the occurrence of the 1989 Salima Earthquake. A magnitude 6.6 quake occurred on March 10 1989 in central Malawi (Figure 23) and claimed a few lives and damaged some property.



Source: Baker *et al.* (1972) in Saemundsson (2010)

Figure 22 – The Afro-Arabian rift system



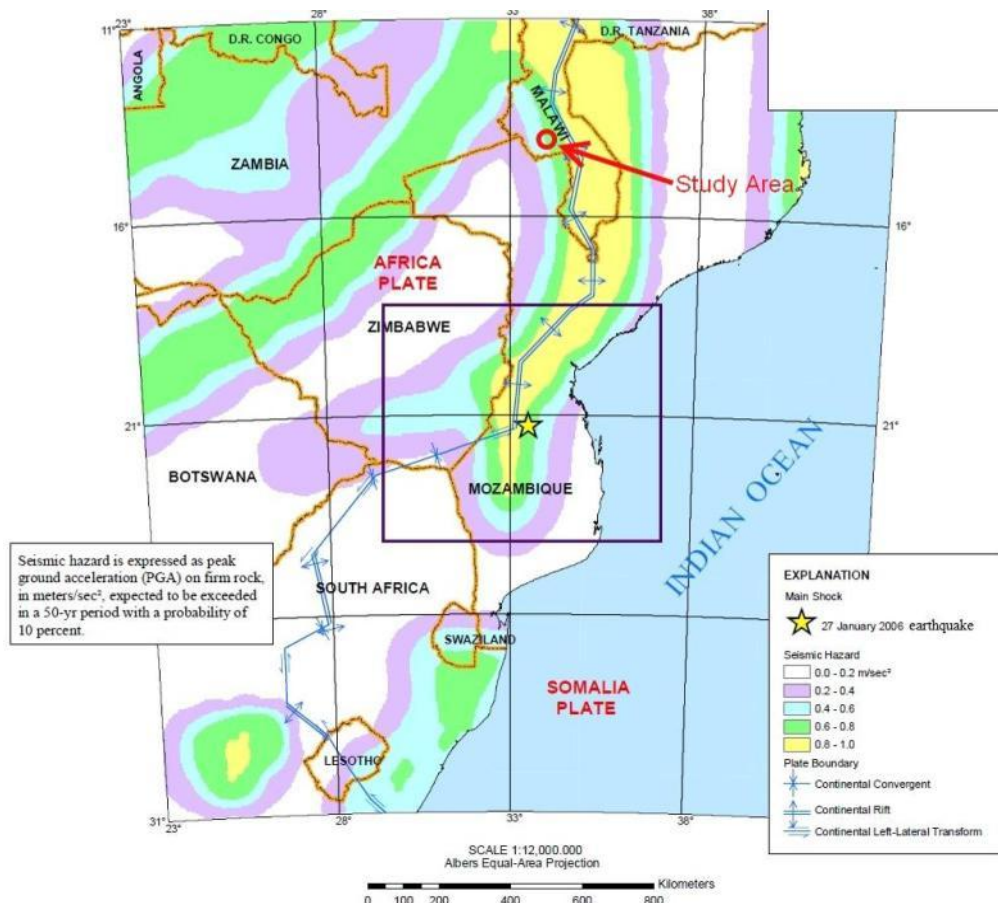
Source: <http://earthquake.usgs.gov/learn/today/index.php?month=3&day=10&submit=View+Date>

Figure 23 – Epicentre of 1989 Salima Earthquake



An estimation of seismic hazard for hard rock sites show that peak ground acceleration (PGA) for a 10% probability of exceedance in 50 years (475 years return period) for the entire country ranges from 180-240 gals. These values correspond to Modified Mercalli Intensity (IMM) of about VIII (Chapola, 2001). Such intensity would cause damage to ordinary brick buildings and completely destroy clay buildings.

A 10% probability of exceedance in 100 years (950 years return period) gives PGA values ranging from 220-320 gals which are equivalent to IMM of VII-IX. For a 50 year return period, PGA values range from 0.70 to 0.95 m/s² (IMM of VI-VII). In the main cities of Mzuzu, Lilongwe and Blantyre, PGA values of 0.80 to 1.30 m/s² corresponding to IMM of VI-VII are expected every 50-100 years (Chapola, 2001). These values are in accordance to those obtained by the USGS for the southeast Africa (Figure 24).



Source: USGS (2006)

Figure 24 – Seismic hazard for Southeast Africa expressed as peak ground acceleration (PGA)



Since the building code of Malawi has no consideration of earthquake ground motion, the anticipated intensities, at all return periods considered, would cause tremendous damage to buildings and would have adverse social and economic impacts. Malawi is today under considerable development, therefore it is expected that vulnerability to earthquakes continues to increase with time.

5.2.5. Economic geology

In the Malingunde Hill, located less than 1 km from the Kamuzu Dam I to the north (Figure 25), iron sulphide deposits have been described and studied at least since Garson *et al.* (1966). The Malingunde Hill itself is largely made up of quartzites and quartzo-feldspathic gneisses and granulites which contain variable amounts of mica, kyanite, graphite, pyrite and pyrrhotite. The sulphides are generally leached out, even when the rocks appears to be fairly fresh and the leached rock often bears a white and yellow powdery encrustation which gives off a strongly sulphurous smell when wetted.

According to Thatcher & Walter (1968), the quantity of sulphides, both pyrite and pyrrhotite, varies with the lithology and while the harder bands of granulite rarely contain more than 10%, gneisses locally contain up to 70% of sulphides. Ten megatons of proven reserves at 10% sulphur occur at Malingunde Hill in the Lilongwe District (BGS, 2009). In the referred hill elevated values of gold, silver, and zinc have been noted. It is probable that there are large unexplored resources in the poorly exposed Lilongwe-Dowa area. Several news in international media report plans for future mining developments in this area.



Source: NEMUS (2014)

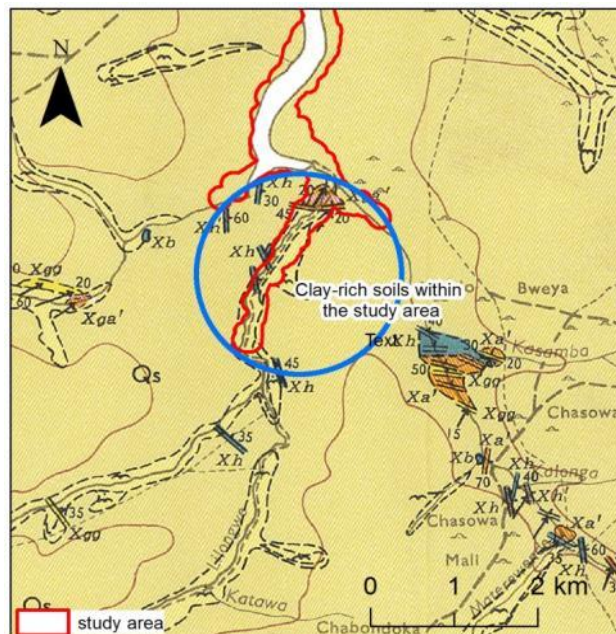
Figure 25 – View of the Malingunde Hill from south



Graphite-rich schistose quartzo-feldspathic granulites underlie large areas north-west of Malingunde Hill. Kyanite is common in the gneisses of the Malingunde area and also in the graphite-gneisses to the north-west.

Sand suitable for building purposes is available in the upper parts of many dambo and along the major rivers (alluvial sands). According to Thatcher & Walter (1968), such sands were used in the construction of the Kamuzu Dam I at Maligunde.

Dambo clays and red-brown lateritic clay soils such as those found within and around the study area are often suitable for brick-making (Figure 26). Despite the availability of resources no borrow pits were identified in the study area during fieldwork.



Source: Thatcher & Walter (1968)

Figure 26 – Location of clay-rich soils within the study area

Another geological resource is groundwater. However, for its importance and particular interest in this project this topic will be dealt separately in the following chapter.



5.3. Soils

5.3.1. Introduction

Soil is a decisive natural resource, from which a variety of environmental and human processes depend. In Malawi, as in other African countries, the challenge to address soil problems is even of a more pressing need, since the African region combines hunger and poverty, along with water limitations presented by extreme events – droughts and floods. Apart from being the support to ecosystems and habitats, in Malawi and in peri-urban/ rural areas (as well as in the study area) agriculture is a critical soil function.

The knowledge of its physical and chemical properties allows to determine its respective importance/aptitude to given soil uses or functions – nutrient exchange/retention, fertility, infiltration versus surface runoff, structural strength, etc. Conservation of soil and its management, especially according to most suitable uses, is essential to future availability and to preserve all supported systems.

In this chapter soil types will be identified and characterised – both physical and chemical main properties. Also, its aptitude/capability for agriculture, the soil pollution and erosion factors and risks that threats soil quality will be addressed.

The soil analysis is based on two soil maps:

- Soil map of Malawi compiled by M.W. Lowole⁶ (versions of 1983 and 1984 – this last one considering the Legend of the FAO-UNESCO Soil Map of the World), scale 1:1,000,000, for the Department of Agricultural Research (EuDASM);
- Soil Types in the Lilongwe Area (MASDAP), according with a Malawi only-valid soil classification system⁷, compatible with the Revised Legend of the FAO-UNESCO Soil Map of the World (ISRIC, 1988).

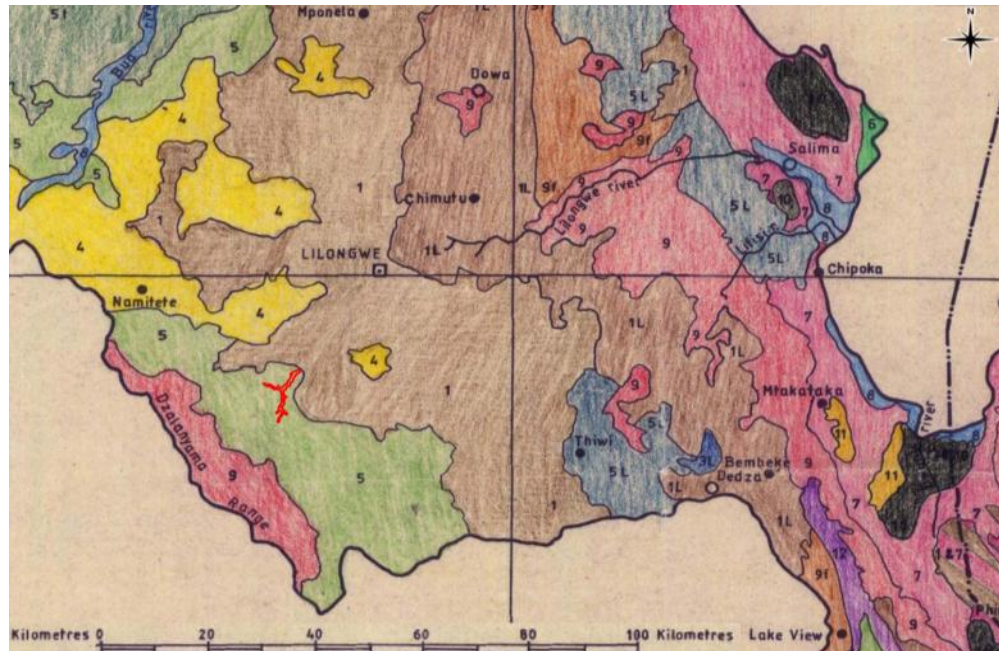
⁶ Based on the work of Young & Brown (1962, 1965), Stobbs (1975), Mitchell & Ntokotha (1974, 1978 – Soil Survey Unit), as well as other Soil Survey Unit Reports (EuDASM)

⁷ Soil classification system designed by the Project of Soil Groups and Soil Families (Land Resources Evaluation Project – Malawi, for Ministry of Agriculture, UNDP and FAO. Venema, 1990, 1991; Venema&Lorkeers, 1991)



5.3.2. Soil types and description

An extract of the Malawi's Soil Map compiled by Lowole is presented next.



STUDY AREA

— FSL at 1,105 masl + 100 m buffer

KEY TO SOIL MAP

Soil Map Key based on Lowole (1983):

Correspondent soil types under FAO Soil System Classification (Lowole, 1984):

1	FERRUGINOUS SOILS	Lf-2a	FERRIC LUVISOLS
1L	FERRUGINOUS WITH LITOSOLS	Lf-2a (l)	FERRIC LUVISOLS dominant (in association with LITOSOLS)
2	FERRISOLS	Nd-2/3b	DYSTIC NITOSOLS
2L	FERRISOLS AND LITOSOLS	Nd-2b & l	DYSTIC NITOSOLS in association with LITOSOLS
3	HUMIC FERRALLITIC SOILS	Fh-2/1a	HUMICFERRALSOLS
3L	HUMIC FERRALLITIC AND LITOSOLS	Fh-2/1a & l	HUMICFERRALSOLS in association with LITOSOLS
4	WEAKLY FERRALLITIC SOILS	Fo-2a	ORTHIC FERRALSOLS
4sf	WEAKLY FERRALLITIC AND SANDY FERRALLITIC SOILS	Fo-2a & Fx-1a	ORTHIC FERRALSOLS in association with XANTHIC FERRALSOLS
5	FERRALLITIC SOILS	Fx-1a	XANTHIC FERRALSOLS
5L	FERRALLITIC WITH LATERITE	Fx-2/1a : ms	XANTHIC FERRALSOLS (with massive laterite or gravel laterite)
5L	FERRALLITIC AND LITOSOLS	Fx-1a & l	XANTHIC FERRALSOLS in association with LITOSOLS
6	REGOSOLS	Re-1a	EUTRIC REGOSOLS
7	ALLUVIAL SOILS	Je-2a & Be-2a	EUTRIC FLUVISOLS in association with EUTRIC CAMBISOLS
7h	ALLUVIAL AND HYDROMORPHIC SOILS	Je-2a & Ge-2a	EUTRIC FLUVISOLS in association with EUTRIC GLEYSOLS
8	HYDROMORPHIC SOILS	Ge-2a	EUTRIC GLEYSOLS
9	LITOSOLS	l	LITOSOLS
9f	LITOSOLS AND FERRUGINOUS SOILS	l, (Lf)	LITOSOLS dominant (in association with FERRIC LUVISOLS)
10	VERTISOLS	Vp-3a	PELLIC VERTISOLS
10	VERTISOLS WITH GRAVELLY SOILS	Vc-2/3a	CHROMIC VERTISOLS
11	MOPANOSOLS	So-2/3a	ORTHIC SOLONETZ
12	FERRUGINOUS, FERRALLITIC AND THEIR INTERGRADES	Fo-1a & Lc-2a	ORTHIC FERRALSOLS in association with CHROMIC LUVISOLS

Figure 27 – Soil map of Malawi (extract)



The future dam reservoir area fits an area of Ferrallitic Soils, or Xanthic Ferralsols (under FAO soil system classification). Ferruginous Soils (Ferric Luvisols) can be found north and east of the study area.

According to Lowole (1983, 1984; EuDASM) and the FAO soil classification system (ISRIC, 1988), these soil types are characterised by:

- Ferrallitic Soils/ Xanthic Ferralsols – slightly or not weathered soils of good drainage. With a brown colouration, these soils are deep with sandy loam topsoils and sandy clay loam or clayey subsoils, characteristic of on level to gently undulating land. The effective cation-exchange capacity is less of 5 me/100 g clay or less;
- Ferruginous Soils/ Ferric Luvisols – soils that result from clay accumulation processes, with sandy clay loam topsoils and clayey subsoils, normally deep and with good structure, present a dark-red or red colour and are characteristic of gently undulating land. Soils with a cation-exchange capacity of 24 me/100 g clay or more, a base saturation of 50% or more and ferric properties.

In general, the dominant soil group in the area, Ferralsols are chemically poor, despite their good physical properties. Therefore they present a low natural fertility and a tendency to fix phosphates, thus limiting its agricultural use.

On the other hand, Luvisols are distinguished by a good internal drainage that makes it potentially suitable for a wide range of agricultural uses because of their moderate stage of weathering and high base saturation. It is important to mention that Luvisols with high silt content are susceptible to structure deterioration if tilled in wet condition and/or with heavy machinery. In steep slopes, these soils, although structurally sound, require erosion control measures.

Under the Land Resources Evaluation Project (LREP; Venema, 1990, 1991; Venema&Lorkeers, 1991), a soil classification system was designed for specific use in Malawi, based on three levels of generalization:

- Soil parent material;
- Soil group;
- Soil family.



In Figure 28 Soil Types for the Lilongwe area are shown, focused on the study area and its vicinity, and considering the LREP classification system.

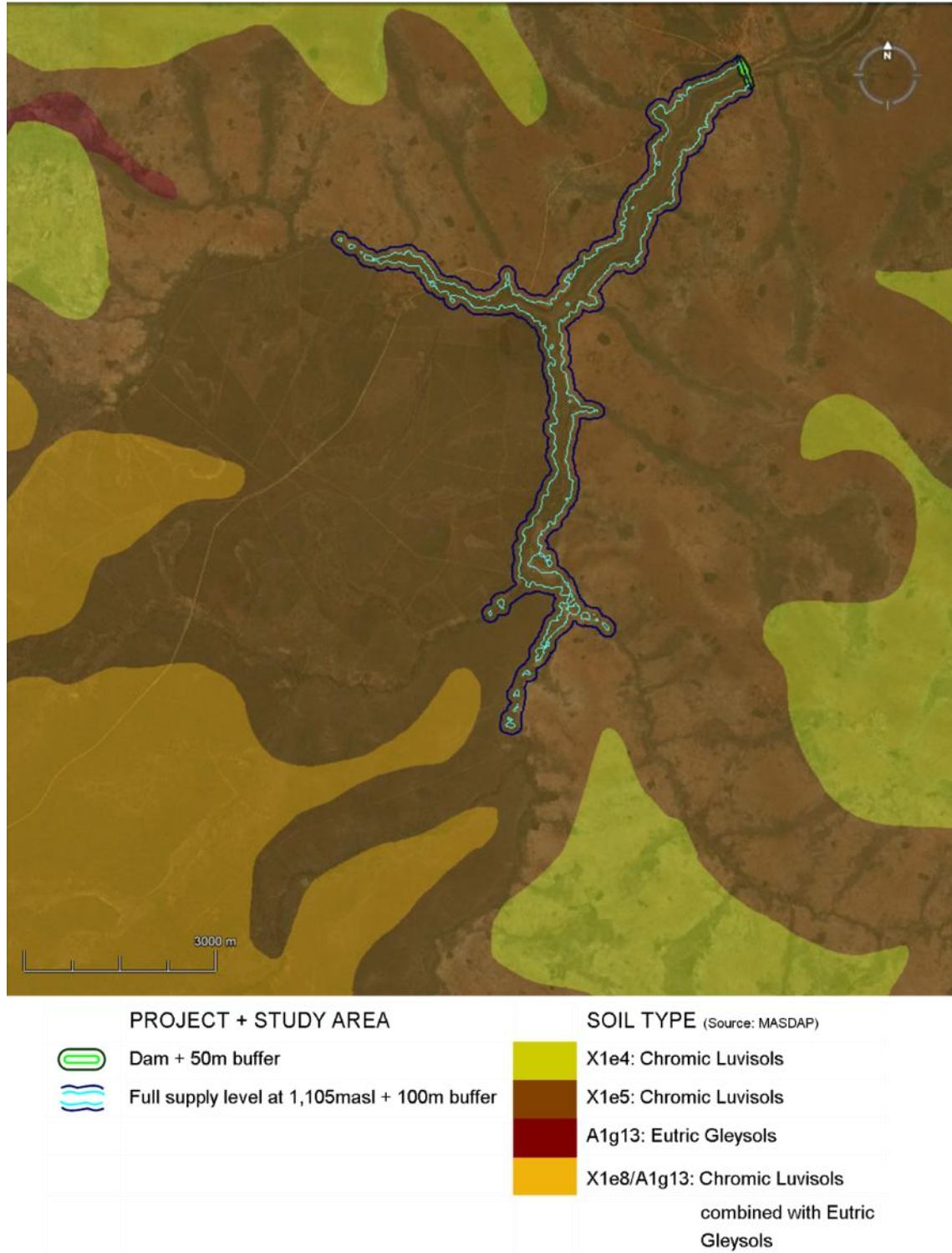


Figure 28 – Soil types in Lilongwe area (extract)



Kamuzu Dam I and the study area are over X1e5 soil unit (Eutric-fersialic soils of the Neno family; or Chromic Luvisols soils under FAO system), surrounded by X1e4 and X1e8 soil unit spots of the same soil group (Mpili and Euthini families, respectively). Finally, Gleyic soils of the Tenthema family can also be identified (A1g13 soil unit, or Eutric Gleysols, inundic phase, under FAO system), either individualized or in conjunction with X1e8 Chromic Luvisols.

X1e5 correspond to soils derived from various Basement Complex rocks (usually gneiss). They are deep (with soil depth being limited by weathered rock), well drained, reddish-brown and have a sandy loam to sandy clay loam topsoil texture, over a sandy clay loam to clay subsoil texture. The surface mostly presents gravel and the soil profile may be slightly gravelled. The topsoil structure is moderate, medium sub angular blocky or moderate crumb and a slightly hard when dry and very friable when moist consistency. Subsoil structure is moderate, medium angular or sub angular blocky and of hard consistence when dry and friable when moist.



Source: NEMUS (2014)

Figure 29 – Soil type (Kapininga)



Source: NEMUS (2014)

Figure 30 – Soil type (Jasoni)

Soil reaction in the upper 50 cm is acid to slightly acid, with a limited NKP content (very low total nitrogen and phosphorus, whilst medium exchangeable potassium is characteristic). The nutrient retention capacity and organic matter content is also restricted.

Table 11 discriminates its respective main characteristics, as well as soil characteristics and properties of the other two identified soil units in Figure 46.



Table 11 – Soil description and properties

SOIL UNIT		X1e5	X1e4	X1e8	A1g13
Soil classes	Parent material	(X): Felsic and intermediate igneous and metamorphic rocks			(A): Fluvial, colluvial and/or lacustrine sediments
	Slope	(1): 0-2% (Flat to almost flat)			
	Group	(e): Eutric-fersialic – soils with a medium to high CEC-clay (>24me/100g) in most of the upper 100cm and a moderate to high base saturation (>50%) throughout the upper 50cm. The relatively high CE-clay indicates an only limited advance of the ferrallitization process and the presence of considerable amounts of weatherable minerals. The moderate to high base saturation indicates a low degree of leaching and the presence of exchangeable bases, particularly calcium, magnesium and potassium			(g): Gleyic – very poorly to poorly drained soils. With a water-saturated topsoil or a high groundwater table during at least part of the year
	Family	Neno	Mphili	Euthini	Tenthema
Soil depth (cm)		100-150	>150	>150	>150



SOIL UNIT		X1e5	X1e4	X1e8	A1g13
Soil drainage		Well	Well	Well	Poor
Particle size	Topsoil (0-30 cm)	Medium	Coarse to medium	Coarse	Variable
	Subsoil (>30 cm)	Medium to fine	Medium to fine	Coarse to medium	Variable
pH (0-50 cm)		5.0-6.5	5.5-6.5	5.5-6.5	5.5-6.5
CEC soil (me/100g) (0-50cm)		5-10	5-10	<5	5-10
NPK content	Nitrogen (%)	0.02-0.06 (Very low)	0.03-0.11 (Low to very low)	<0.08 (Very low)	Variable
	Phosphorus (ppm)	<6 (Very low)	1-17 (Low to very low)	(very variable)	Very low
	Potassium (me/100g)	0.2-0.4 (Medium)	0.2-0.4 (Medium)	(very variable)	Variable



SOIL UNIT	X1e5	X1e4	X1e8	A1g13
Organic matter content (%) (0-30cm)	1-1.5 (Low)	1-2 (Low)	1.2-2.5 (Low to medium)	1.2-2.5 (Low to medium)
Colour (subsoil)	Dark brown	Reddish brown	Reddish brown	Grey
Surface stoniness & rockiness (%)	<1	<1	<1	<1
Present erosion	Slight	Slight	None to Slight	None
Flooding	None	None	None	Exceptional to none
Landform	Uplands; plains	Plains; footslopes	Uplands; plains	Dambos

Source: adapted from Venema (1990, 1991), Venema&Lorkeers (1991)



5.3.3. Soil aptitude and capability

In the Malawian context, the soil suitability for agriculture is the essential soil use indicator, especially considering the dependency of a great portion of the population from this activity for subsistence. Allocating the soil hectares with a good quality for agriculture is one of the main factors that should guide any process of strategic planning, a premise that should be combined with other sustainability factors – habitats and ecosystems supported, physiographic and potential erosion control and management and human settlement, among others.

As previously observed, the soils of the study area – Ferralsols or Eutric-fersialic soils of the Neno family – could be considered in general soils of good quality (especially in terms of structure and drainage), although marked by potential nutrient limitations. The characteristic physiography of the region could be interpreted by two opposing views: as a regional plain, the low slopes decreases the rapid horizontal drainage of nutrients, favouring their infiltration and fixation in good quality soils; on the other hand, the extreme precipitation events and maximized runoff represent the potential to water logging and sedimentation of infertile soil drained from upland.

In LREP (Venema&Lorkeers, 1991), a set of factors was pondered to evaluate the land quality and suitability for the Lilongwe ADD:

- Temperature regime;
- Erosion hazard;
- Flooding hazard;
- Soil workability;
- Moisture regime;
- Nutrient availability;
- Nutrient retention capacity;
- Rooting conditions;
- Oxygen availability;
- Toxicity/acidity;
- Other soil related factors;



These factors determine both the suitability and agricultural potential for a number of uses, such as rain-fed cultivation (either under traditional management or improved farming practices which include soil conservation measures), wetland rice cultivation and forestry.

The output of the referred assessment is synthesised in Table 12. In it, the assessed suitability for the above-mentioned uses is reported (and the limiting factor for not achieving the higher class rank), considering the soil types identified in Figure 28 and also maize, tobacco and groundnuts cultivation (cultures identified during fieldwork as more relevant in the study area). Once the assessment was performed for a number of land units which location was not possible to rigorously determine, the suitability classification presented is a result of the most common suitability class for each soil type in the Lilongwe ADD.

Table 12 – Suitability for different land uses considering the study area soil types

Soil Unit		A1g13	X1e4	X1e5	X1e8
Rainfed agriculture under traditional management	Maize	Nw	S2n	S2/3n	S2/3n
	Groundnuts	Nw	S2n	S2/3n	S2/3n
	Tobacco	N.A.	N.A.	N.A.	N.A.
Rainfed agriculture under improved traditional management	Maize (long cycle variety)	Nw	S2/3mt	S2mt	S2/3t
	Maize (short cycle variety)	Nw	S2ct	S2ct	S2/3t
	Groundnuts (long cycle variety)	Nw	S1/2t	S2x	S2t
	Groundnuts (short cycle variety)	Nw	S2/3c	S2/3c	S2/3c
	Tobacco	Nw	S2c	S2cx	S2ct
Wetland rice		Nm	N.A.	N.A.	N.A.
Forest	<i>Acacia albida</i>	Ns	S2/3m	S2/3c	S2m-S3cm
	<i>Azadirachta indica</i>	Ns	S1/S2m	S2cm	S2cm
	<i>Callitria calcarata</i>	Ns	S2/3m	S3c	S2m
	<i>Callitris hugelii</i>	Ns	S2c	S2/3c	S2cm-S3c
	<i>Cassia Siamea</i>	Ns	S2c	S3c	S2/3c
	<i>Cordyla africana</i>	Ns	S2/3c	S2/3c	S2/3c
	<i>Eucalyptus camaldulensis</i>	S3s	S1/S2m	S1/S2m	S1-S2c
	<i>Eucalyptus grandis</i>	Ns	S2/3m	S2m	S2m
	<i>Eucalyptus tereticornis</i>	Ns	S1/S2cm	S1/S2c	S1-S2c



Soil Unit		A1g13	X1e4	X1e5	X1e8
Forest (cont.)	<i>Gmelina arborea</i>	S3s	S2c	S1/S2c	S1-S2c
	<i>Melia Azedarach</i>	Ns	S1/S2m	S1/S2c	S1-S2/3m
	<i>Pinus caribaea</i>	Ns	S2/3m	S2/3m	S2/3m
	<i>Pinus kesiya</i>	Ns	S2/3m	S2/3m	S1-S2/3m
	<i>Pinus patula</i>	Ns	S3m	S3m	S2/3m

Source: adapted from Venema&Lorkeer (1991)

N.A. – Not applicable

Land suitability classes:

S1: Highly Suitable

S2: Moderately Suitable

S3: Marginally Suitable

N: Not Suitable

Land suitability subclasses:

c – temperature regime

e – erosion hazard

f – flooding hazard

k – soil workability

m – moisture regime

n – nutrient availability

r – rooting conditions

s – soil related factors

t – nutrient retention capacity

w – oxygen availability

x – toxicity/acidity

Focusing on X1e5 soils, they are commonly moderately suitable for the considered crops, as well as for most of the forest species (especially the *Eucalyptus*, *Gmelina* and *Melia* species).

The following Figure 31 presents the potential for agricultural use of the Lilongwe region and the study area in particular – Good Quality Soils for Rainfed Agriculture. The soil quality allocation considers the cultivation of the following crops, according with Table 13:

- Maize, long season varieties such as CCA, UCA and MH15;
- Groundnuts, long season varieties such as Chalimbana;
- Sun flower;
- Fire cured and burley tobacco;
- Soya beans.

Table 13 – Agricultural potential classes for rainfed agriculture

Class	Land quality description	Land suitability for rainfed crops under improved traditional management
1	Good quality	S1, S1/2 or S2 for 8 or more crops
2	Moderate quality	S1, S1/2 or S2 for 1 to 7 crops
3	Marginal quality	S3 or S3/N for 1 or more crops; S1, S1/2 or S2 do not occur
4	Unsuitable	N for all crops

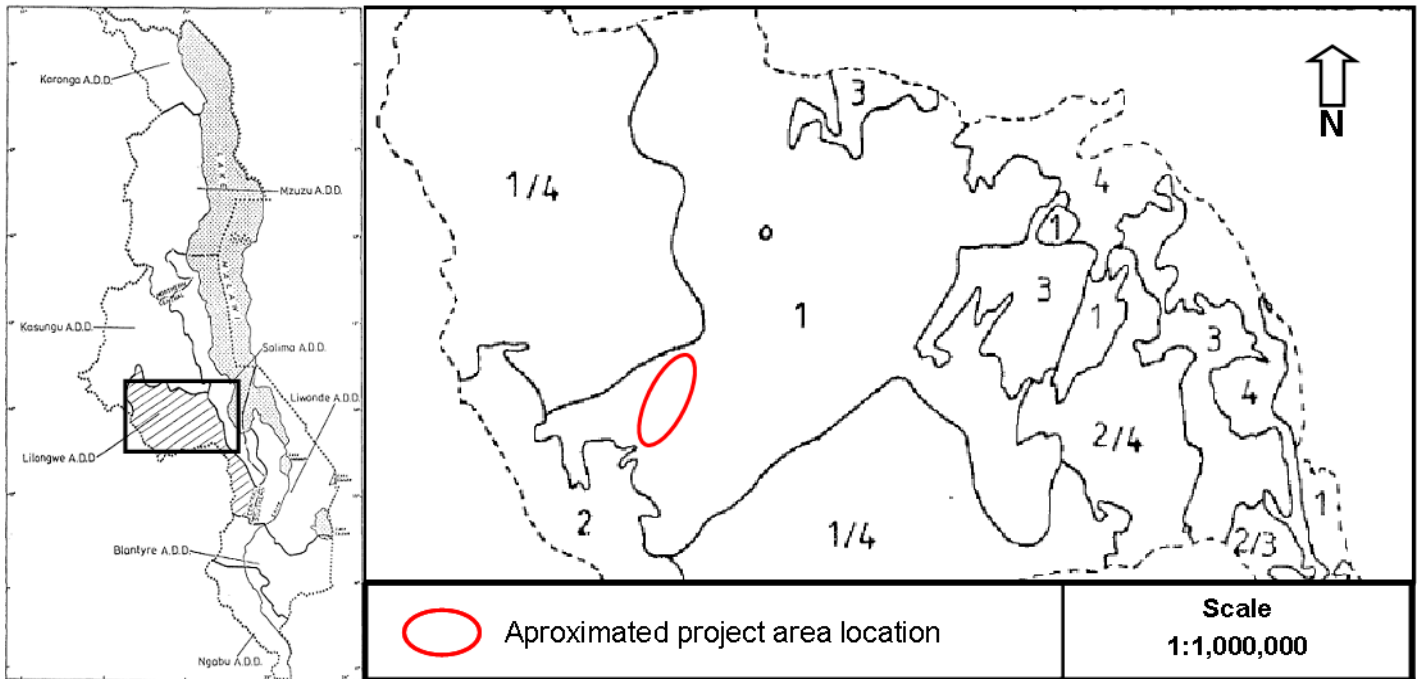
Source: Venema&Lorkeers (1991)

S1: Highly Suitable

S2: Moderately Suitable

S3: Marginally Suitable

N: Not Suitable



Source: adapted from Venema&Lorkeer (1991)
Note: Suitability classes accordingly with Table 13.

Figure 31 – Agricultural potential for rainfed agriculture under improved traditional management

5.3.4. Soil erosion risk and factors

In the sections above, it is evident the potential impact that soil erosion – which is, in essence, a loss of a natural resource – can have in the population's subsistence capacity. Soil erosion is given by a number of factors that are combined and interact with the soil intrinsic properties.

The degree with which these factors affect the soil is firstly a result of the resilience of the soil profile – structure, content, etc. As recalled, the most common soil types in the study area have an erosion risk/occurrence of low significance (Table 11), mainly due to a good structure, medium sized soil particles (fine sand has more tendency to erode), good drainage and the existent characteristic landform (plains).

The following factors occur/may occur in the study area and its surroundings, enhancing the erosion phenomena:



- Although steep slopes are absent in general, riverbanks may present locally accentuated slopes;



Source: NEMUS (2014)



Source: NEMUS (2014)

Figure 32 – Soil erosion in riverbanks (1)

Figure 33 – Soil erosion in riverbanks (2)

- Extent cultivated areas (the post-harvest period implies the exposal of bare soil)/ production forest areas;



Source: NEMUS (2014)

Figure 34 – Exposed soil in agricultural land (180° view)



Source: NEMUS (2014)

Figure 35 – Exposed soil in forest production area



- Exposure of bare soil in the dry season, usually flooded in the wet season;



Source: NEMUS (2014)

Figure 36 – Exposed soil in flood land (near KD1)

- Short period and erosive-intensity precipitation;
- Intense water runoff from upland and potential local water logging in extreme precipitation events;
- High intensity winds during the dry season;
- Drought periods.

Despite their exposure, some major erosion factors are not observed, such as frequent steep slopes, sand/soil mining in riverbanks, soil waterproofing (artificial paved areas), agricultural land within the dam reservoir buffer zone and use of heavy agricultural machinery. The flow control given by the Kamuzu Dams I and II also diminishes the potential for intense upstream flow that could significantly disaggregate riverbanks' slopes and soils.

As observed in the fieldwork, the major concern to arise from local conditions is the agricultural and production forest use, in riverbanks for locations upstream the dam reservoir (Lilongwe and Katete River, as well as other tributaries), and immediately adjacent (upland) to the dam reservoir buffer zone.

It should be pointed out that the susceptibility to water erosion is especially elevated during the beginning of the rainy season, where intense precipitation events concur with little or no ground cover on cultivated lands.



The estimated erosion rate for the Lilongwe ADD is higher than the national average [20t/ha/yr according to World Bank (1992)], as shown in Table 14.

Table 14 – Soil loss on gross arable land by ADD

ADD	Soil loss (t/ha/yr)
<i>Karonga</i>	29
<i>Mzuzu</i>	22
<i>Lilongwe</i>	22
<i>Salima</i>	16
<i>Liwonde</i>	13
<i>Blantyre</i>	29
<i>Ngabu</i>	17

Source: World Bank (1992)

5.3.5. Soil pollution

While soil erosion directly affects the physical quality of the soil, soil pollution preferably impacts its chemical quality. Nevertheless, these phenomena are interlinked.

Soil pollution derives from the anthropogenic sources developed in the area. Local conditions favour the infiltration of the pollutants into soil horizons instead of its runoff to water streams and rivers – good soil drainage, null to very low slopes, creating a context where significant pollution sources will impact the soil quality and its functions/supported land uses.

Considering the rural context of the project area, the following pollution sources prevail:

- Fertilizer usage in agriculture – main crops identified in the area include maize, tobacco and groundnuts. Maize crops are widely spread and with relevant dimension (diffuse source). Even considering the low socio-economical level associated to an impoverished rural population, some smallholder farmers use fertilizers to improve crop's productivity, according to fieldwork undertaken. Regardless, maize and groundnuts crops are usually cultivated without recurring to these products. The use of animal manure is also expected, especially associated with tobacco crops;



Source: NEMUS (2014)

Figure 37 – Use of manure in tobacco plantation's preparation

- Farmyards and animal grazing – animal excretion is a diffuse soil pollution source. It can occur in the form of livestock grazing, along pastures (more frequent in exposed flooded areas near Kamuzu Dam I) and cultivation areas in a rotation scheme or in farmyards where the animals are kept and the residues are concentrated. Given the inexistence of dairy farms or large livestock farmyards, smallholders farm animals represent a low quantitative potential for soil pollution;



Source: NEMUS (2014)

Figure 38 – Livestock grazing in exposed flooded area

- Wastewater – the common use of latrines, along with other sorts of domestic sewage rural structures, are a source of pollutants directed to



the soil (especially in human settlements away from water streams and rivers).

Solid waste does not present itself as a relevant hazard in terms of soil pollution. As assessed in situ, the waste quantities are very limited and there are no waste landfills, open dumps or other high waste concentration areas – only small roadside waste areas at Malingunde.

Finally, burnt bricks stoves and other sorts of biomass combustion (domestic, crop residues, waste) are limited and occur in very strictly located sources, usually near the upland villages.

5.4. Hydrogeology

5.4.1. Type of aquifer and other general aspects

The study area is included in the vast aquifer in altered formations of the crystalline basement rock of the plateau (Figure 39).

Generally, the alteration zone is 15 m to 30 m thick on the plateau and sometimes more. In the study area and surroundings it can reach more than 40 m (see Appendix 1 – Map 5). Normally, the alteration zone is thinner in the vicinity of rock outcrops and thicker in the faulted zones.

The degree of alteration increases from the parent rock upwards to the soil. The texture can change considerably from one point to another and so the permeable horizons can thus be very small in extent.

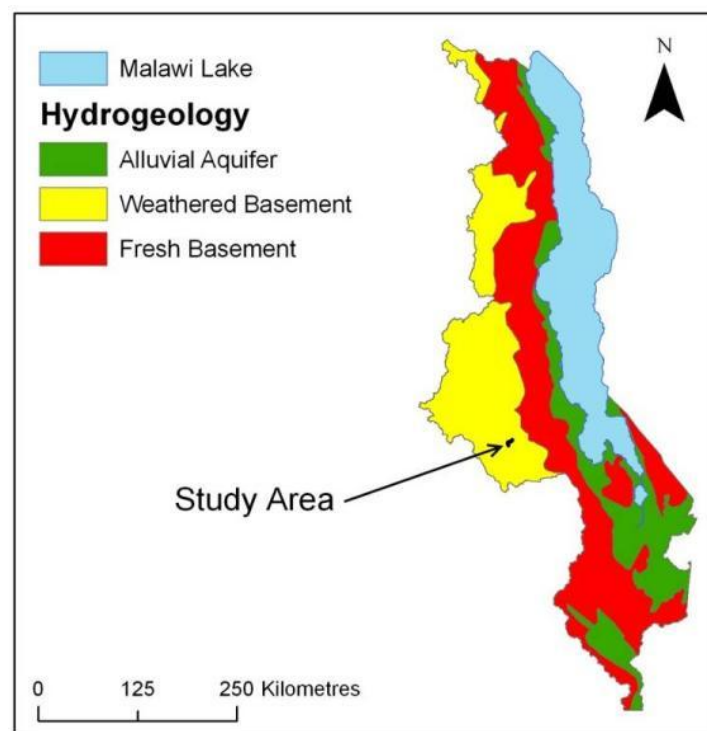
It is possible to distinguish from bottom to top:

- The fractured and unaltered substratum where water is found only in the fractures;
- The dislocated substratum with impermeable blocks, where the water is found in the gaps. The size of blocks declines rapidly in the vertical direction and they acquire a sandy or gravelly texture, with the original structure more or less preserved.



The formation becomes less consolidated from bottom to top. The upper layers consist mainly of sandy clays and argillaceous sands overlain close to the surface by compact clays.

The groundwater is usually under slight pressure beneath the clay strata. The available yields depend on the thickness of the water-bearing stratum. It is usually possible to count on an aquifer 10 m thick for rural boreholes equipped with hand pumps. If the water-bearing stratum is too thin or the water depth too great, the available yields will probably be insufficient. In addition, the alteration formation must not be too argillaceous. Lateritic strata are often found, particularly when the aquifer is close to the surface, for fluctuations in the water level lead to their formation. The lateritic fossil crusts have very poor porosity and permeability and therefore do not facilitate infiltration.



Source: MASDAP

Figure 39 – Major hydrogeological zones in Malawi



5.4.2. Weathered basement: aquifer properties

With only a few exceptions, the fractured and unaltered basement rock is not a very productive aquifer. When these fractures are tapped by pumping in fairly deep boreholes (60 m to 70 m), it is possible to drain the underlying alteration formations.

It was noted that in the Lilongwe zone wells equipped with strainers after 1973 had better yields (1.5 l/s). The low yields are probably due in many cases to insufficient pumping capacity.

In any event, the exploitation of rural wells is limited by the capacity of the hand pump with which they are equipped (0.25 to 0.50 l/s). Similar yields can be expected from all the alteration formations of the crystalline basement, provided that they are sufficiently thick, and it is probable that this result can be obtained without prior geophysical prospecting.

In fact, it is the thickness of the saturated alteration stratum rather than the depth of the borehole which determines a satisfactory yield. For example, at Lilongwe International Airport yields of 1.5 to 5.0 l/s were obtained from alteration formations 20 to 29 m thick, under pressure beneath the compact clays.

Specific capacity data give a better indication of borehole and aquifer performance than records of yield alone as they reflect aquifer permeability and thickness. According to Chilton & Smith-Carington (1984), the specific capacities of the boreholes constructed in the Lilongwe area in the early years of the eighties of the 20th century are relatively high ($0.07 - 0.20 \text{ l.s}^{-1}.\text{m}^{-1}$), especially comparing to those obtained in Dowa West and Livulezi at that time ($0.01 - 0.02 \text{ l.s}^{-1}.\text{m}^{-1}$). Below these values a borehole will not even sustain a village hand pump supply.

The known values of the transmissivity coefficient (T) are in the order of 5 to $30 \text{ m}^2/\text{day}$ for the altered basement rock. It should be noted that the heterogeneity of the material both vertically and laterally results in highly variable flow from different horizons.

The nature of the aquifer, with relict mineralogical or structural banding persisting in the weathered material, will ensure that aquifer properties are



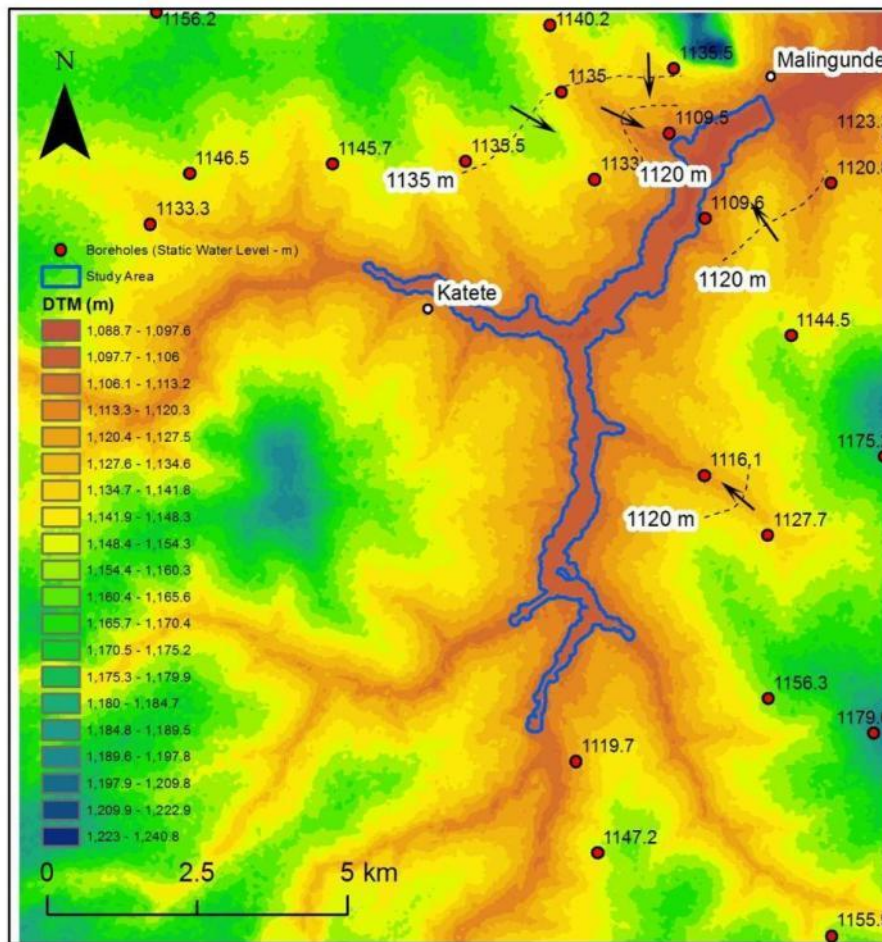
highly anisotropic. Vertical permeability is likely to be much lower than horizontal permeability, and there may also be great variation laterally. Regional values for permeability coefficient (K) are 0.5 to 1.5 m/day (BGS, 1983).

5.4.3. Regional groundwater flow

Regionally, the piezometric levels are close to the ground surface in areas where the rainfall is highest. They tend to form a subdued impression of the surface topography being closest to the ground level near surface water courses and deeper under interfluvies (DWM-MWS, 1986).

Over the plateau areas, rest water levels are generally less than 25 m and commonly less than 15 m below ground level, but they may be deeper towards the rift valley escarpment or in other localised areas. Near the dambo, groundwater levels may rise to ground level during the wet season (DWM-MWS, 1986).

Data from 22 boreholes from the study area and its immediate surroundings was obtained from the Lilongwe Water Board. The whole dataset had static water level for a date which was not given (Figure 40) and a subset of these boreholes (13) had information obtained at the time of construction, including static water level and date of construction (see Appendix 1 – Map 5).



Source: Raw data provided by LWB

Note: arrows indicate direction of groundwater flux; values indicated are in metres and refer to mean sea-level

Figure 40 – Static water level in boreholes and inferred groundwater flow direction

Despite the lack of detailed information, from Figure 40 one may conclude that:

- 1) at this period the static water levels was not deeper than 11 m from the ground surface and had an average depth of 5.5 m;
- 2) the direction of the groundwater movement is likely to be locally very variable, with flow towards each superficial watercourse.

According to the DWM-MWS (1986), the weathered basement aquifer is likely to be in direct hydraulic continuity with the dambo and is probably responsible for most of the baseflow in any surface watercourses. In fact, considering data collected between 1941 and 1997, Meigh *et al.* (2002) reports that the Lilongwe river shows a baseflow index of 0.51 in this area, which means that the proportion of river runoff derived from groundwater is on average 51%.



In such a plain area it is possible that during heavy rain periods the water level in the river increases rapidly above the piezometric level leading to local recharge of the aquifer from the river.

5.4.4. Groundwater level fluctuations

The greater the recharge, the closer the piezometric level gets to the surface. In fact, the surface of the aquifer reproduces the configuration of the ground surface on a smaller scale. On the plateaus the piezometric level of the aquifer at rest is usually less than 25 m below the surface, and in most cases less than 15 m. The aquifer spreads in the dambos in the rainy season. It lies at 30 m or deeper in the leeward areas which receive less rainfall. Near the Malawi Lake it is directly influenced by the level of the lake (BGS, 1983).

Measurements of groundwater levels taken over the seventies of the last century by boreholes maintenance units indicate a range of seasonal fluctuations in water levels of 1 – 5 m. However, these measurements were relatively infrequent (when a hand was removed for repairs) and should only be used as a general guide. Groundwater levels were then monitored with autographic recorders at several sites. On the plateau north of Lilongwe, seasonal fluctuations of 2.0 – 3.5 m have been recorded in 1980 – 1981 and 1981 – 1982, and only 1.0 – 2.0 m in 1983.

Significant changes in water level clearly have important implications for this relatively thin and shallow aquifer, especially when drawdowns during pumping are large. Where the aquifer is only 15 – 20 m thick, a drop in water level of 5 m could result in a loss of aquifer transmissivity and a decline in borehole performance (Chilton & Smith-Carington, 1984).

From the 13 boreholes which had static water levels for two dates, nine of them show higher static water levels at the date of construction, with a highest drop of 6.9 m. Since there is no date for the second monitoring it is unclear if this is related to seasonal variation or to a continuous decrease due to exploitation. Despite this, most of the decrease values fit within the range given above for seasonal fluctuations in water levels.



5.4.5. Groundwater quality

From the limited information available, groundwater compositions in Malawi appear to be spatially variable and highly dependent on aquifer lithology (BGS, 2004).

In Chilton & Smith-Carington (1984) and in the DWM-MWS (1986), the authors refer that the chemical quality of groundwater in the plateau areas is generally good, indicating that the weathered zone is highly leached of solute minerals, and groundwater is likely to be derived from relatively recent recharge. Although this paper is quite outdated in terms of what the present-day quality of the water in the aquifer is, its interest lays on the fact that there seems to be no natural process affecting the quality of groundwater on a regional scale. These authors refer that water can be classified as predominantly calcium-bicarbonate type, although in some cases cation exchange may have occurred and magnesium or sodium may be dominant.

Table 15 summarises the results from quality analyses performed in 43 samples of groundwater from the Lilongwe area. From this summary, it appears that groundwater in selected areas may have high values of electrical conductivity (EC) (40% of the analysed samples) as well as high concentrations of total dissolved solids (TDS) (35%) and calcium (30%). Values of turbidity were also high in 28% of the analysed samples.

High concentrations of fluoride, reaching 4.5 mg/l, have been reported for the area of Natherenje (southeast from Lilongwe City) (Msonda *et al.*, 2007). Nonetheless, concentrations in the Lilongwe area seem to be lower and only two samples showed contents higher than 1.5 mg/l.

Table 15 – Parameters from groundwater in the Lilongwe area from 1997 and 1999 (N = 43) and drinking water quality standards and guidelines from MBS (2005) and WHO (2011)

Parameters	Range (Groundwater)	% of samples with concentrations above guidelines	MBS standard	WHO guidelines
pH	6.3 – 8.8	-	5.0 – 9.5	6.5 – 8.5
EC (µS/cm)	81 - 2010	40	< 700	-
TDS (mg/l)	72 - 1307	35 (> 450)	< 450	< 600
CO ₃ (mg/l)	0 - 67	-	-	-



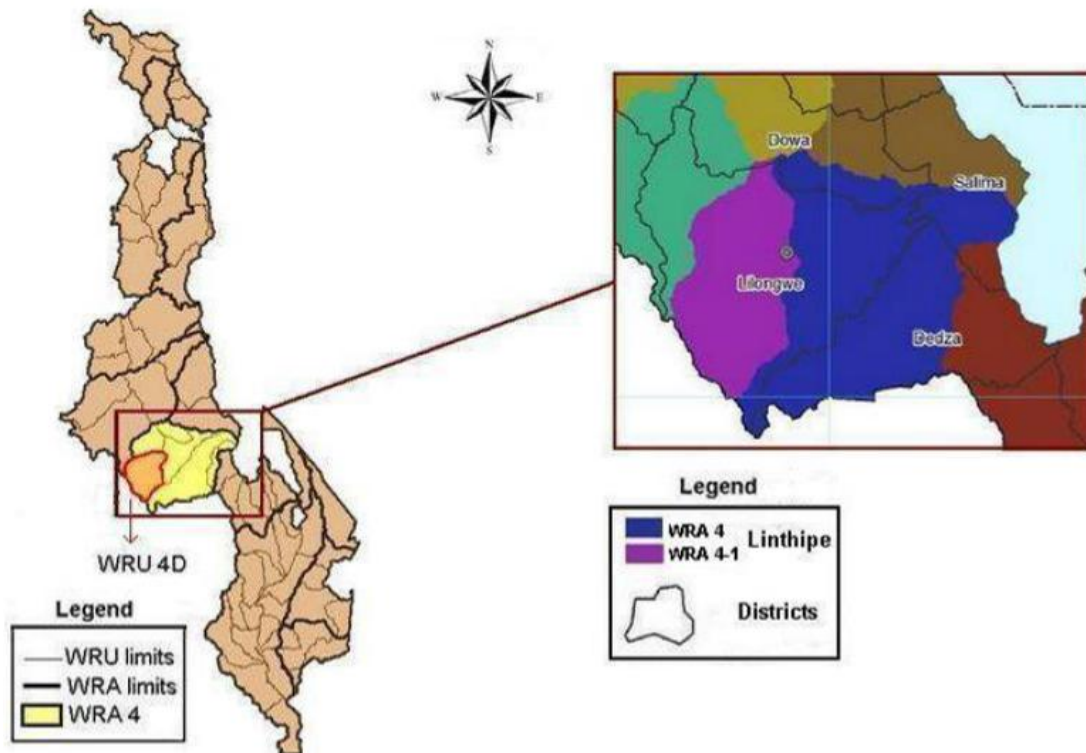
Parameters	Range (Groundwater)	% of samples with concentrations above guidelines	MBS standard	WHO guidelines
HCO ₃ (mg/l)	35 - 586	-	-	-
Cl (mg/l)	4.0 – 58.1	-	< 100	< 200
SO ₄ (mg/l)	1.8 - 870	9 (> 200)	< 200	< 250
NO ₃ (mg/l)	0 – 11.3	-	-	< 50
F (mg/l)	0.10 – 1.58	38 (>0.7); 5 (>1.5)	< 0.7	< 1.50
Na (mg/l)	7 - 210	7 (>100)	< 100	< 200
K (mg/l)	0.7 – 8.1	-	< 25	-
Ca (mg/l)	6.4 – 262.4	30	< 80	-
Mg (mg/l)	4.0 – 62.2	9	< 30	-
Fe (mg/l)	0.01 – 0.35	9	-	< 0.30
Turbidity (NTU)	1 - 65	28	-	< 5

Source: adapted from NIRAS-Norconsult (2000)

Through scrutiny of the information and data in the NIRAS-Norconsult (2000) one concludes that groundwater in general can be classified as suitable for drinking purposes and only in a few rather limited areas data indicates otherwise. It should be noted however that this data was collected between 1997 and 1999 and present-day conditions may have changed considerably. On the other hand, results of organic and bacteriologic analyses were not reported in the WRDPS (2000) and these parameters may well condition the suitability of groundwater for drinking purposes.

5.5. Hydrology

The drainage system of Malawi has been divided into 17 Water Resources Areas (WRA) with each one pertaining to one river basin. The WRA were sub-divided into 78 Water Resources Units (UN-DTCV, 1986a). Kamuzu Dam I is located at Lilongwe River, which belongs to the Water Resource Unit 4D of the Linthipe catchment Water Resource Area 4 (Figure 41).



Source: UN-DCTV (1986a)

Figure 41 – Malawi Water Resource Areas (WRA) and Water Resource Units (WRU)

The Lilongwe River flows from the Mountain Range of Dzalanyama on the Western Malawi-Mozambique border to Linthipe River. Its main tributaries are Lumbadzi and Lingadzi. The Lilongwe River catchment area is the largest subcatchment of the Linthipe River catchment. Linthipe River flows into Lake Malawi.

Lilongwe River is regulated upstream Lilongwe City by two dams: Kamuzu Dam I and Kamuzu Dam II. These dams regulate the flow in Lilongwe River, preventing that flow rates decrease dramatically in dry season thus assuring water supply to Lilongwe City. Water from Kamuzu Dam I supplies Kamuzu Dam II, which is located immediately downstream, and from there is released as needed to Lilongwe River, flowing about 20 km down to the raw water intake weir at the treatment plant in Lilongwe City. Kamuzu Dams also prevent and control flood events downstream, due to their storage capacity.

Kamuzu Dam I was built between 1963 and 1966 and has a storage capacity of 5 million m³. The catchment area upstream of Kamuzu Dam I is shown in Map 6 (Appendix 1). Its total area is 757 km² and the length of the longest watercourse



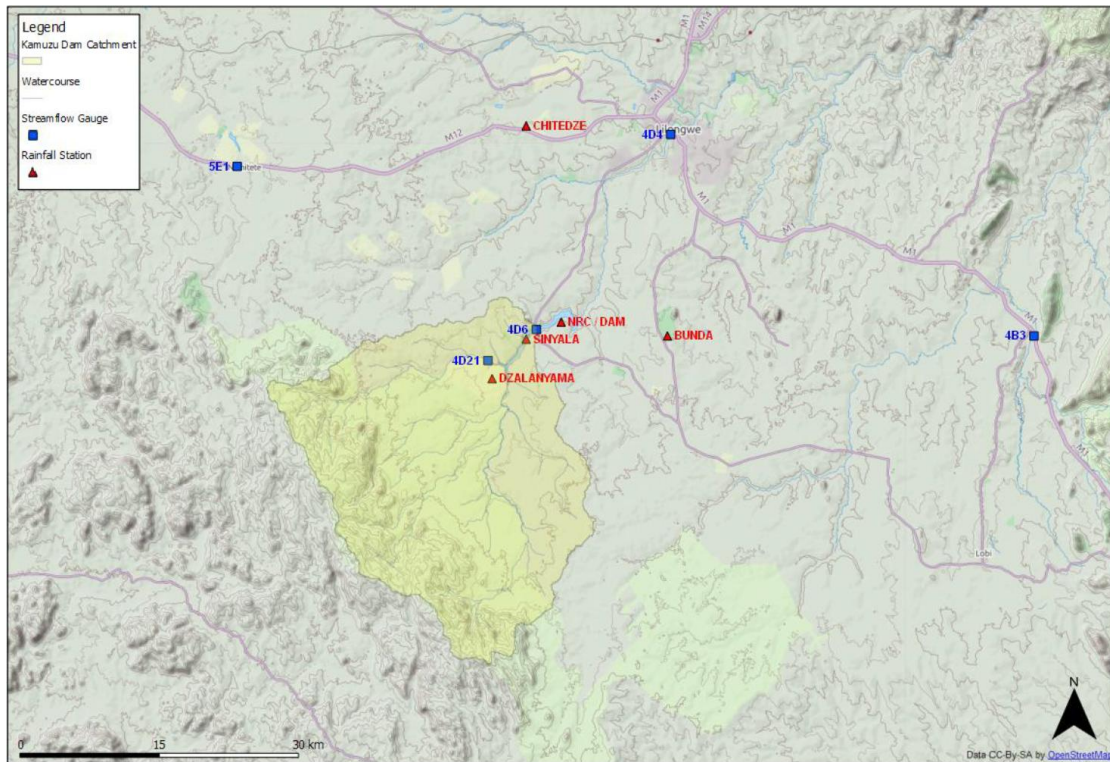
47 km. Upstream Kamuzu Dam I the most important tributary of Lilongwe River is Katete River with a catchment area of 197 km², approximately 26% of Kamuzu Dam I catchment area.

5.5.1. Rainfall data

According to the National Water Resources Master Plan (UN-DTCV, 1986b) the rainy season extends from November to April and Linthipe River (Lilongwe River is a tributary) catchment receives over 95% of its annual rainfall, on average.

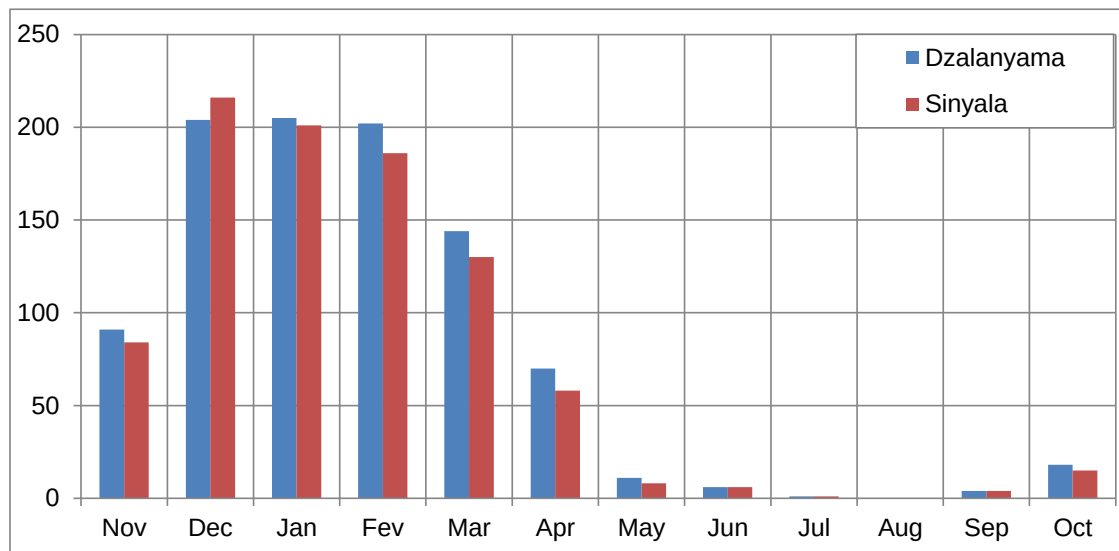
Existing rainfall stations in the study area are shown in Figure 42. At Kamuzu Dam I catchment area, the two most representative rainfall stations are Dzalanyama and Sinyala, which started operating in 1953 and 1952, respectively. The National Water Resources Master Plan (UN-DTCV, 1986b) presents records of the period from 1953 to 1980 for Dzalanyama and from 1952 to 1979 for Sinyala (in both rainfall stations there is one year of missing data).

The monthly rainfall distribution for these periods is shown in Figure 43. The mean annual precipitation is of 964 mm at Dzalanyama and 913 mm at Sinyala. Of the total annual rainfall 95% and 91% occurs between November and April in Dzalanyama and Sinyala, respectively. From June to September the precipitation is 1.1% of the total annual rainfall in both stations.



Source: Aurecon (2013b)

Figure 42 – Map showing rainfall stations and stream flow gauges



Source: UN-DTCV (1986a)

Figure 43 – Monthly mean rainfall distribution (mm) in Dzalanyama and Sinyala stations (1953 to 1980 and 1952 to 1979, respectively)



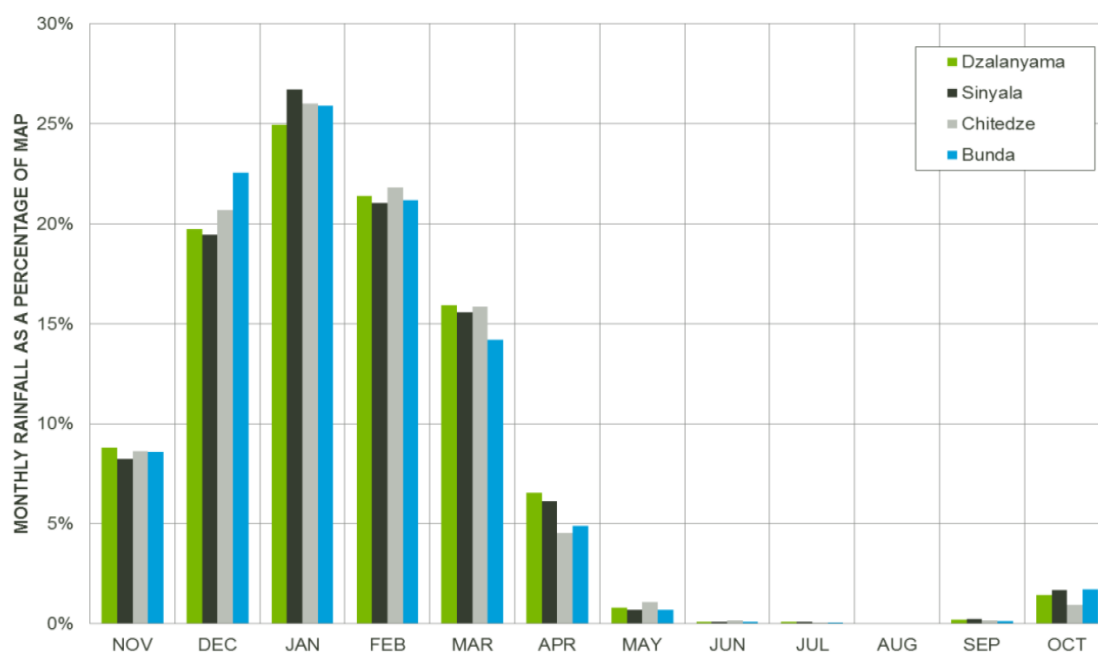
Aurecon (2013b) also presents rainfall data for the study area for a larger and more recent period. The mean annual precipitation (MAP) and data period for the rainfall stations presented in Aurecon (2013b) study are shown in Table 16. As can be seen, the mean annual precipitation in Dzalanyama is almost the same as the one previously reported by UN-DTCV (1986b) (964 mm between 1953 and 1980 and 965 mm between 1970 and 2011). As for Sinyala, the mean annual precipitation for the most recent period 1970-2011 is not significantly different (893 mm) than the MAP registered for the 1952-1979 period (913 mm, UN-DTCV, 1986b).

Table 16 – Rainfall stations mean annual precipitation and data period

Rainfall station	MAP (mm)	Data period
Bunda	861	1967-2012
Chitedze	891	1949-2011
Dzalanyama	965	1970-2011
N.R.C. (Kamuzu Dam)	827	1940-1990
Sinyala	893	1970-2011

Source: Aurecon (2013b)

The seasonal rainfall distribution for recent years is presented in Figure 44 (N.R.C. rainfall station was excluded due to the prevalence of missing data).



Source: Aurecon (2013b)

Figure 44 – Monthly rainfall distribution



From this chart it can be seen that more than 75% of the total annual rainfall occurs in 3 months, from December to February and about 92% in 6 months from November to April. January is the rainiest month with more than 25% (220-240 mm) of the annual rainfall on average. From June to September the precipitation is almost nil.

5.5.2. Flow data

Stream flow gauges for the study area are shown in Figure 42. Two of these are located on the Lilongwe River and one in the Katete River.

Station 4D6 – Lilongwe at Malingunde – was located $\frac{1}{2}$ km downstream of Kamuzu Dam I, with a catchment area of 763 km². The discharge measurements at this station were taken since June 1958. The seasonal regime has been affected by operation of the dam since 1965. The effect is generally an augmented flow during the end of the dry season (UN-DTCV, 1986b). It was closed in 1989 due to inundation as a result of the construction of Kamuzu Dam II.

The other gauge located on the Lilongwe River is Station 4D4 – Lilongwe at Lilongwe Old Town Bridge –, with a record beginning in 1953 and a catchment area of 1,870 km². However this station is located downstream of both Kamuzu Dams I and II and of Lilongwe Water Board abstraction point, which affects the flow measurement at this station. This station record crosschecks extremely well with station 4D6. This last one has a catchment area which is 41% of station 4D4 and the flow is about 50% of station 4D4 (UN-DTCV, 1986b).

The station located at the Katete River, Station 4D21 – Katete river at Kaweche was located immediately upstream of the reservoir of Kamuzu Dam I and was opened in June 1969 designed to monitor the Katete River portion of the inflow to the reservoir. Its catchment area was 197 km². The records of this station suffer from substantial backwater effects from downstream, making the ratings very complicated, and there are substantial breaks in the record. However the seven complete years crosscheck quite well with station 4D6 below Kamuzu Dam I (UN-DTCV, 1986b).



Lilongwe Water Board provided the records of Station 4D4 between the hydrological years of 1952/53 and 2001/02. The monthly mean flow data is presented in Table 17. The years were classified as dry (years falling below 20% of the long-term – 38-year – average runoff recorded at the station), wet (years falling above 80% of the long-term – 38-year – average runoff recorded at the station) and average years. The dry and wet years were shaded pink, and blue, respectively. The years with missing data were grey shaded and not considered in the classification in dry, wet and average years.

Table 17 – 4D4: Lilongwe at Lilongwe Old Town Bridge monthly mean flow

Hydrological Year	Monthly mean flow (m ³ /s)												Mean annual flow (m ³ /s)	Runoff (mm)
	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT		
1952/1953									0.56	0.40	0.25	0.12		
1953/1954	0.08	2.51	2.54	5.41	7.65	1.77	0.70	0.35	0.25	0.18	0.09	0.03	1.80	30
1954/1955	0.72	2.81	3.93	29.56	33.06	7.98	8.35	2.70	1.67	1.03	0.72	0.26	7.73	130
1955/1956	0.07	2.06	3.76	21.15	17.45	23.35	6.79	3.79	1.99	1.14	0.58	0.27	6.87	116
1956/1957	0.83	11.13	21.34	61.82	31.22	21.09	9.01	3.89	2.49	1.67	0.91	0.39	13.82	233
1957/1958	0.17	3.22	10.92	32.50	13.51	7.55	2.34	1.38	1.06	0.85	0.46	0.16	6.18	104
1958/1959	0.15	2.05	3.79	15.70	8.63	3.16	1.17	0.53	0.36	0.26	0.17	0.06	3.00	51
1959/1960	0.01	3.35	5.08	7.44	5.49	1.96	0.57	0.32	0.25	0.15	0.08	0.04	2.06	35
1960/1961	0.34	1.27	6.69	8.51	24.97	11.10	4.09	1.81	1.28	0.65	0.31	0.09	5.09	86
1961/1962	0.96	6.72	25.60	31.62	23.62	16.09	6.16	3.48	2.37	1.64	0.89	0.37	9.96	168
1962/1963	0.59	9.18	20.91	26.10	40.23	16.03	6.12	3.85	3.18	2.07	1.02	0.38	10.80	182
1963/1964	4.54	8.40	15.44	43.51	11.59	4.18	2.56	1.96	1.80	1.32	0.81	0.29	8.03	135
1964/1965	0.45	3.46	21.53	44.56	19.20	8.89	3.60	2.64	2.01	1.38	0.89	0.39	9.08	153
1965/1966	0.26	2.36	3.81	24.19	21.55	6.40	3.72	2.24	1.40	0.87	0.63	0.29	5.64	95
1966/1967	0.39	1.48	3.10	4.56	18.49	10.45	2.81	1.72	1.24	0.79	0.51	0.35	3.82	64
1967/1968	0.79	1.13	6.27	6.39	7.11	2.86	0.92	0.63	0.44	0.25	0.42	0.31	2.30	39
1968/1969	1.74	18.02	50.64	53.28	14.94	26.96	8.16	4.33	2.74	1.76	0.87	0.40	15.32	258
1969/1970	0.59	7.45	12.56	33.24	5.85	2.47	1.10	0.63	0.45	0.27	0.21	0.21	5.42	91
1970/1971	0.82	19.48	37.51	61.13	22.79	9.96	4.41	2.95	2.11	1.08	0.49	0.48	13.60	229
1971/1972	1.06	2.55	11.49	12.08	13.79	9.47	4.59	2.18	1.44	0.81	0.53	0.51	5.04	85
1972/1973	0.59	1.81	3.53	4.60	3.44	6.32	1.46	0.59	0.36	0.30	0.33	0.27	1.97	33
1973/1974	0.37	3.16	20.00	39.45	38.00	32.09	10.77	4.99	4.45	2.25	0.93	0.36	13.07	220
1974/1975	0.52	7.23	9.20	24.73	23.17	8.86	3.61	2.30	1.67	1.46	0.90	0.49	7.01	118
1975/1976	0.79	1.83	8.55	52.43	40.33	31.77	10.23	5.32	3.36	2.26	1.45	1.14	13.29	224



Hydrological Year	Monthly mean flow (m ³ /s)												Mean annual flow (m ³ /s)	Runoff (mm)
	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT		
1976/1977	1.01	4.88	19.82	25.64	41.11	12.96	5.10	3.10	2.43	1.72	0.96	0.69	9.95	168
1977/1978	0.80	2.62	28.32	43.91	128.5	29.79	9.32	6.39	4.48	2.67	1.38	0.80	21.58	364
1978/1979	0.96	16.43	10.64	16.47	27.97	9.24	4.48	2.56	2.09	1.26	0.60	0.54	7.77	131
1979/1980	3.39	11.77	12.87	49.93	23.91	13.30	4.60	3.05	2.06	1.13	0.66	0.74	10.62	179
1980/1981	0.71	11.20	10.38	100.4	62.28	16.63	7.37	4.80	3.38	2.34	1.18	0.87	18.46	311
1981/1982	0.85	2.49	126.2	88.54	60.46	23.06	13.17	6.75	4.01	2.60	1.30	1.16	27.55	465
1982/1983								3.87	2.24	1.31	0.68	0.68		
1983/1984	0.58	5.41	15.77	16.11	15.38	6.45	3.23	1.45	1.14	0.55	0.15	0.18	5.53	93
1984/1985	1.27	12.77	14.85	29.16	23.61	18.36	7.21	4.02	2.84	1.56	0.89	0.48	9.75	164
1985/1986	2.33	19.79	50.44	70.82	34.14	18.98	10.88	7.01	4.52	2.81	1.34	1.88	18.74	316
1986/1987	2.19	6.45	19.11	23.19	19.98	10.26	4.34	2.27	1.73	1.15	0.51	1.00	7.68	130
1987/1988	0.23	2.36	8.04	20.43	21.75	12.30	6.25	2.71	1.48	0.79	0.42	0.19	6.41	108
1988/1989	0.45	1.15	18.72	48.39	50.16	15.10	11.06	6.50	3.66	2.49	2.32	0.68	13.39	226
1989/1990	4.68	13.88	43.94	23.08	10.11	14.20	10.69	4.12	2.82	2.16	0.98	1.28	11.00	185
1990/1991	0.44	1.04	8.77	16.01	12.55	5.31	1.74	0.74	0.41	0.29	0.25	0.45	4.00	67
1991/1992	0.56	2.66	5.70	3.02	1.95	1.82	0.60		0.30	0.27	0.10	0.39		
1992/1993	0.45	2.63	4.89	5.88		6.98	6.01	3.81	1.90	1.60	0.55	0.36		
1993/1994	0.39	0.52	1.82	6.09	4.21	2.99	1.24	0.15	0.12	0.12	0.10	0.10	1.49	25
1994/1995	0.21	0.90	4.16	4.14	1.79	0.46	0.07							
1995/1996			1.63	1.81	1.71	2.99	2.06	1.38	0.27	0.11	0.07			
1996/1997							2.04	1.11	1.01	1.04	0.93	1.13		
1997/1998	1.12	1.80			6.92	6.72	3.09	2.21	1.30	1.24	0.76	0.31		
1998/1999	0.24	0.87	6.94		6.91	6.71	5.59							
1999/2000					7.00									
2000/2001	2.12	2.08	3.30				1.47	0.67	0.28					
2001/2002			4.92	3.56	2.77		2.43	1.51						
No. of years	44	44	45	43	45	44	47	45	46	45	45	44	38	38
Minimum	0.01	0.52	1.63	1.81	1.71	0.46	0.07	0.15	0.12	0.11	0.07	0.03	1.49	25
Maximum	4.7	19.8	126.2	100.4	128.5	32.1	13.2	7.0	4.5	2.8	2.3	1.9	27.5	465
Mean	0.95	5.60	16.21	28.85	22.47	11.49	4.84	2.77	1.81	1.20	0.68	0.49	9.1	153
Mean 1952-53 – 1964/65	0.74	4.68	11.79	27.32	19.72	10.26	4.29	2.22	1.48	0.98	0.55	0.22	7.0	119



Hydrological Year		Monthly mean flow (m ³ /s)												Mean annual flow (m ³ /s)	Runoff (mm)
		NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT		
Dry Years	No.of years	8	8	8	8	8	8	8	8	8	8	8	8	8	8
	Min	0.01	0.52	1.82	4.56	3.44	1.77	0.57	0.15	0.12	0.12	0.08	0.03	1.49	25
	Max	0.8	3.4	8.8	16.0	18.5	10.4	2.8	1.7	1.2	0.8	0.5	0.4	4.0	67
	Mean	0.36	1.74	4.36	8.27	8.45	4.35	1.33	0.63	0.43	0.29	0.24	0.20	2.55	43
Wet Years	No.of years	8	8	8	8	8	8	8	8	8	8	8	8	8	8
	Min	0.45	1.15	10.38	43.91	14.94	9.96	4.41	2.95	2.11	1.08	0.49	0.39	13.39	226
	Max	2.3	19.8	126.2	100.4	128.5	29.8	13.2	7.0	4.5	2.8	2.3	1.9	27.5	465
	Mean	1.07	10.74	42.94	66.04	50.56	20.19	9.17	5.33	3.42	2.18	1.22	0.83	17.81	300
Average Years	No.of years	22	22	22	22	22	22	22	22	22	22	22	22	22	22
	Min	0.07	1.27	3.76	8.51	5.85	2.47	1.10	0.63	0.45	0.27	0.15	0.09	5.04	85
	Max	4.7	16.4	43.9	52.4	41.1	32.1	10.8	5.3	4.4	2.3	1.4	1.3	13.3	224
	Mean	1.17	6.17	14.52	28.53	23.19	12.88	5.45	2.84	2.03	1.29	0.70	0.47	8.27	139

Source: data provided by LWB

In Table 17 the mean flows before the opening of Kamuzu Dam I (1952/53 – 1964/65) and after (1965/66-2001/02) are also shown. As can be seen the difference of the mean flow before the opening of Kamuzu Dam I to the mean of the entire period is a slightly, not significant, less flow and runoff. The months with more flow are from December to May, being February the month with more flow, on average. From June to November the flow is very low, being October the month with lower flow, on average. The runoff varied from 25 mm to 465 mm in this period, being the mean runoff 153 mm.

From the National Water Resources Master Plan (UN-DTCV, 1986b) the records for station 4D6 between the hydrological years of 1957/58 and 1981/82 were available. The monthly mean flow data is presented in Table 18. The years were also classified as dry, wet and average years. The dry and wet years were shaded pink, and blue, respectively. The years with missing data were grey shaded and not considered in the classification in dry, wet and average years.



Table 18 – 4D6: Lilongwe at Malingunde monthly mean flow

Hydrological Year	Monthly mean flow (m ³ /s)												Mean annual flow (m ³ /s)	Runoff (mm)
	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT		
1957/1958									0.51	0.40	0.20	0.07		
1958/1959	0.08							0.37	0.25	0.14	0.07	0.02		
1959/1960	0.01	1.10	1.39	4.36	3.20	1.22	0.51	0.28	0.16	0.08	0.03	0.01	1.03	43
1960/1961	0.04	0.42	2.30	3.55	14.60	8.81	2.69	1.33	0.85	0.40	0.17	0.06	2.94	121
1961/1962	0.30	3.09	9.13	12.90	12.70	11.00	4.53	2.89	1.81	1.05	0.48	0.20	5.01	207
1962/1963	0.24	3.02	10.70	13.70	22.60	9.15	3.99	2.72	1.76	0.96	0.51	0.21	5.80	240
1963/1964	1.53	4.56	8.00	24.00	6.52	2.78	1.57	1.25	0.79	0.51	0.28	0.16	4.33	179
1964/1965	0.23	1.90	8.39	20.50	10.80	5.18	2.55	1.61	1.02	0.65	0.37	0.14	4.45	184
1965/1966	0.13	0.65	1.42	10.70	11.20	4.59	2.35	1.22	0.68	0.35	0.25	0.14	2.81	116
1966/1967	0.24	0.20	1.61	2.75	9.52	6.01	2.18	1.27	0.85	0.48	0.35	0.34	2.15	89
1967/1968	0.33	0.17	3.34	4.00	4.76	2.29	0.71	0.45	0.25	0.14	0.32	0.27	1.42	59
1968/1969	0.27	7.03	28.50	34.30	15.10	18.30	6.72	3.51	2.18	1.27	0.57	0.31	9.84	407
1969/1970	0.74	2.97	6.02	15.30	3.40	1.59	0.65	0.31	0.20	0.16	0.20	0.23	2.65	109
1970/1971	0.30	8.61	17.30	26.80	11.60	2.12	2.91	1.73	1.24	0.45	0.30	0.38	6.15	254
1971/1972	0.65	1.00	4.79	5.92	8.50	5.04	3.26	1.59	0.93	0.40	0.45	0.54	2.76	114
1972/1973	0.76	0.54	1.53	2.35	1.70	3.37	0.91	0.31	0.17	0.14	0.26	0.31	1.03	43
1973/1974	0.31	0.48	8.41	20.00	14.20	19.20	5.35	2.89	2.44	1.02	0.31	0.17	6.23	258
1974/1975	0.54	1.90	4.38	9.18	10.40	4.39	2.04	1.10	0.62	0.54	0.35	0.31	2.98	123
1975/1976	0.31	0.38	3.20	24.80	21.60	17.40	7.17	3.68	2.32	1.19	0.79	0.68	6.96	288
1976/1977	0.62	0.74	8.84	11.70	20.00	7.71	3.43	1.98	1.22	0.79	0.48	0.48	4.83	200
1977/1978	0.51	0.79	12.20	17.80	65.80	16.80	6.49	4.05	2.74	1.53	0.71	0.62	10.84	448
1978/1979	0.69	4.31	3.29	6.57	12.00	5.67	2.97	1.49	1.22	0.68	0.33	0.40	3.30	136
1979/1980	1.59	6.26	6.26	18.90	14.60	10.50	3.94	2.44	1.47	0.82	0.59	0.68	5.67	234
1980/1981	0.62	2.72	7.34	44.80	31.20	10.10	5.24	3.26	2.15	1.19	0.82	0.74	9.18	379
1981/1982	0.55	0.98	27.0	22.8	17.1	9.53	6.84	3.62	2.29	1.38	0.70	0.62	7.78	322
No. of years	24	23	23	23	23	23	23	24	25	25	25	25	23	23
Minimum	0.01	0.17	1.39	2.35	1.70	1.22	0.51	0.28	0.16	0.08	0.03	0.01	1.03	43
Maximum	1.6	8.6	28.5	44.8	65.8	19.2	7.2	4.1	2.7	1.5	0.8	0.7	10.8	448
Mean	0.35	2.35	6.65	13.17	11.74	6.36	2.64	1.49	0.89	0.52	0.26	0.11	3.92	162
Mean 1952-53 – 1964/65	0.48	2.34	8.06	15.55	14.92	7.95	3.43	1.89	1.20	0.67	0.40	0.32	4.79	198



Hydrological Year		Monthly mean flow (m ³ /s)												Mean annual flow (m ³ /s)	Runoff (mm)
		NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT		
Dry Years	No.of years	5	5	5	5	5	5	5	5	5	5	5	5	5	5
	Min	0.01	0.17	1.39	2.35	1.70	1.22	0.51	0.28	0.16	0.08	0.03	0.01	1.03	43
	Max	0.8	3.0	6.0	15.3	9.5	6.0	2.2	1.3	0.9	0.5	0.4	0.3	2.6	109
	Mean	0.42	1.00	2.78	5.75	4.52	2.90	0.99	0.52	0.33	0.20	0.23	0.23	1.66	68
Wet Years	No.of years	5	5	5	5	5	5	5	5	5	5	5	5	5	5
	Min	0.27	0.38	3.20	17.80	15.10	9.53	5.24	3.26	2.15	1.19	0.57	0.31	6.96	288
	Max	0.6	7.0	28.5	44.8	65.8	18.3	7.2	4.1	2.7	1.5	0.8	0.7	10.8	448
	Mean	0.45	2.38	15.65	28.90	30.16	14.43	6.49	3.62	2.34	1.31	0.72	0.59	8.92	369
Average Years	No.of years	13	13	13	13	13	13	13	13	13	13	13	13	13	13
	Min	0.04	0.42	1.42	3.55	6.52	2.12	1.57	1.10	0.62	0.35	0.17	0.06	2.76	114
	Max	1.6	8.6	17.3	26.8	22.6	19.2	5.4	2.9	2.4	1.1	0.6	0.7	6.2	258
	Mean	0.55	2.84	7.17	14.19	13.06	7.40	3.20	1.86	1.23	0.66	0.37	0.30	4.40	182

Source: UN-DTCV (1986b)

In Table 18 the mean flows before the opening of Kamuzu Dam I (1952/53 – 1964/65) and after (1965/66-1981/82) are also shown. As can be seen the difference of the mean flow before the opening of Kamuzu Dam I to the mean of the entire period is a slightly, not significant, less flow and runoff. The months with more flow are from December to May, being February the month with more flow on average. From June to November the flow is very low being October the month with lower flow. The runoff varied from 43 mm to 448 mm in this period, being the mean runoff 160 mm.

As stated before this station crosschecks extremely well with station 4D4. It has a catchment area which is 41 % of station 4D4 and the flow is about 50% of station 4D4 on average.

The records for station 4D21 between the hydrological years of 1968/69 and 1979/80 were available from the National Water Resources Master Plan (UN-DTCV, 1986b). The monthly mean flow data is presented in Table 9. Due to the short period of records available for this station the years weren't classified.



Table 19 – 4D21: Katete River at Kaweche monthly mean flow

Hydrological Year	Monthly mean flow (m ³ /s)												Mean annual flow (m ³ /s)	Runoff (mm)
	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT		
1968/1969									0.40	0.26	0.13	0.05		
1969/1970	0.01	0.67	2.07	5.09	0.96	0.34	0.14	0.09	0.05	0.02	0.13	0.01	0.80	128
1970/1971	0.09	3.39	5.65	6.90	4.08	2.32	0.80	0.54	0.37	0.19	0.12	0.05	2.04	327
1971/1972	0.07	0.32	1.16			1.12	0.60	0.34	0.20	0.15	0.10	0.09		
1972/1973	0.06	0.19	0.67	0.69	0.75	1.25	0.45	0.18	0.13	0.10	0.07	0.05	0.38	61
1973/1974	0.04	0.25	2.26	4.27	4.61	5.49	1.81	1.41	1.09	0.54	0.30	0.26	1.86	298
1974/1975														
1975/1976		0.03	1.18			3.95	1.25		0.47	0.26	0.15	0.09		
1976/1977	0.19	0.33	1.67	2.96	4.49	1.84	0.73	0.43	0.30	0.19	0.09	0.06	1.11	177
1977/1978	0.01	0.01	2.19	3.00		3.40	0.58	0.50	0.41	0.19	0.11	0.04		
1978/1979	0.04	0.90	0.90	2.40	3.98	1.55	0.67	0.44	0.37	0.21	0.08	0.01	0.96	154
1979/1980	0.32	1.78	3.52	4.46	5.59	2.64	1.11	0.75	0.54	0.35	0.17	0.36	1.80	288
No. of years	9	10	10	8	7	10	10	9	11	11	11	11	7	7
Minimum	0.01	0.01	0.67	0.69	0.75	0.34	0.14	0.09	0.05	0.02	0.07	0.01	0.38	61
Maximum	0.3	3.4	5.7	6.9	5.6	5.5	1.8	1.4	1.1	0.5	0.3	0.4	2.0	327
Mean	0.09	0.79	2.13	3.72	3.49	2.39	0.81	0.52	0.39	0.22	0.13	0.10	1.28	205

Source: UN-DTCV (1986b)

As can be seen in Table 19 the months with more flow are from December to May, being February the month with more flow, on average. From June to November the flow is very low, being November and October the months with lower flows. The runoff varied from 61 mm to 327 mm in this period, being the mean runoff 205 mm.

As stated before this station crosschecks extremely well with station 4D6. It has a catchment area which is 26% of station 4D6 and the flow is about 31% of station 4D6 on average.

Comparing the two Lilongwe River stations flow records before the opening of Kamuzu Dam I and the flow records after the opening, we can observe an increase of flow and runoff for both stations after the opening of Kamuzu Dam I.



In station 4D4, after the opening of Kamuzu Dam I, the increase in flow and runoff is on average around 42% (with an increase in mean annual flow of $3.0 \text{ m}^3/\text{s}$ and 50 mm in runoff) being October the month that has the biggest increase, 177% (more $0.39 \text{ m}^3/\text{s}$), and February the month with the smallest increase 8% (more $2.12 \text{ m}^3/\text{s}$). For station 4D6 after the opening of Kamuzu Dam I the increase in flow and runoff is on average about 30% (with an increase in mean annual flow of $1.2 \text{ m}^3/\text{s}$ and 48 mm in runoff) being October the month with the biggest increase, 290% (more $0.32 \text{ m}^3/\text{s}$) and February the month with the smallest increase 24.5% (more $3.22 \text{ m}^3/\text{s}$). December has a slight decrease in flow -0.5% ($-0.01 \text{ m}^3/\text{s}$).

5.5.2.1. Environmental Flow

Alterations to the natural hydrologic regime have led to both direct ecological and indirect geomorphic responses that have degraded the health of riverine ecosystems and depreciated the services they provide (Poff *et al.*, 1997; Bunn & Arthington, 2002).

An environmental flow is the water regime provided within a river, wetland or coastal zone to maintain ecosystems and their benefits (Tharme and King, 1998). It is also referred to as an ecologically acceptable flow regime designed to maintain a river in an agreed or pre-determined state. Therefore, the environmental flow is a compromise between water resources development on one hand, and river maintenance in a healthy or at least reasonable condition on another.

Environmental flows can help to:

- Protect aquatic ecosystems and reduce aquatic weeds and frequency of algal blooms;
- Improve river health;
- Improve conditions for native fish, frogs, water birds and river-dependent plants and animals that rely on different flows to trigger migration and breeding;
- Protect river condition for recreation such as boating and swimming.



More than 200 environmental flow methodologies, that can be grouped into six categories, namely hydrological, hydraulic rating, habitat simulation (or rating), and holistic methodologies, with two more categories representing combination-type and other approaches have been developed (Tharme, 2003). But to determine ecological flow requirements for specific river basins and reaches remains a daunting challenge (Arthington, 2006). Some methods have been developed for particular river ecosystem objectives and have their specific applying conditions. Some methods are subjected to related hydrological and/or ecological data availability. Some methods tend to be time-consuming and expensive by employing scientific expertise from a variety of disciplines and sophisticated computational models and tools. So they are most appropriate for in-depth, site specific analysis of environmental flow needs (Tharme 2003).

Reconnaissance-level initiatives relying on hydrological methodologies are the largest group, applied in all world regions. At more comprehensive scales of assessment, the instream flow incremental methodology (IFIM) or other similarly structured approaches are used, these methodologies are the second most widely applied worldwide, with emphasis on complex, hydrodynamic habitat modelling (Tharme, 2003).

According to an information from the Ministry of Agriculture, Irrigation and Water Development, the policy on ascertaining the environmental flow is the hydrological index using the flow duration curve, such that all designs are to allow a 90% percentile compensation flow, i.e. Q_{90} , which is interpreted as “the flow which is available 90 percent of the time” should be released as environmental flow.

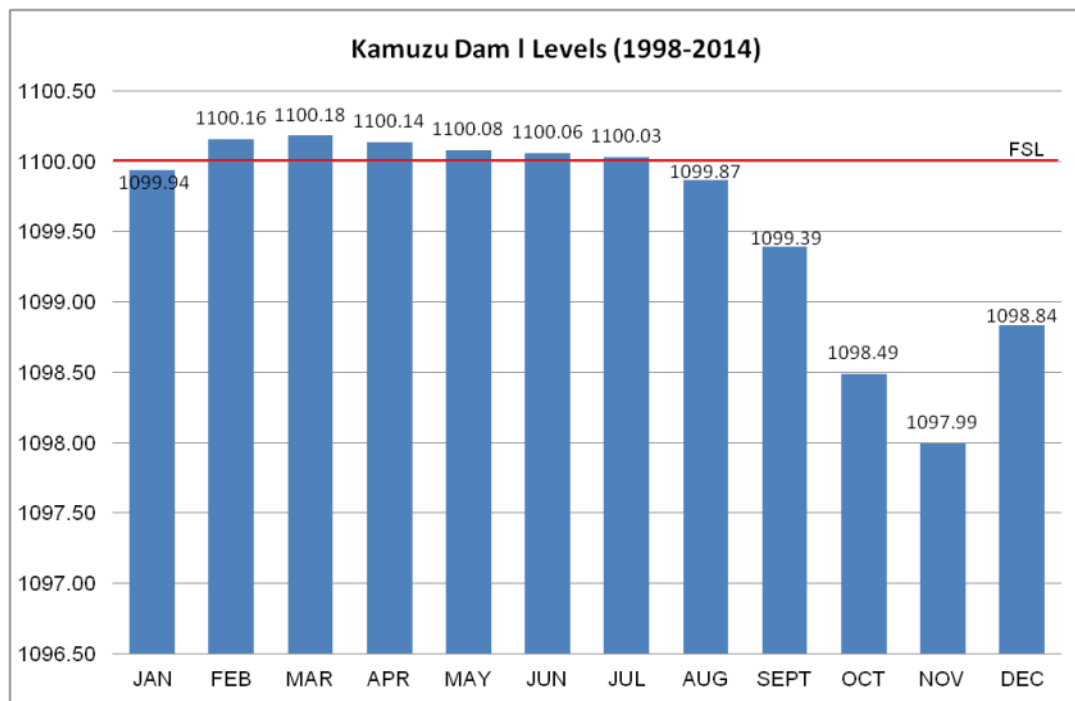
Aurecon (2013b) refers that SMEC (2013) quotes the National Water Policy (2005) which indicates that an amount equivalent to 8% of available water resources within a catchment should be left for environmental flows. Aurecon (2013b) also states that the environmental water requirements releases are effectively available downstream of the abstraction point on the Lilongwe River.



5.5.3. Water levels at Kamuzu Dam I

Currently, Kamuzu Dams regulate the water level at the existent weir located immediately downstream the raw water intakes of the treatment plants situated in Lilongwe City, 20 km downstream Kamuzu Dam II.

Data provided by LWB allows knowing the water levels in Kamuzu Dams over each year between 1998 and November 2014. The analysis of the water levels at Kamuzu Dam I for the last 16 years illustrates the availability of water in the upstream part of Lilongwe River watershed and the dam's annual regime.



Source: data provided by LWB

Figure 45 – Kamuzu Dam I mean levels for 1998-2014 (November) period

As can be observed in above figure, during six months per year, statistically between February and July, water levels are above FSL (1,100 masl), usually peaking in March (1,100.18 masl). In those months water from Kamuzu Dam I is being freely discharged through the dam's spillway towards Kamuzu Dam II reservoir.



From August to January water levels are normally below FSL, with minimum values typically occurrent in November (mean water level of 1,097.99 masl). As presented in previous sections, in Kamuzu Dam I catchment the precipitation is almost nil from June to September and the flow is very low from June to November, so it is understandable that the water levels drop below FSL during this period and only go above a while later.

Usually in August or September and until December, operation control valves in both Kamuzu Dams are opened as needed in order to assure a minimum flow in Lilongwe River and an adequate water level at Lilongwe City water treatment plants intake.

The mean annual water level for the data period was 1,099.60 masl, with an average of 195 days per year above 1,100 masl.

5.5.4. Floods

A study from the European Commission reports that from 1985 to 2010 Lilongwe District has been severely affected by floods (5 to 10 floods between those years).

To evaluate extreme flood events it is necessary to determine the peak flows for a specific return period. The peak flow for a specific return period is the peak flow during a flood event, where the flow is equalled or exceeded on average every given period in years. Higher return periods are associated with higher peak flows.

In the Design Flood and Yield Analysis Report (Aurecon, 2013b) peak flows for Kamuzu Dam I were calculated for different return periods using different methods. Since historical daily flow data across the study area was available, probabilistic flood analysis was used. In addition, rainfall based deterministic methods (Rational Method and the Soil Conservation Service – SCS – method) were computed. To crosscheck the order of magnitude of the floods Regional Maximum Flood (RMF) empirical method was also used.



For the probabilistic flood analysis in Aurecon (2013b) flow data from five (5) stream flow gauging stations within or close to the study area were used. These data provided series of annual maxima ranging from 22 to 49 years of data depending on the station. Aurecon (2013b) study used two approaches in order to determine the peak flows:

- A single-site probabilistic flood analyses considering data from station 4D6 (Lilongwe at Malingunde), located immediately downstream Kamuzu Dam I;
- A regional probabilistic flood analyses considering data of the 5 stream flow gauging stations within or close to the study area (4D4, 4D6, 4D21, 4B3 and 5E1).

Four different probability distributions were considered for the probabilistic analysis: Log-Normal (LN), Log-Pearson Type III (LPIII), General Extreme Value using methods of moments (GEV_{VMM}) and General Extreme Value using probability weighted moments (GEV_{PWM}).

The LN distribution was chosen to calculate high recurrence interval flood peaks as a conservative measure given the relatively short record period. Since the daily flow data are not instantaneous and are based on an average single point reading for the day, Aurecon (2013b) study repeated the probabilistic flood analysis increasing each annual maxima by 20% to account for the difference between average daily values and instantaneous daily values.

The predicted design inflow flood peaks for each approach for different return periods (100, 200, 10,000) were calculated and are presented in Table 20.

Table 20 – Probabilistic analysis design flood peaks

Recurrence intervals	Peak flood (m ³ /s) – Approach 1		Peak flood (m ³ /s) – Approach 2	
	LN	LN-peaks scaled 20%	LN	LN-peaks scaled 20%
100	707	825	625	750
200	921	1,072	808	970
10,000	3,087	3,562	2,622	3,146

Source: Aurecon (2013b)



Although the use of rational method is only recommended for small basins (less than 20 km²) due to the shortage of good quality data Aurecon (2013b) study applied the Rational Method as an alternative to determine the peak floods. Also applied were the Soil Conservation Service Method and as a crosscheck of the order of magnitude of extreme flood peaks the empirical Francou-Rodier (1967) flood estimation technique was also used. The estimated design inflow flood peaks for each approach for different return periods (100, 200, 10,000, Probable Maximum Flood – PMF – and Regional Maximum Flood – RMF) are presented in Table 21.

Table 21 – Design inflow flood peaks for Rational method, SCS method and RMF

Recurrence intervals	Rational method	SCS method	RMF
100	868	654	-
200	951	786	-
10,000	1,485	1,745	-
PMF	3,440	5,216	-
RMF	-	-	2,751

Source: Aurecon (2013b)

Based on the interpretation of the results from the various methods Aurecon (2013b) report recommends a 1 in 200 year (Recommended Design Flood – RDF) inflow flood peak of 900 m³/s and a Probable Maximum Flood (PMF) inflow flood peak of 3,500 m³/s.

5.5.5. Droughts

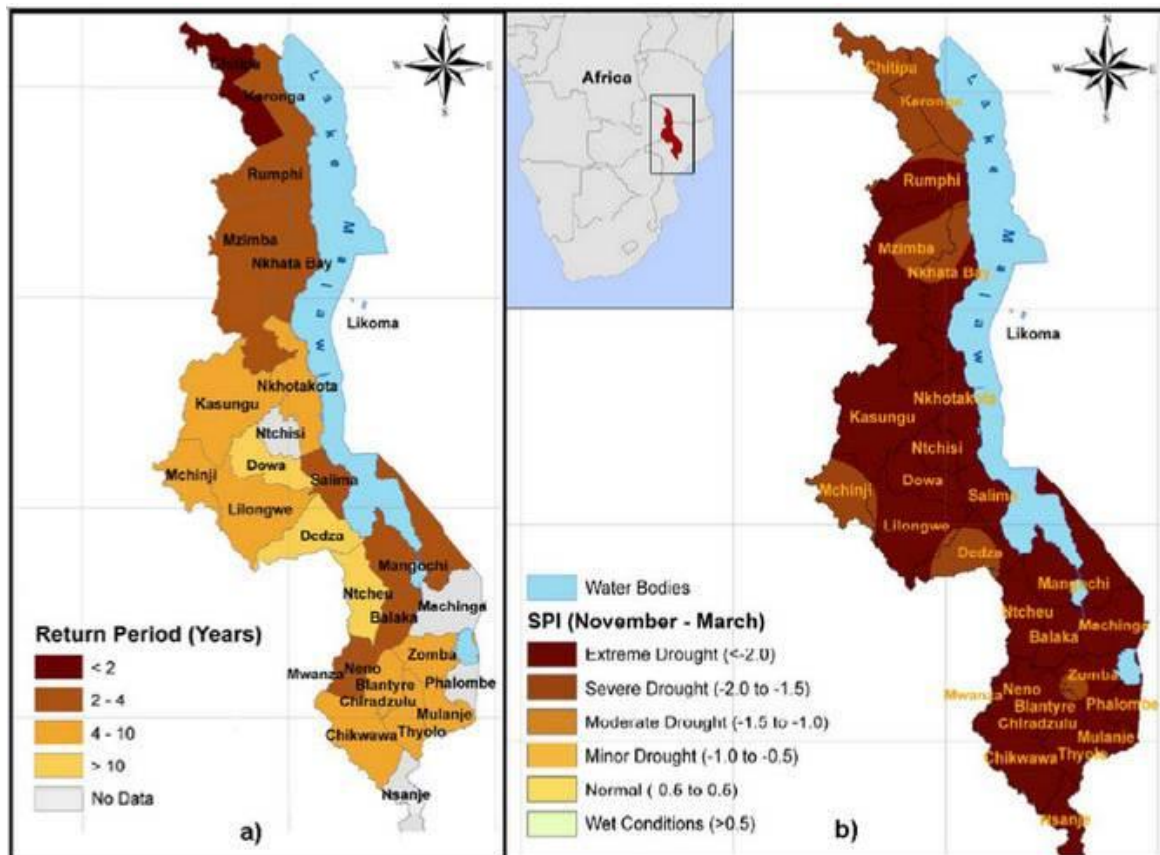
A study from the World Bank (2009) shows the frequency of drought occurrence in each region, over the last 40 years (Figure 46,a) and a typical 50-year drought hazard map (Figure 46,b). That study adopts the following drought definition:“(…)a meteorological drought is defined by seasonal cumulative rainfall (November-March) falling below 75% of the long-term (40-year) average recorded at each weather station”. Several researches have also shown that the norm of “75% of normal” is often associated with dry events and droughts.

The standardized precipitation index (SPI) was selected as the hazard index in that study. SPI corresponding to 75% of the long-term average seasonal rainfall



at each weather station is taken as the “drought threshold value”. Any year for which the SPI fell below this threshold is considered as a drought year.

Based on Figure 46 drought occurs in Lilongwe District once every 4-10 years and the 50-year return drought represents an extreme drought.



Source: World Bank (2009)

Figure 46 – a) Drought return period map generated from 40 years of historical data (1968-2007); b) 50-year return period drought map using SPI

According to Atkins (2011), based on the water demand and surface water availability assumptions, there is a water deficit in the study area (WRA 4.1) in average dry season which contrasts with most part of the country where there is surplus of water. This deficit will tend to increase in this WRA in the future, due to population and economic growth, if no measures are taken.

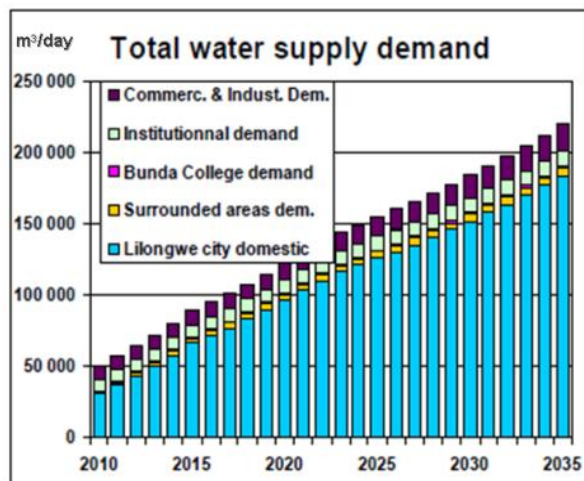


5.5.6. Water demand

The water stored in Kamuzu Dams I and II is released into Lilongwe River according to needs, and flows in its natural course up to the raw water intake point at the treatment plant of the water supply system of Lilongwe Water Board.

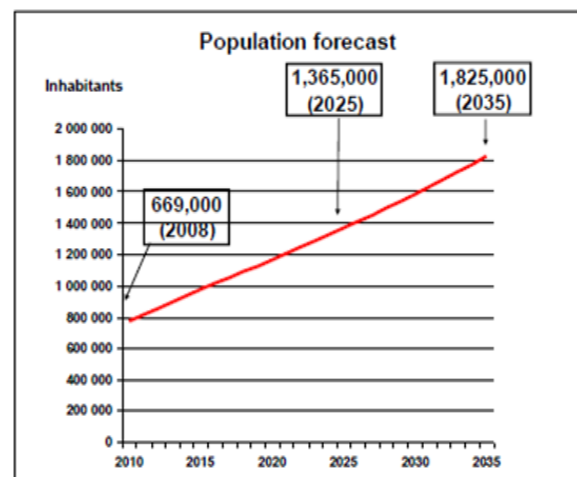
According to Aurecon (2013a), based on Sogreah (2010) the combined treated water supply demand in 2013 for the two treatment works for Lilongwe Water Board was 71,000 m³/day, being the total water demand 75,000 m³/day, resulting in a deficit of 4,000 m³/day. The total water supply demand constitutes: commercial and industrial demand; institutional demand; Bunda College demand; Lilongwe City demand and surrounding areas demand.

The increase in demand is the consequence of the increase in population and in water supply coverage. This can be observed in Figure 47 and Figure 48, where a significant increase in water supply demand mainly in Lilongwe City, following the forecasted increase in population can be seen. The other four total water supply demand components have an insignificant increase when compared to the water supply demand in Lilongwe City.



Source: Aurecon (2013a)

Figure 47 – Total water supply demand (2010-2035)



Source: Aurecon (2013a)

Figure 48 – Population forecast (2010-2035)



According to Lilongwe Water Board, the water demand in 2014 was estimated in 75,000 m³/day and the water supply was 62,700 m³/day, resulting in a 12,300 m³/day deficit. Furthermore, the population of Lilongwe City, approximately 805,345 inhabitants in 2014, is expected to increase to 1,914,280 inhabitants in 2035, based on Sogreah Studies for LWB. The forecasted population, water demand and water supply are presented in Table 22.

The values of projected population and water demand in this table are slightly higher than the previous ones, but it should be noticed that they were provided by the Lilongwe Water Board based on a more recent study.

Table 22 – Forecasted Population, water demand, water supply and water deficit for Lilongwe City

Year	Projected Population	Water Demand (m ³ /day)	Water Supply (m ³ /day)	Water Deficit (m ³ /day)
2014	805,345	75,000	62,700	12,300
2015	1,040,182	123,211	82,500	40,711
2020	1,233,668	163,384	102,300	61,084
2025	1,449,155	200,951	102,300	98,651
2030	1,664,642	239,960	102,300	137,660
2035	1,914,280	286,206	102,300	183,906

Source: Final Draft National Water Resources Master Plan to 2035 – Based on Sogreah Studies for LWB (data provided by LWB)

5.5.7. Sediment dynamics

5.5.7.1. Introduction

Watercourses carry sediments from soil and rocks of their beds and banks. The sediment load of a river is usually analyzed by two components, suspended load (suspended sediments) and bed load (solids transported through sliding, rolling or saltation). Figure 49 shows a schematic representation of the sediment transport process in a watercourse.



While erosion of riverbanks due to deforestation and land use activities can increase sediments runoff into watercourses, raising sediment loads in rivers, the construction of dams or weirs has an opposite impact because sediment flow is interrupted by a physical barrier, causing sediment retention upstream the structures.

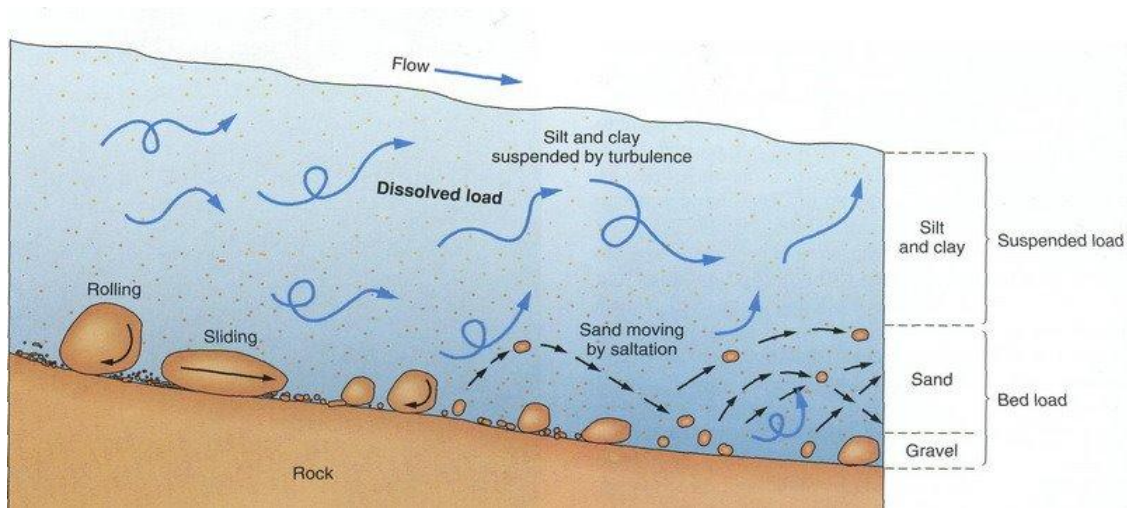


Figure 49 – Schematic representation of the sediment transport process in a watercourse

5.5.7.2. General view of river siltation issues in Malawi

Most of the rivers in Malawi flow into the Lake Malawi, the largest lake in the country located along the eastern border and shared with Mozambique. Sediments from the upper watersheds are increasingly entering the lake through the several rivers and tributaries. As a result, the mouth of these rivers is becoming blocked and preventing the flow of water in and out of the lake (Julien and Shah, 2005).

As previously mentioned, Lilongwe River flows into Linthipe River, which then flows into Lake Malawi. Figure 50 below shows the flow of sediments from Linthipe River entering into Lake Malawi.



A study from the National Commission for Science and Technology of Malawi (Malawi SDPN⁸) refers that case studies show that catchment areas with high deforestation-rates have higher rates of discharge, which in turn lead to increased levels of turbidity and suspended solids.



Figure 50 – Aerial view of sediments flow from Linthipe River entering Lake Malawi

According to a draft report done to UNESCO (Julien and Shah, 2005), Linthipe, Songwe and Dwangwa Rivers have heavy sediment problems due to the impacts of the upper watershed. The significant increase of agricultural activities and deforestation in the watersheds are inducing the siltation of the rivers and the lakes in Malawi.

High sediment loads were also observed in Lilongwe River, especially in the beginning of the rainy season.

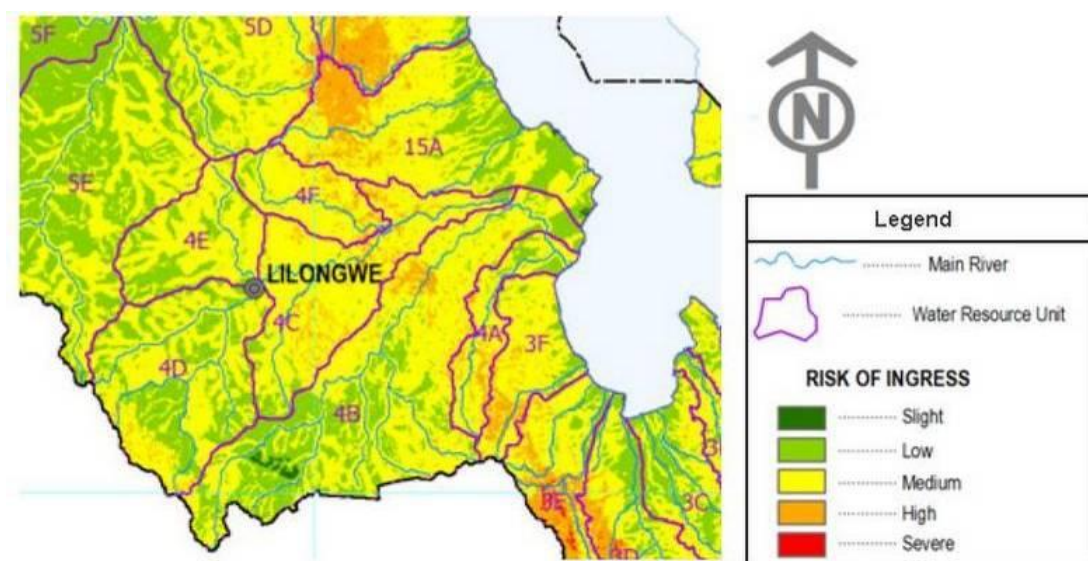
⁸ Malawi SDNP is a Malawi Government Programme executed by the National Commission for Science and Technology established under the Science and Technology Act of 2003. The main objective of Malawi SDNP is to assist with development of Internet and Information Services with emphasis on sustainable development.



As runoff from eroded soils into watercourses occurs when it rains, it is expected that during the rainy season Lilongwe River and tributaries will carry significant loads of sediments to Kamuzu Dam I reservoir. As mentioned above, this situation is exacerbated at the beginning of the first rains, after a dry period, in which the solid flow transported by the river is supposed to be much higher than that transported due to the subsequent rains because vegetation cover is poorer. This is usually referred to as "first flush floods".

Atkins (2011) determined the risk of ingress of eroded soil to watercourses. This risk was assessed using a matrix that combined a series of factors that might contribute to the risk categorisation (i.e. slight, low, medium, high and severe) of ingress of sediments to watercourses for each WRU and WRA.

Overall, for the study area (WRU 4D), the results suggest there is a low/medium risk of ingress of eroded soil to watercourses, as shown in the Figure below.



Source: Atkins (2011)

Figure 51 – Risk of ingress of eroded soil to watercourses



5.5.7.3. Sediment load in Lilongwe River and Kamuzu Dam I

Snowy Mountains Engineering Corporation (SMEC) conducted a hydrographical survey of Kamuzu I Dam in 1993, as part of the studies for the Third Lilongwe Water Supply Project. They deduced a sediment concentration in the Lilongwe River flow of 185 ppm (HYDROPLAN, 2010).

However, according to SAFEGE (2002) (*in* HYDROPLAN, 2010), there are no exact records of the SMEC survey of 1993, and its accuracy could not be verified.

In studies conducted in Likuni and Diamphwe, a catchment that has similar characteristics in topography and land use to the Lilongwe River catchment, the sediment concentration obtained was 500 ppm and the authors stated it is reasonable to assume similar levels of sediment concentration in the Lilongwe river flows (HYDROPLAN, 2010). According with the same source, this value was determined in 2002 and therefore HYDROPLAN (2010) state that it would be reasonable to consider an increase of 10% due to an increase in agricultural activities in the last years, so a value of 550 ppm was an ideal sediment concentration in the river flow at that time.

Another study from the Water Development Department for the year 1960 refers the total annual suspended sediment load for Lilongwe River, in the station located in Lilongwe town (4/D/4) expressed as the "silt factor" which is the ratio of the total annual suspended sediment load to the total annual water flow. For Lilongwe River, the "silt factor" obtained over seven years before 1960 was 0.15 tons per acre foot or 0.121 kg/m^3 .

According to Aurecon (2013b), Kamuzu Dam I has a full supply level of 1,100 masl which equates to a volume of 5.1 million m^3 . The dead storage level based on a 50 year sedimentation load and consideration of the minimum outlet levels is 0.6 million m^3 , giving a live storage of 4.5 million m^3 .

Aurecon (2013a) states that previous studies have confirmed the presence of silt in the reservoir. The level of silt which has settled against the dam wall is 1,087.7 masl.



5.5.7.4. Sediments trapped in Kamuzu Dam I

Reservoir sedimentation is the process of sediment deposition into a lake formed after a dam construction.

Available information is very scarce, but the best estimates known indicate that sediment accumulation ratio between 1966 and 2001 could have been around 17 thousand of cubic meters per year, resulting in a loss of capacity of about 0.6 millions of cubic meters.

A model to study the evolution of sedimentation in Kamuzu Dam I reservoir in the last years was developed and is presented in Appendix 2. Model results show a considerable agreement with the available estimates.

In particular, the accumulated sedimentation between 1986 and 2001 was estimated by the model to be 0.22 millions of cubic meters, a value that results in an accumulation ratio of nearly 12 thousand of cubic meters per year – lower than the average 17 cubic meters per year estimated between 1966 and 2001 but it is known that the sedimentation rate will decrease with time as the C/I ratio decreases.

The yearly sedimentation rates range from 11.5 and 16 thousand of cubic meters per year, also in agreement with the known mean value of 17 thousand of cubic meters per year.

5.6. Surface Water Quality

5.6.1. Methodology

This subchapter includes the following steps:

- Water uses influencing and being influenced by the existing surface water quality on Kamuzu Dam I;
- Description of the major surface water pollution sources for Kamuzu Dam I;
- Surface water quality baseline assessment based on primary and secondary available data.



The assessment of the major pollution sources and relevant water uses was based on fieldwork and local interviews carried out in November 2014 for the present assignment.

Water quality assessment was based on regular monitoring data for KD1, provided by Lilongwe Water Board (LWB), covering 2004 to 2012 period. Location and sampled parameters for available LWB sampling sites with relevance for the assessment are presented in the Table 23.

One isolated sampling was performed in both dams for typical algae/cyanobacteria concentration and heavy metals and fertilizers (2009).

Katete River sampling site is representative of present water quality in upstream area of KD1 reservoir, which likely will be the most influenced by project induced changes, namely the increase of the flooded area.

In less degree, Kamuzu Dam I sampling site is representative of the conditions in the downstream area, near the dam's overflow to Kamuzu Dam II, which will be changed.

While no changes are expected in Kamuzu Dam II sampling site due to the project, data was included for comparison purposes to Kamuzu Dam I/ Katete River sites.

The water quality sampling locations from LWB are presented in Figure 52.

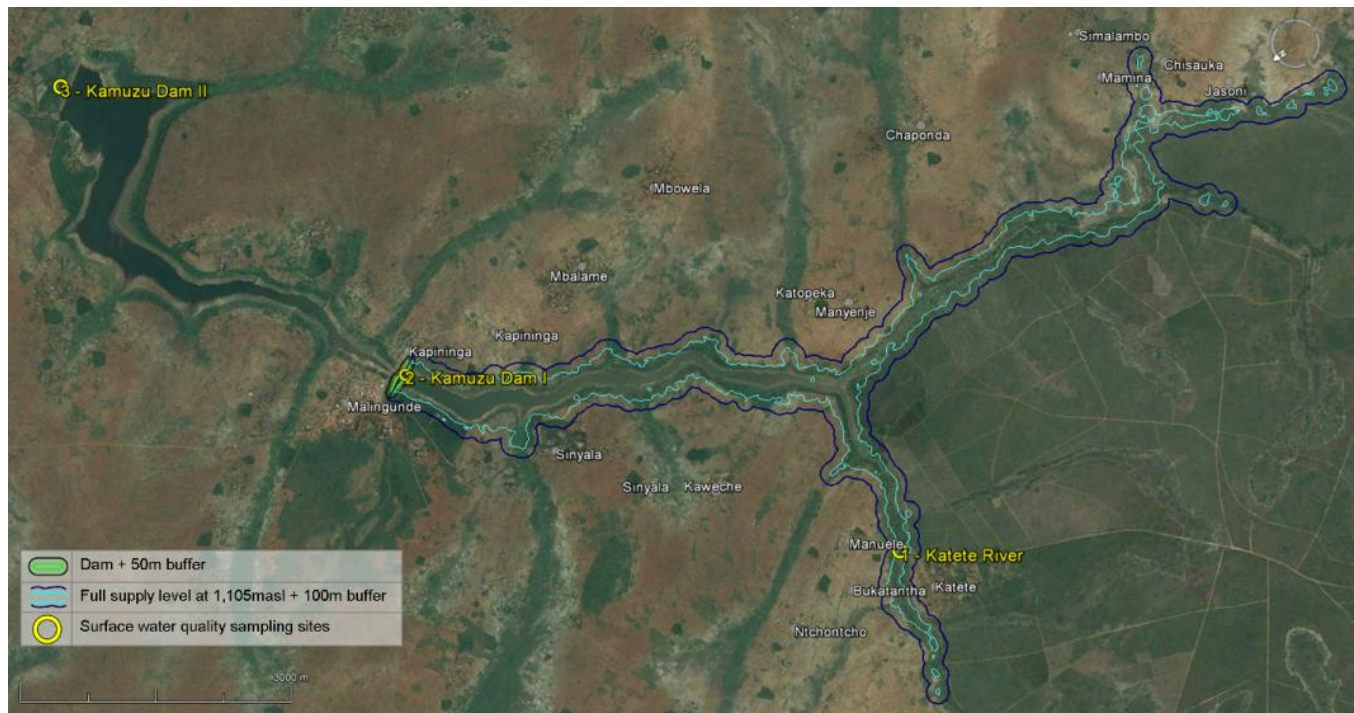
Table 23 – Location, sampled parameters and sampling dates of LWB surface water quality monitoring sites

Site	Description	Lat(°S)	Long(°E)	Parameters	Sampling dates
1	Katete River (at the bridge to Dzalanyama Forest)	14.203	33.596	Physical: pH Suspended Solids (mg/l) Turbidity (NTU) Chemical: Electrical conductivity (µS/cm) Total Dissolved Solids (mg/l) Hardness (mg/l), Alkalinity (mg/l) Na (mg/l), K (mg/l), Ca (mg/l) Mg (mg/l), Mn (mg/l), Fe (mg/l)	12-02-04 08-05-04 11-06-05 11-11-08 03-01-09 07-10-09
2	Kamuzu Dam I (raw water)	14.175	33.642		



Site	Description	Lat(°S)	Long(°E)	Parameters	Sampling dates
3	Kamuzu Dam II (raw water)	14.165	33.687	SO ₄ (mg/l), NO ₃ (mg/l), F (mg/l) Cl (mg/l), HCO ₃ (mg/l) Biological: Faecal coliforms (counts/100 ml)	05-03-10 14-02-12 10-11-12

Source: data provided by LWB



Source: aerial image Google Earth (December, 2013)

Figure 52 – LWB sampling sites used for water quality assessment

The Malawian Bureau of Standards (MBS) Drinking Water specification (MS 214:2005), the World Health Organization Guidelines for Drinking-water Quality (WHO, 2011) and WHO Guidelines for Safe Recreational Water Environments (WHO, 2003), presented in Table 24, were considered in water quality analysis. These standard/guidelines are considered for water suitability assessment for drinking and bathing uses. The FAO guideline for irrigation water quality (FAO, 1985) was also considered.



Table 24 – Water quality standards and guidelines

Parameter	Drinking water		Bathing water	Irrigation water
	MBS standard (2005)	WHO guideline (2011)	WHO guideline (2003)	FAO guideline (1985)
pH*	6.5-8.5	6.5-8.5	-	6.5-8.4
Suspended Solids (mg/l)	<400	-	-	-
Turbidity (NTU)*	<5	<5	-	-
Electrical conductivity (μS/cm)	<1400	-	-	<700 (no restriction on use) 700-3,000 (slight to moderate restriction on use) >3,000 (severe restriction on use)
Total Dissolved Solids (mg/l)*	<1000	<1000	-	<450 (no restriction on use) 450-2,000 (slight to moderate restriction on use) >2,000 (severe restriction on use)
Hardness (mg/l)*	<500	<500	-	-
Alkalinity (mg/l)	-	-	-	-
Na (mg/l)*	<200	<200	-	-
K (mg/l)	-	-	-	-
Ca (mg/l)*	<200	100-300 (taste threshold)	-	-
Mg (mg/l)*	<150	-	-	-
Mn (mg/l)*	<2.0	<0.4	-	-
Fe (mg/l)*	<1.0	<0.3	-	-
SO ₄ (mg/l)*	<400	<250	-	-
NO ₃ (mg/l)	<100	<50	-	-



Parameter	Drinking water		Bathing water	Irrigation water
	MBS standard (2005)	WHO guideline (2011)	WHO guideline (2003)	FAO guideline (1985)
F (mg/l)	<2.0	<1.5	-	-
Cl (mg/l)	<600	<200	-	-
HCO ₃ (mg/l)	-	-	-	-
Dissolved Oxygen (mg/l)	-	-	-	-
BOD ₅ (mg/l)	<20	-	-	-
COD (mg/l)	-	-	-	-
PO ₄ - (mg/l)	-	-	-	-
Pb (mg/l)	<0.01	<0.01	-	-
Cd (mg/l)	<0.003	<0.003	-	-
Faecal coliforms (counts/100 ml)	-	0	-	-
Cyanobacteria (cells/ml)	-	-	<20,000 (relatively low probability of adverse health effects)	-

Note: * constituent /characteristic of acceptability significance.

5.6.2. Water uses

The main human water uses in KD1 are:

- Raw water supply to Kamuzu Dam II;
- Domestic use (washing, personal hygiene, both on site and at home);
- Bathing;
- Fishing (limited to a few months per year);
- Collection for irrigating (in very small scale during the dry season, transported in small reservoirs to nearby cultivated plots);
- Livestock consumption (in small scale, around the reservoir).



Source: NEMUS (2014)



Source: NEMUS (2014)

Figure 53 – Water collection from Kamuzu Dam I (1)

Figure 54 – Water collection from Kamuzu Dam I (2)



Source: NEMUS (2014)

Figure 55 – Washing clothes and bathing at Kamuzu Dam I



Source: NEMUS (2014)



Source: NEMUS (2014)

Figure 56 – Fishing at Kamuzu Dam I (1)

Figure 57 – Fishing at Kamuzu Dam I (2)



Drinking water for human consumption abstracted from the dam occurs for infrastructures near the KD1, under license – Water Falls Lodge, LWB/ Land Conservation Department offices, Youth Camp and KIX nursery school.

Upstream that area, although no evidence of direct human consumption for drinking was found, it can occur sporadically according to village leaders and contacted population, either for isolated households near the river (using untreated water or just boiling it), either in cases of groundwater problems (failure in pumps or other groundwater abstraction infrastructures).

Water uses for Kamuzu Dam II reservoir are the same as described above, with the difference of having a significant role as raw water supplier for Lilongwe City, through Lilongwe River.

Having into account the surface water uses, water quality should be at least suitable for drinking, bathing/ recreational use and irrigation.

5.6.3. Pollution sources

Kamuzu Dam I reservoir's major pollution sources and its likely water quality impacts are presented in Table 25.

Table 25 – Kamuzu Dam I reservoir major pollution sources and associated water quality impacts

Pollution source	Type of pollution	Water quality impact	Major locations
Washing and bathing (on reservoir)	Diffuse	BOD Faecal coliform Turbidity Phosphates	Nearest settlements around the reservoir
Farming (maize, tobacco, groundnuts, beans, potatoes, vegetables), using manure as fertilizer. Poor agricultural practices lead to increased soil erosion	Diffuse (fields runoff)	Phosphates and nitrates enrichment Algae growth Oxygen depletion BOD Faecal coliform Siltation/ Turbidity	Mainly upstream (Chaponda, etc.). LWB protection buffer is widely respected



Pollution source	Type of pollution	Water quality impact	Major locations
Human settlements	Diffuse (solid waste/faecal matter runoff)	BOD Faecal coliform Turbidity	Settlements around the reservoir and tributaries
Livestock grazing	Diffuse (grazing areas runoff)	BOD Faecal coliform Turbidity Nutrient enrichment	Around the reservoir, including within the protection buffer. Usually in small numbers



Source: NEMUS (2014)

Figure 58 – Farming areas around Kamuzu Dam I (Kapininga)



Source: NEMUS (2014)

Note the use of manure as fertilizer

Figure 59 – Farming areas around Kamuzu Dam I (Manyenje)



Source: NEMUS (2014)

Figure 60 – Livestock grazing around Kamuzu Dam I (Sinyala, within the protection buffer)



Source: NEMUS (2014)

Figure 61 – Livestock grazing around Kamuzu Dam I (Kapininga, within the protection buffer)



Within KD I reservoir area, the upstream area represented by Katete's River monitoring site is the most sensitive to the referred pollution sources, in general, mainly because there is less dilution capacity. Cattle grazing and agricultural runoff will be the main ones. However this area has less populated areas and consequent human activity than downstream, where larger settlements like Malingude, Kapininga and Mbalane are located.

Diffuse pollution should be more important following the first precipitation events of the wet season, dragging accumulated cattle manure from the dry season, as well as the exposed soil from large uncultivated areas.

Runoff from settlement areas in the vicinity of the reservoir is also more important in the beginning of the wet season. The lack of organized sanitation and solid waste management is a major source for contaminants such as coliforms.

Pollution sources for Kamuzu Dam II reservoir are generally the same as described above.

5.6.4. Water quality assessment

5.6.4.1. Suitability for use

Considering the LWB sampling sites for the study area and the standards and guidelines presented before in Table 24, the following table presents a compliance assessment for the available data (2004 to 2012).

Table 26 – Water quality standard/guidelines compliance assessment

LWB sampling site	Non-complied parameters (percentage of total samples, standard/guideline@year)
1 – Katete River	Iron (29% – MBS drinking water@2008/2009; 86% – WHO drinking water@2004/2008/2009/2010) Turbidity (63% – MBS/WHO drinking water@2004/2008/ 2009/2010) pH (25% – MBS/WHO drinking water@2004/2008; 38% – FAO irrigation@2004/2008/2009)



LWB sampling site	Non-complied parameters (percentage of total samples, standard/guideline@year)
	Faecal coliforms (100% – WHO drinking water)
2 – Kamuzu Dam I	Iron (43% – WHO drinking water@2004/2010/2012) Turbidity (78% – MBS/WHO drinking water@2004/2005/2008/2010/2012) pH (22% – MBS/WHO drinking water/ FAO irrigation@2004/2012) Faecal coliforms (100% – WHO drinking water)
3 – Kamuzu Dam II (raw water)	Iron (29% – WHO drinking water@2009/2010) Turbidity (44% – MBS/WHO drinking water@2004/2005/2010) pH (22% – MBS/WHO drinking water/ FAO irrigation@2004) Faecal coliforms (100% – WHO drinking water)

Faecal coliforms shows the most non-compliance cases, all samples in all three locations, including KD II, considering available guidelines for drinking water, a very unlikely use except in very sporadic cases.

The highest result was in Katete River, 1,050/100 ml in 11-11-2008, being the lowest 2/100 ml in KD2 (08-05-2004), so great variability existed between sampling dates and sites. Mean value obtained in Katete River is 2 to 3 times higher than in KD1 and KD2.

Over general biological issues, some problems were detected concerning iron and turbidity concentrations, especially in KD1 site, but again only very demanding (drinking water) guidelines were available for these parameters (MBS/WHO).

pH showed slight non-compliances for all sites and in both drinking water and irrigation guidelines.



5.6.5. Variability along monitoring sites

From all available LWB's sampled parameters, Turbidity and Suspended Solids are assumed to be representative of general physical quality. Electrical Conductivity, Total Dissolved Solids, Nitrates and Iron were considered representative of general chemical quality and adequate for assessing existing pollution sources, such as runoff from agricultural areas. Finally, Faecal Coliforms is taken to be representative of general biological quality.

Data from algae/ cyanobacteria monitoring in both KD1 and KD2 will also be presented and discussed. However, only one sample at each reservoir was provided by LWB. No other sampling of this kind was available to the present date. Data for metals and fertilizer residues was also available, but again only from one sampling performed in 2009.

Turbidity results were generally low (Figure 62), except for two samples from Katete River station in November 2008 and January 2009 (200 NTU). Both were collected in the wet season, the first one in the beginning and the second one in middle of the rainy period, which could link the obtained values to strong storm runoff. Existing precipitation records for KD2 meteorological station showed that the month of November 2008 was indeed considerably rainier than monthly average. January 2009 was within average. Nevertheless, other wet season samples such as February 2004, March 2010 and February 2012 presented much lower records.

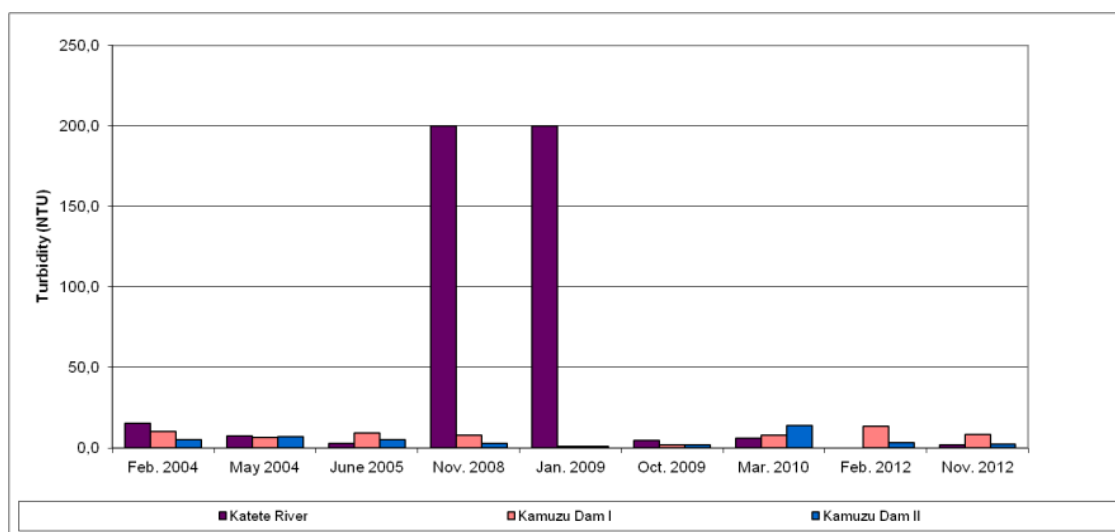


Figure 62 – Turbidity results for 2004-2012 monitoring



Subtracting those two outlier results, mean for Katete River data is equivalent to KD1 and KD2's, around 6 NTU.

Suspend solids concentration (Figure 63) follows the same pattern as turbidity, with November 2008 and January 2009 samples showing outlier values (134 mg/l). Subtracting those two outlier results, mean for Katete River data is equivalent to KD1 and KD2's, around 3 to 5 mg/l. KD I shows the highest mean value, with a evident peak in November 2012 (13.6 mg/l).

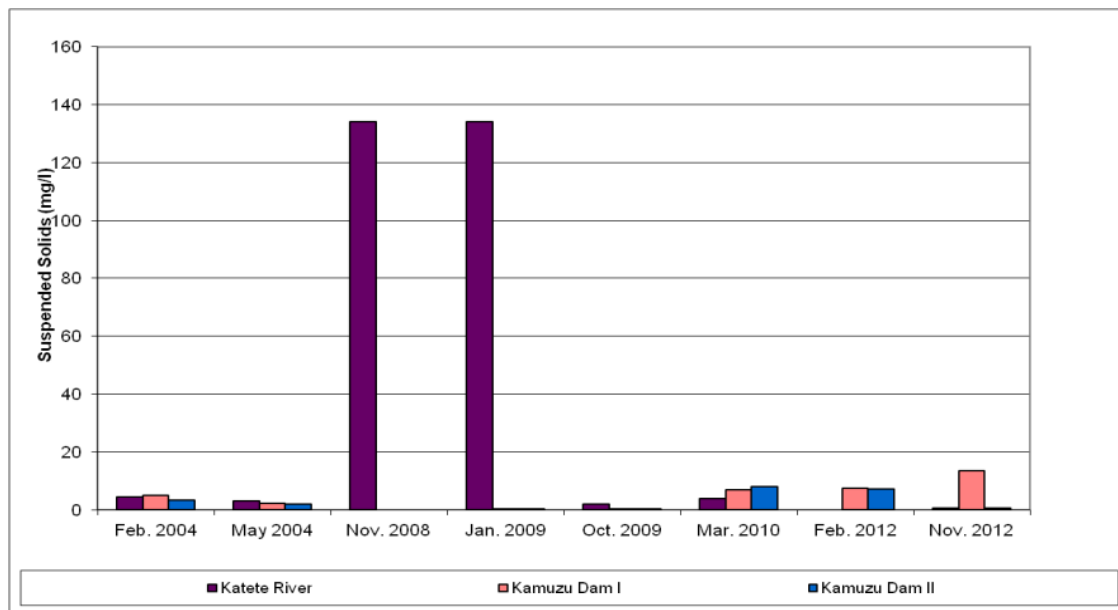


Figure 63 – Suspended solids results for 2004-2012 monitoring

Electrical conductivity (Figure 64) showed higher in Katete River, with a mean value around 120 $\mu\text{S}/\text{cm}$, but without a significant difference to KD1 (96 $\mu\text{S}/\text{cm}$) and KD2 (91 $\mu\text{S}/\text{cm}$). No correlation with precipitation is apparent.

Again, peaks were found in November 2008 and January 2009 sampling, especially in Katete River, but also in KD1 site.

According to FAO irrigation water guidelines all results present no restriction on use (<700 mg/l). Samples even comply with MBS drinking water standards for electric conductivity (<1,400 $\mu\text{S}/\text{cm}$).

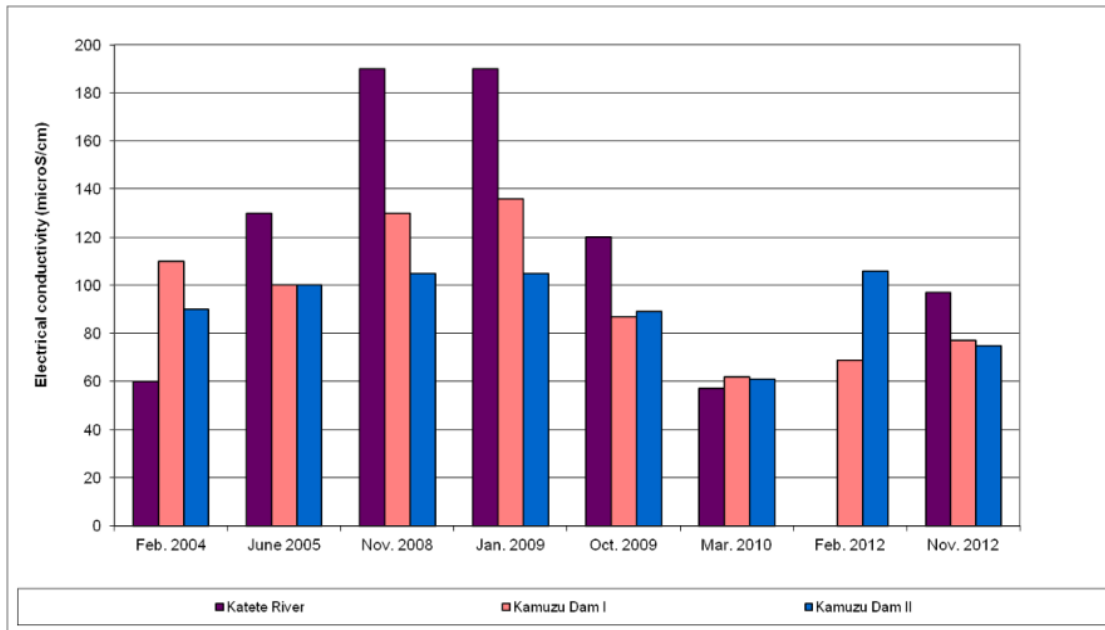


Figure 64 – Electrical conductivity results for 2004-2012 monitoring

Total Dissolved Solids data shows consistently higher values in Katete River, compared with KD1 and KD2 (Figure 65). This situation is within expected, considering Katete River's monitoring site location upstream the reservoir, where solid flow is more intense. Again, November 2008 and January 2009 samples show the highest values, for both Katete River and KD I.

According to FAO irrigation water guidelines all results present no restriction on use (<450 mg/l). Samples even comply with MBS/WHO drinking water standards for total dissolved solids (<1,000 mg/l).

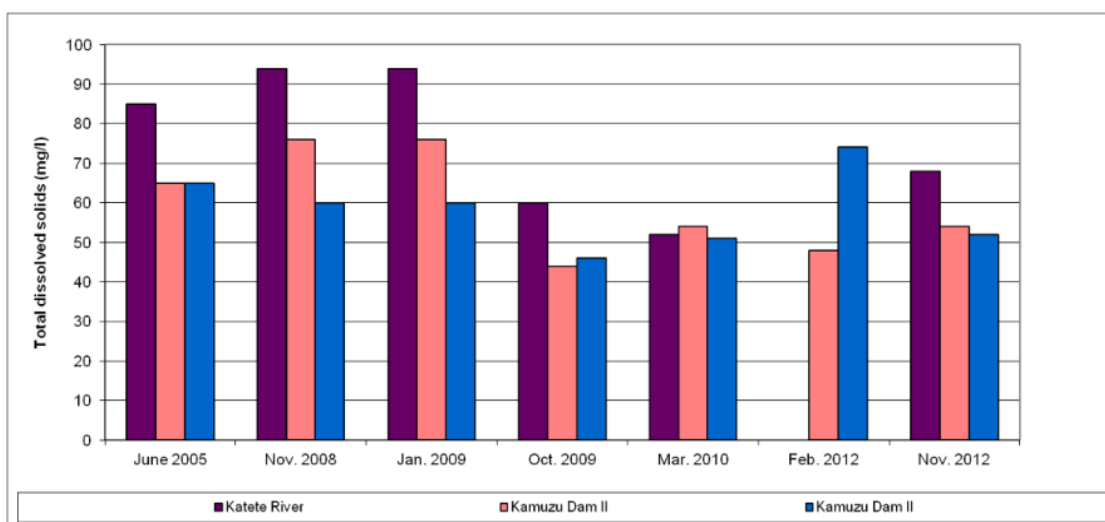


Figure 65 – Total dissolved solids results for 2004-2012 monitoring



Nitrate concentrations are generally low in all sites (Figure 66), except for the June 2005 sample, where almost 5 times higher results were consistently obtained straight from Katete River, upstream KD1, through KD2 all the way downstream. 2005 was indeed a dry year, with only 0.5 mm in June, but both reservoirs were at their maximum level that month. If we subtract what seems to be this outlier sample, mean values are below 0.5 mg/l, including several samples <0.01 mg/l, in both Katete River and KD1.

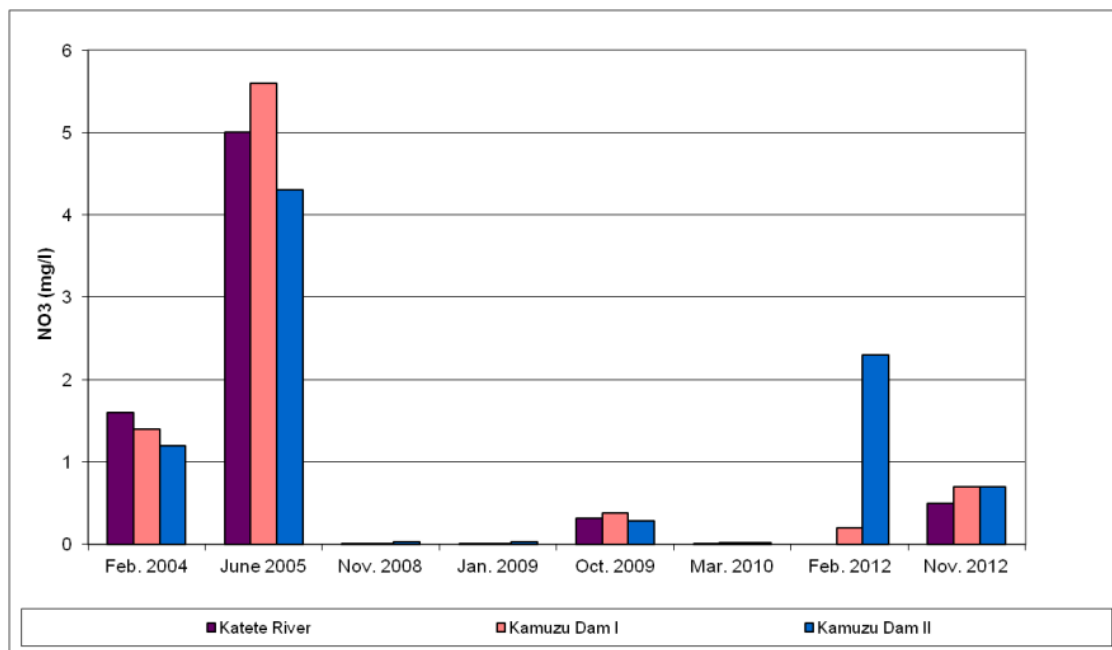


Figure 66 – Nitrates results for 2004-2012 monitoring

Accordingly to these data, surface water nutrient enrichment, typically from diffuse pollution sources such as agriculture and always a concern in reservoirs, does not seem to be a significant issue in the region. The scarce use of chemical fertilizers and the respect for the reservoirs' protection buffer (all farmland is located upland the planted cactus line that demark the protection buffer) are probably the main reasons. Furthermore, as previously stated, November 2008 and January 2009 samples showed a much higher than average solids concentration, probably due to intense runoff events, but as can be observed in Figure 66, no nitrates peak was associated.

Iron results peaked between November 2008 to October 2009, surpassing 1 mg/l (MBS standard for drinking water) in the first two samples for this period (Figure 67). Correlation with November 2008 and January 2009 high peak for



solids in Katete River (Figure 63 and Figure 65) suggests that iron comes from soil erosion.

Iron concentration is somewhat reduced further downstream, with KD2 having the lowest mean value, most of time below the MBS drinking water standard (<1 mg/l), even in raw water.

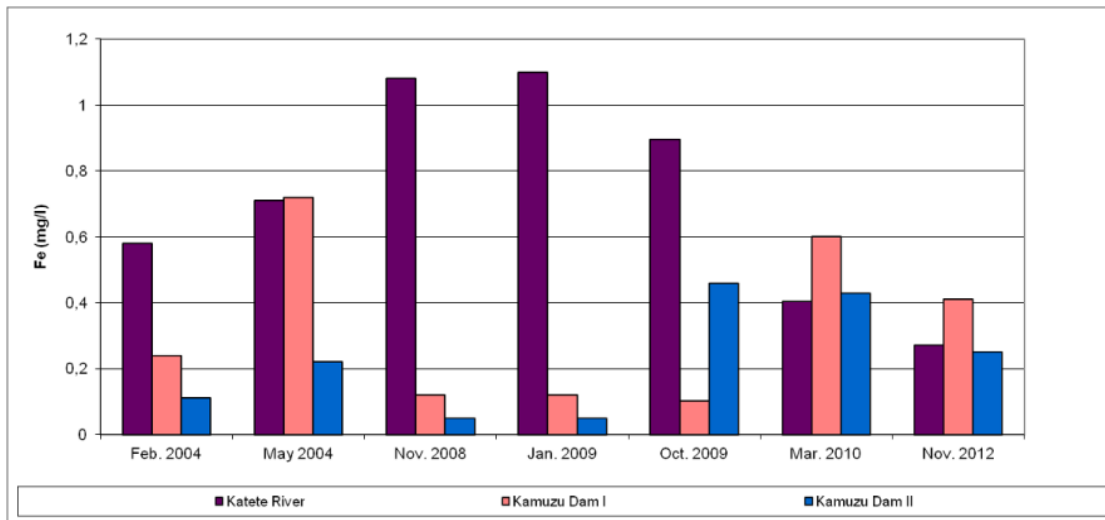


Figure 67 – Iron results for 2004-2012 monitoring

Faecal coliforms are good indicators of organic pollution sources, namely from human settlements and cattle grazing areas. Manure spreading as fertilizer on fields during wet periods can also be a local source.

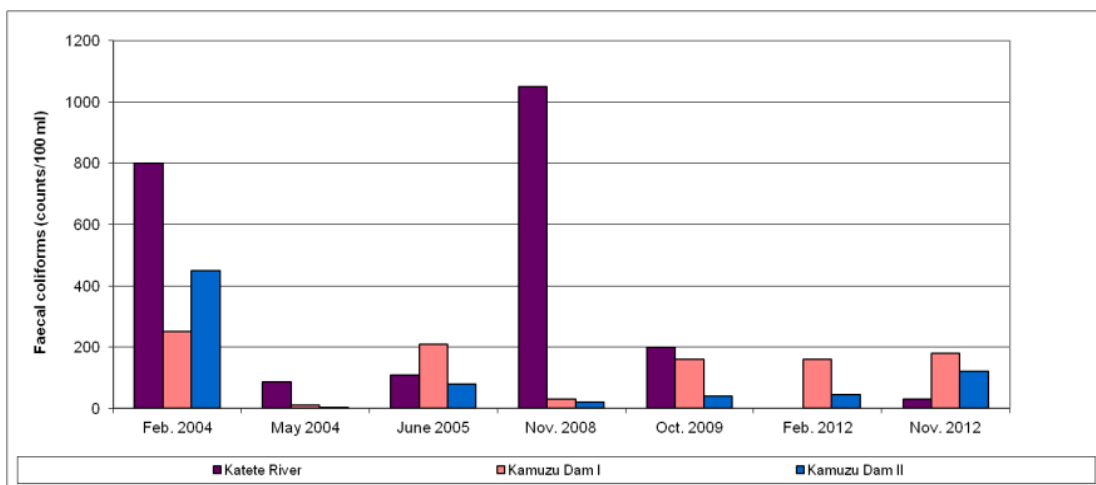


Figure 68 – Faecal coliforms results for 2004-2012 monitoring



As can be observed above (Figure 68), Katete River seems to be most affected by this kind of contamination, strongly influenced by the high values from February 2004 and November 2008. This can be due to cattle grazing directly on the margins, as observed during fieldwork, and the proximity of Katete, Manuele and other settlements, where no sanitation exists.

Contamination usually peaks in the beginning of the wet season, following the first rains, when accumulated faecal matter in the fields during the dry season (when cattle comes to graze near the water) is washed to the river. November 2008 sample for Katete River most likely shows this kind of situation, with a strong peak over 1,000 count/100 ml. February 2004 sample follows with 800 count/100 ml after a rainy January, the real start of the 2003-2004 wet season, following a drought that lasted from mid-March all the way through mid-December in 2003.

Except for the two referred peak situations, mean values for the three sites are below 125 count/100 ml in all monitored sites, which is relatively low and allows a generally safe recreational use.

There is no clear pattern of spatial variation which likely means that pollutions sources, while of the same kind, have distinct ways (or seasons) of influencing water quality. In a general way, KD2 has the lowest values, which is likely due to larger dilution capacity of this water body.

Kamuzu Dam's I and II typical levels of cyanobacteria and algae are presented in the following figure, according to LWB's available data.

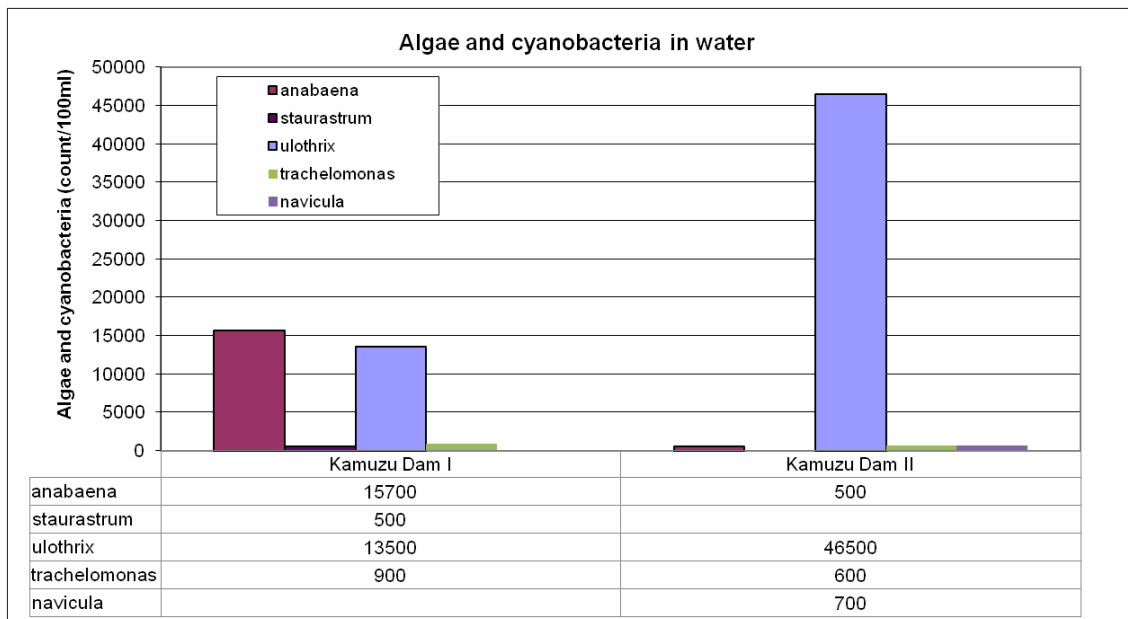


Figure 69 – Faecal coliforms results for 2004-2012 monitoring

Cyanobacteria *Anabaena* concentration was found to be much higher in KD1, almost by 2.5 times. This species can cause toxic effects in vertebrates (liver and neurological disruption) and fish (damage to liver, heart, kidney, gills, skin and spleen), although bloom toxicity may vary in time and space (Chorus & Bartram, 1999; WHO, 2003). However, observed concentrations are not expected to pose adverse health effects to humans for recreational use or livestock (lower than the 20,000 cells/ml WHO guideline) but may cause taste and odour problems (production of earthy and musty smelling compounds; Chorus & Bartram, 1999). HYDROPLAN (2010) reports the algae blooms coincident with the occurrence of musty odours in Kamuzu Dam II.

The cyanobacteria concentrations are also indicative of relatively high phosphorus levels (Guildford *et al.*, 1999). The work of Sibanda (2005) for Zimbabwe indicates that Southern Africa eutrophication is generally limited by Phosphorous, because soils tend to be deficient in phosphorus and nitrogen deficiencies can be compensated by cyanobacteria's air nitrogen fixation. In a situation of excessive phosphorous cyanobacteria proliferate over other *genera*, while if both phosphorous and nitrogen are in excess nitrogen non-fixing *genera* proliferate (Ghosh & Mondal, 2012).



Ulothrix genera algae counts increase from KD1 to KD2, almost 3.5 times. This genera, as *Navicula*, is generally characteristic of relatively unpolluted waters, including low turbidity and electrical conductivity (Niyogi *et al.*, 1999; Triest *et al.*, 2010). These results seem to demonstrate this correlation, as KD2 shows less turbidity and lower electric conductivity than KD1, on average.

No regular monitoring data is available to assess the seasonality of the algae/cyanobacteria blooms. However, *Anabaena* is known to cause water quality problems in Southern Lake Malawi from March to May, following the wet season precipitation, which has been related to Linthipe River (downstream Lilongwe River) Phosphorous pollution (Hecky *et al.*, 1999). Due to this cyanobacteria Phosphorous limitation and the wet season's typical higher turbidity, it is reasonable to assume that cyanobacteria and other algae blooms are most likely to occur in the end of the wet season, following river water enrichment with runoff phosphorus (from soil erosion and farming fields) and the progressive reduction of turbidity.

LWB's 2009 sampling for fertilizer residues and metals in Kamuzu Dam I and II waters resulted in the following:

Table 27 – Metals and fertilizer residues in Kamuzu Dam I and II

Site	Nitrate (mg/l)	Phosphate (mg/l)	Lead (mg/l)	Copper (mg/l)	Iron (mg/l)	Zinc (mg/l)	Manganese (mg/l)	Cadmium (mg/l)	Chromium (mg/l)
Kamuzu Dam 1	0.00	0.01	0.00	0.11	0.16	0.01	0.06	0.001	0.00
Kamuzu Dam 2	0.00	0.03	0.00	0.08	0.10	0.01	0.04	0.001	0.00

As can be seen above, concentrations for metals are quite low, complying with available MBS/WHO drinking water standard and guideline. The same can be said for fertilizer residues nitrate and phosphate. However this was the result of a single sampling and not the one from regular monitoring over time, so no solid conclusions can be drawn.



5.7. Noise

5.7.1. Noise standards

There are no explicit mentions to the assessment of environmental noise impacts or quality/reference standards/limits set in Malawian legislation, exception made to standard MS 173: Acoustics Noise Pollution – Tolerance limits⁹. According to it, maximum allowable noise limits in industrial, commercial, residential and silence zone areas are prescribed. Table 28 shows the established noise standards for daytime and night-time period.

Table 28 – Tolerance limits for ambient noise according to Malawi standard

Area	dB	
	Daytime (6-21h)	Night-time (21-6h)
A – Industrial area	75	70
B – Commercial area	65	55
C – Residential area	55	45
D – Silence zone	50	40

Source: MS 173:2005 (MBS)

There is no information regarding formal declared silence zone areas around Malingunde/Kapininga educational infrastructures (TDC, KIX nursery school and Dalitso Trust) – that is, “areas up to 100 metres around such premises as hospitals, educational institutions, libraries and courts”. Such decision is under Environmental Affairs Department or Local Authorities responsibility.

Furthermore, referring to Occupational Health and Safety standards for noise, the following sound levels should not be exceeded¹⁰, otherwise, such areas shall be categorised as ear protection areas and to be cordoned off:

⁹ The Malawian Bureau of Standards developed standards regarding “*Noise with respect to human beings*” (13.140), focused in indoor noise control. In terms of “*Acoustics and acoustic measurements*” (17.140), noise pollution tolerance limits, along with sound level requirements for indoors of non-industrial buildings (MS 173:2005), and noise reduction provisions for noise reduction in industrial buildings (MS 217:2005), are valid for Malawi.

¹⁰ If exposure is for periods other than eight hours, or if the sound level is fluctuating, an equivalent sound level shall be calculated, and this resultant noise shall not exceed the



- “70 dB(A) of continuous level in any one day;
- 85 dB(A) of reasonably constant level for 8 hours continuously in any one day;
- 135 dB(A) as measured with an instrument set at “fast” in any one day;
- 150 dB(A) in case of impulse as measured with an instrument set at “fast” in any one day.”

The World Health Organization (WHO) produced guidelines to address community noise (or environmental noise; defined as noise emitted from all sources, except noise at the industrial workplace; WHO, 1999) that addresses noise sources and their measurement, the adverse health effects of noise, guideline values and noise management.

The IFC (International Finance Corporation), a subsidiary of the World Bank Group, refer to those stipulated by the WHO in its Environmental, Health and Safety (EHS) Guidelines, in particular at the Noise Management Guidelines (IFC, 2007).

Table 29 – IFCs’ reference noise levels for ambient noise

Receptor	One Hour LAeq dB(A)	
	Daytime (7-22h)	Night-time (22-7h)
Residential; institutional; educational	55	45
Industrial; commercial	70	70

Source: IFC EHS Guidelines (2007)

WHO or IFC don’t define reference ambient noise levels for rural areas – as is most of the study area. However, WHO mention that “existing quiet outdoor areas should be preserved and the ratio of intruding noise to natural background sound should be kept low”.

The reference noise levels are supplemented by the 3 dB(A) criterion – that is, noise levels should not exceed those presented in Table 29 or result in a

equivalent of 85 dB(A); The non-continuous exposure at a sound level in excess of 85 dB(A) shall be regarded as exceeding 85 dB(A).



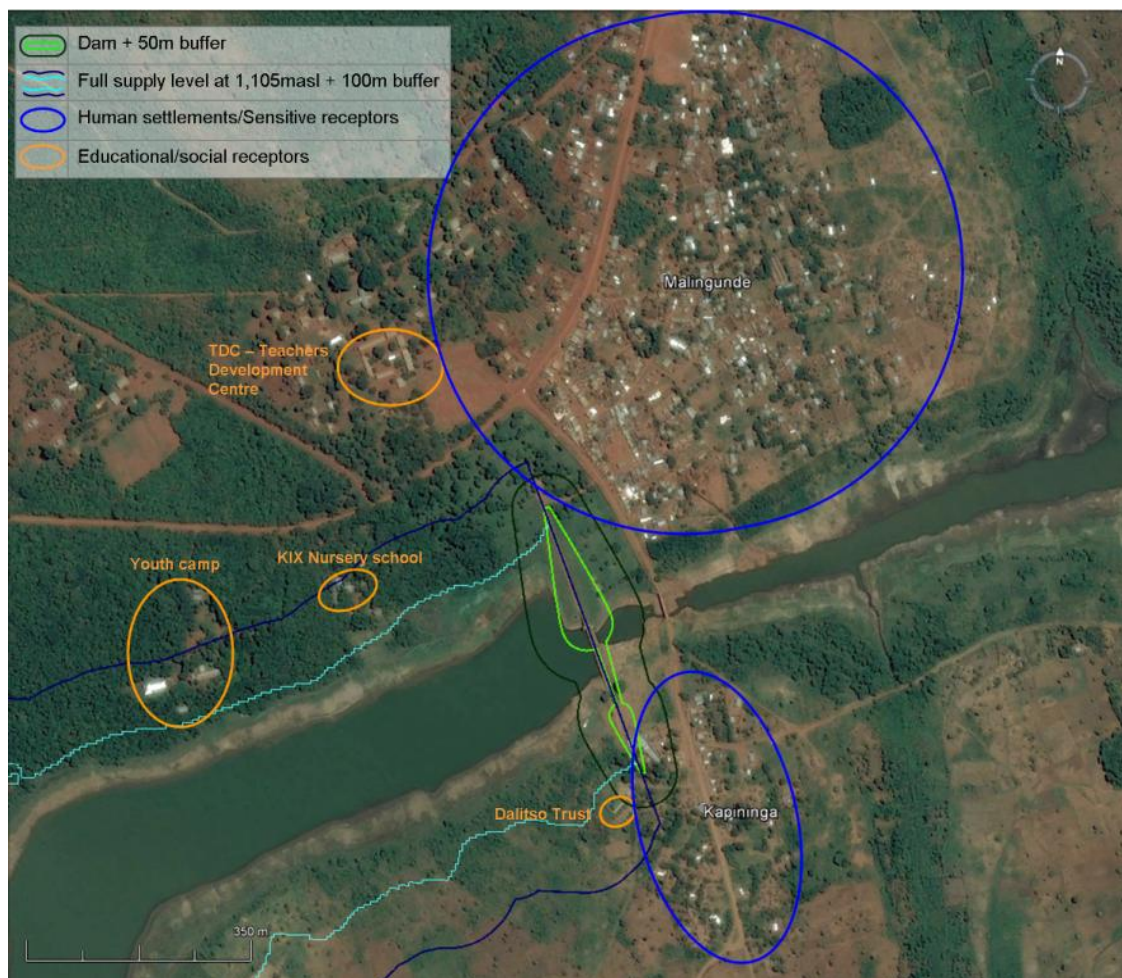
maximum increase in background levels of 3 dB(A) at the nearest receptor location off-site.

5.7.2. Sensitive receptors

Two areas can be defined to typify sensitive receptors location and dispersion.

Kamuzu Dam I section area (Malingunde/Kapininga)

The Kamuzu Dam I infrastructures' site is located at Malingunde, which is the most densely populated settlement of the area, extending its influence to Kapininga, on the right margin of Lilongwe River.



Source: aerial image from Google Earth (December, 2013)

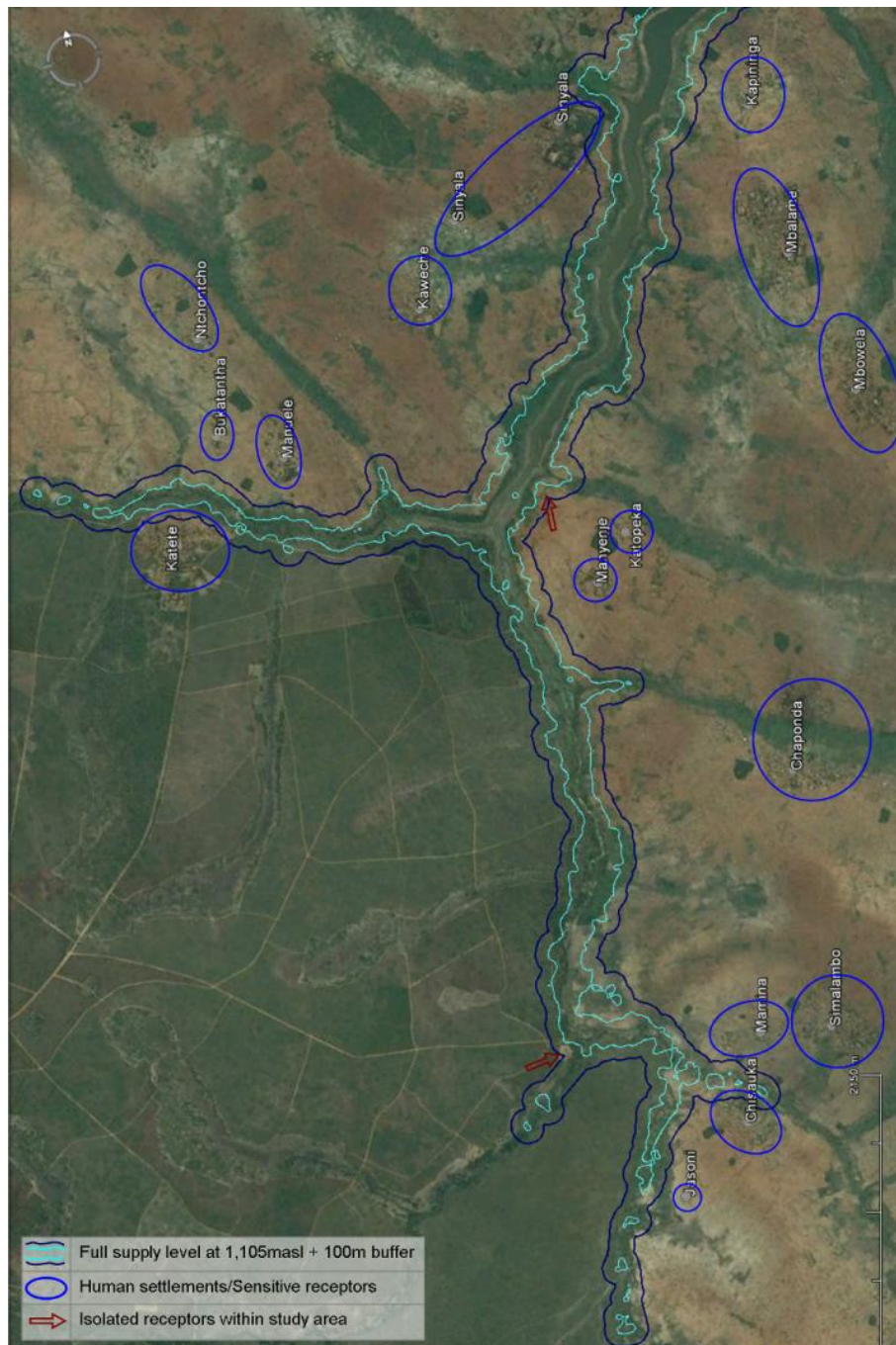
Figure 70 – Identification of sensitive receptors: Kamuzu Dam I section at Malingunde/Kapininga



Four educational/social institutions/facilities are found near the KD1 area of influence: Dalitso Trust, KIX Nursery School, Malingunde Youth Camp and the Teachers Development Centre.

Water Reservoir section area (dispersed upland villages)

The land occupation in study area and its surroundings is typical of rural areas, with disperse low density human settlements and natural/agricultural land.





Source: aerial image from Google Earth (December, 2013)

Figure 71 – Identification of sensitive receptors: Water reservoir section, upstream
Kamuzu Dam I

As mentioned, the upstream section of Kamuzu Dam I and its surroundings is markedly rural, with small and scattered settlements interspersed with agricultural land and, especially in riverbanks, natural vegetation. The south left riverbank enclosed by the Katete and Lilongwe Rivers is characterised by woodlands, either of natural occurrence or planted for production purposes.

Exception made to Katete, Sinyala and Chisauka, all other villages and settlements are located upland the water bodies (Katete River, Lilongwe River and KD1 water reservoir).

Focusing only on the study area upstream Kamuzu Dam I, the human occupation is residual – besides two isolated households, only at Sinyala, Katete and Chisauka a few sensitive receptors were identified within the study area.

5.7.3. Noise pollution sources

Since the project area is in a rural area, without industry or major areas of economic activity, the main noise sources are traffic in main roads and commercial activities in human settlements.

Road traffic

T364 is an unpaved road that connects Malingunde to the North-western region of the Lilongwe District (Namitete), as an extension of S124 (or Likuni road). Although the S124 connects Likuni to Lilongwe, the traffic volume originated by movements between Likuni and Lilongwe doesn't significantly influences the traffic in T364.



Therefore, the traffic flow to and from Malingunde is not relevant compared to the one that occurs in S124¹¹. Thus, even considering that T364 is locally (considering the study area and its surroundings) the main road with the most intense traffic volume, it originates limited noise emissions.

From Malingunde to D197 and local roads to the west and south (all unpaved road accesses), the traffic volume is even lower – for local road accesses the traffic volume can be considered residual, as people usually use bicycles for their dislocations or walk.

Also, given that all roads are unpaved, vehicles circulate at low speeds, although the irregular unpaved surface increases the noise emissions and induces higher engine revs.

Commercial activity

The commercial activity (markets, small businesses and stores, food and drink barracks) is more intense at Malingunde and Kapininga, near Kamuzu Dam I, where noise emissions from people's concentration and circulation, music and trading activity represents a relevant proportion of the current environmental noise.

In rural areas upstream Kamuzu Dam I, no significant noise sources could be identified, except natural sources and agricultural and social activity in small settlements. A mention to the fact that no heavy machinery is used in agriculture.

5.7.4. Local ambient noise

In order to quantify and characterise current noise levels an *in situ* noise measurement campaign was conducted in November 14th at two locations. Daytime measurements (6h-21h; 7h-22h) were made with a precision sound analyser, accredited and calibrated.

¹¹ For reference, in 2009, a traffic survey (JICA, 2010) identified that the traffic flow from and to Lilongwe (City Centre and Old Town) in Likuni road was of 680 vehicles per day (excluding bus and minibus), and of 1,800 minibus vehicles per day.



In rural areas like the project area, noise levels, especially during the night, are fairly uniform, with animals and wind affecting readings most significantly, resulting in low noise levels (below the residential standards limit). Additionally, no construction works are expected in this period and the dam's operation will not generate relevant noise emissions. Therefore, no night-time measurements were made. The goal was to set an environmental noise baseline in daytime, to support assessment of possible temporary impacts in the construction phase (operation of heavy machinery, earthworks, traffic).

The selection of representative locations/receptors was sought to reflect the typical and/or worst case scenarios, weighing the sensitiveness of receptors and its density, the noise sources (type, quantity and diversity) to which they are exposed and their location considering the future pipeline.

Considering future construction and operation impacts, only receptors located near the Kamuzu Dam I infrastructures are to be impacted by construction activities.

Therefore, two sampling sites were selected – at Kapininga, near the right embankment of the dam (Figure 72), and Malingunde, near the left embankment (Figure 73) – result of weighing the vicinity to the dam embankments, the proximity to unpaved roads (considering construction vehicles circulation), the presence of commercial activity in the area and the absence of obstacles to sound emissions (topography and LWB wall).



Source: aerial image from Google Earth (December 2013); NEMUS (2014)

Figure 72 – Noise measurement at #1 (RB) – Water Falls Lodge (Kapininga)



Source: aerial image from Google Earth (December 2013); NEMUS (2014)

Figure 73 – Noise measurement at #2 (LB) – Malingunde

The following table shows the detailed campaign results.

Table 30 – Noise levels measurements

Site Location	Time	Temp	Wind	LAeq	LA50	LAmix	LAmix	Main noise sources
		°C	km/h	[dB(A)]				
#1 (RB) – Kapininga	14-11-14 13:50	36.5	v<3	61.0	60.2	80.9	52.0	Residual road traffic (one van and two motorbikes); commercial activity (three bars with loud music, dominating ambient noise, and fish stand); people circulating and chatting (10-20m away)
#2 (RB) – Malingunde	14-11-14 16:30	33.6	v<1	53.7	49.8	79.9	43.4	Residual road traffic (one car and six motorbikes); farm animals; children playing nearby; people circulating and chatting (10-20m away); music from a distant bar



Based on the registered noise values, its compliance with the Malawian standards (Table 28) and IFC standards (Table 29) is synthesised in Figure 74 and Figure 75, considering the threshold for residential areas/receptors.

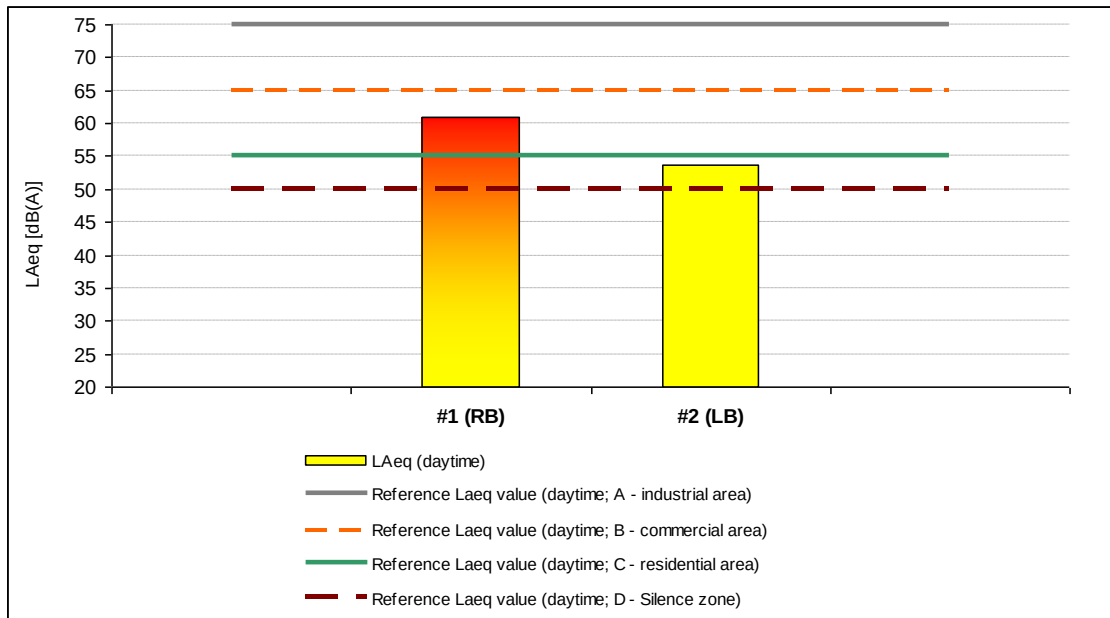


Figure 74 – Compliance with Malawian standards for ambient noise

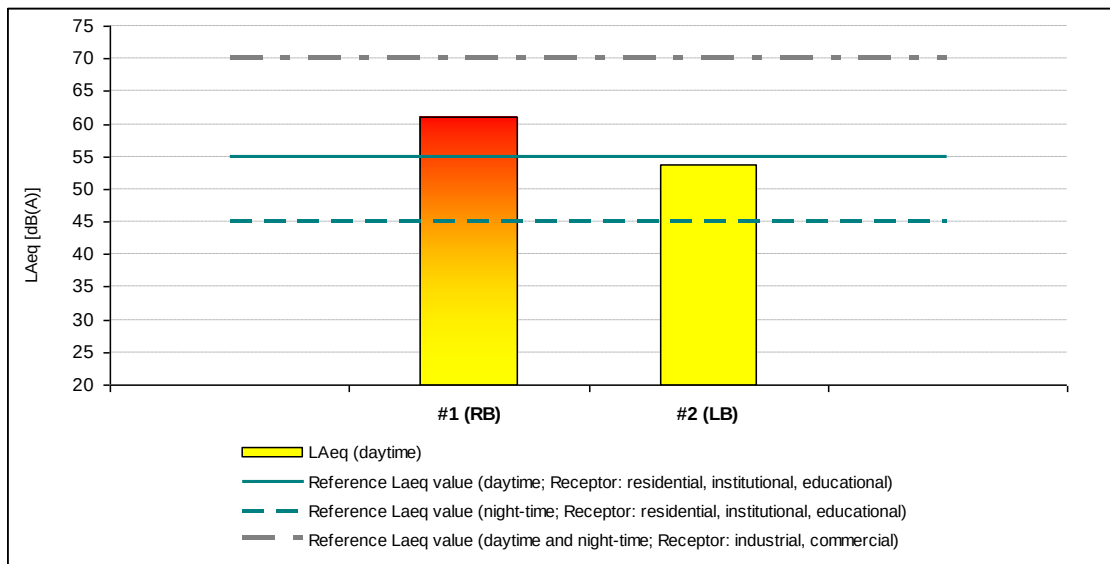


Figure 75 – Compliance with IFC standards for ambient noise



For both reference standards for residential areas/receptors, the threshold was exceeded only for site #1, at Kapininga. The noise values, as mentioned in Table 30, were significantly influenced by the commercial activity present at that location (bars with loud music). Therefore, considering the commercial use, the 65 dB(A) limit recommended is complied.

In light of the above, it is evident that baseline noise levels are fairly low and mostly as a result of typical rural community life. Noise measurements elevations occur in the vicinity of commercial areas, as road traffic was not identified as a significant source, given the low traffic volume demonstrated in situ.

In conclusion, considering the strict study area buffer (around the dam and water reservoir), it could be extrapolated that the typical noise values are under 55 dB(A) – compliance of #2 with daytime LAeq – in general, with the exception of the Malingunde/ Kapininga area, where values above 55 dB(A) could be more frequent, especially in the vicinity of areas with commercial activity.

5.8. Air Quality

5.8.1. Air quality standards

No national quality/reference standards or limits are set for air pollution. Therefore, international guidelines are to be used in order to provide reference ambient air quality goals.

The World Health Organization produced a guidance book on Air Pollution and Quality (WHO, 2006), which includes revised guideline values for the four most common air pollutants – particulate matter, ozone, nitrogen dioxide and sulphur dioxide.

The IFC, a subsidiary of the World Bank Group, refers to those stipulated by the WHO in its Environmental, Health, and Safety (EHS) Guidelines, in particular at the Air Emissions and Ambient Air Quality Guidelines (IFC, 2007), as follows.



Table 31 – IFCs' reference guidelines for ambient air quality

Pollutant	Averaging period	Guideline value ($\mu\text{g}/\text{m}^3$)
Sulphur dioxide (SO_2)	24-hour	125 (Interim target-1) 50 (Interim target-2) 20 (guideline)
	10 minute	500 (guideline)
Nitrogen dioxide (NO_2)	1-year	40 (guideline)
	1-hour	200 (guideline)
Particulate Matter PM10	1-year	70 (Interim target-1) 50 (Interim target-2) 30 (Interim target-3) 20 (guideline)
	24-hour	150 (Interim target-1) 100 (Interim target-2) 75 (Interim target-3) 50 (guideline)
Particulate Matter PM2.5	1-year	35 (Interim target-1) 25 (Interim target-2) 15 (Interim target-3) 10 (guideline)
Particulate Matter PM2.5	24-hour	75 (Interim target-1) 50 (Interim target-2) 37.5 (Interim target-3) 25 (guideline)
Ozone	8-hour daily maximum	160 (Interim target-1) 100 (guideline)

Source: IFC EHS Guidelines (2007)

5.8.2. Sensitive receptors

The strict analysis to the study area shows a very residual presence of human settlements, as these are usually located upland of the water border. In the broad view of the surrounding area of the dam reservoir, population density is low, located in scarce and dispersed settlements, with a land occupation marked by agricultural land.



The one exception is the close vicinity of the Kamuzu Dam I site, located near a more populated area – Malingunde.

See section 5.7.2 for a more detailed description of sensitive receptors in the local context of the study area, including the location of the main settlements.

5.8.3. Air pollution sources

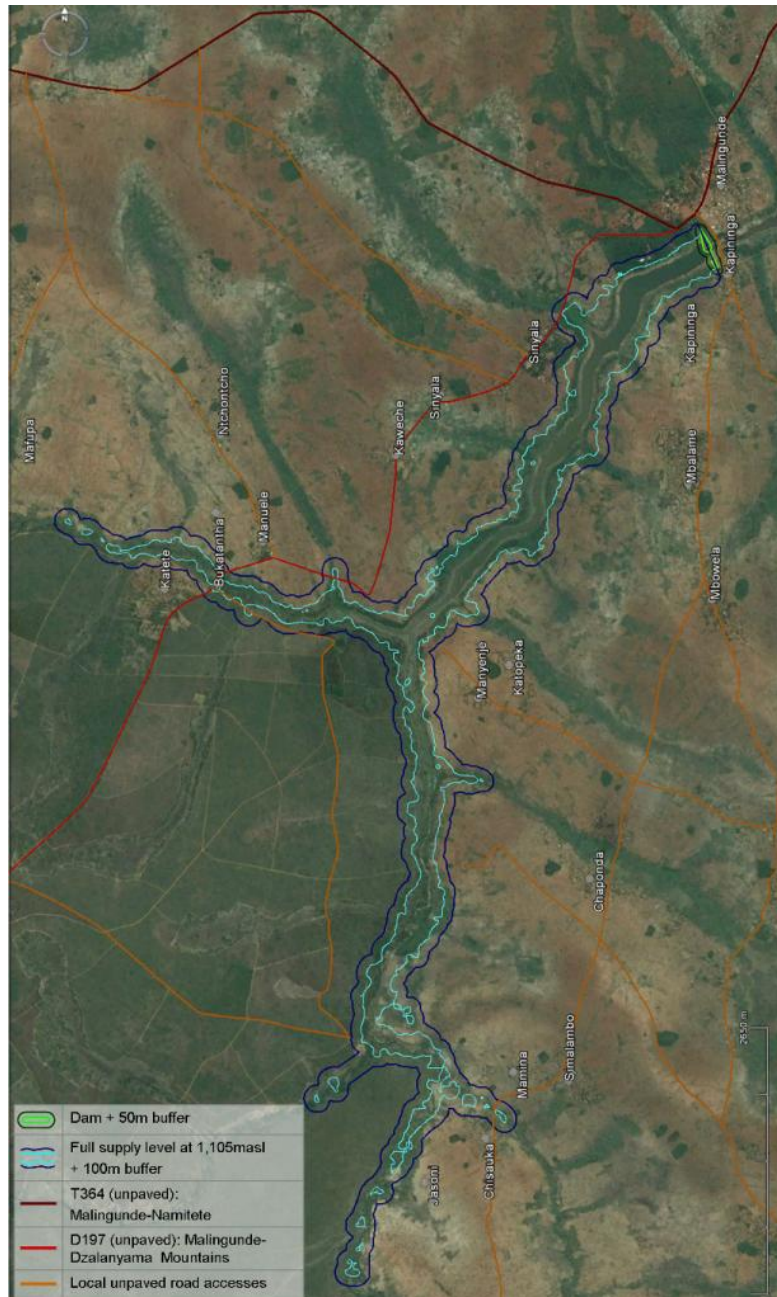
As a rural area, its characteristics define and reflect the main pollution sources:

- Very limited road traffic, concentrated at T364, D197 and local crossing of the Lilongwe River to south/east directions; for other local accesses, the traffic volume is residual to null;
- Residential/rural combustion.

The emission of atmospheric substances is therefore mostly related with the burning of fossil fuels and biomass combustion, resulting in a local increase in pollutants as carbon monoxide (CO), carbon dioxide (CO₂), and sulphur oxides (NO_x) and, especially, particulate matter (PM).

Road traffic

Traffic emissions can be discussed under different perspectives: gaseous emissions directly associated with traffic volume and circulation speed, and particulate emissions, related not only with incomplete combustion products, but also with the re-suspension of dust in unpaved surfaces. Figure 76 highlights the relevant road accesses surrounding the study area.



Source: aerial image from Google Earth (December 2013)

Figure 76 – Unpaved roads and local accesses in the vicinity of the study area

Based on *in situ* observations and contact with local village leaders and population, it was observed that the great majority of traffic flows occur between Likuni and Lilongwe City, representing the typical commuting that reflects the dependency of peri-urban/rural suburbs on a major city (Lilongwe). The traffic flow from Likuni to Malingunde is far less significant, even though it represents the main traffic volume and road connection of the study area – T364. This road



not only allows the connection to Likuni and Lilongwe City, but also connects with the western region of the Lilongwe District (directly or through D197).



Source: NEMUS (2014)

Figure 77 – T364 road (Malingunde)



Source: NEMUS (2014)

Figure 78 – D197 road (Katete)

The study area is mainly served by local unpaved road accesses (Figure 76) with a very residual traffic volume, as local movements are mainly pedestrian or by bicycle.



Source: NEMUS (2014)

Figure 79 – Local access Malingunde-Kapininga (KD1)



Source: NEMUS (2014)

Figure 80 – Local access (Sinyala)

The conclusion drawn from all of the above is that the population along the study area and its surroundings is exposed to limited concentrations of traffic gaseous emissions. Also, although the road accesses are dirt roads, the scarce circulation of vehicles and the dominant population movements made on foot or by bicycle decreases the significance of re-suspended particulate matter/dust.



Source: NEMUS (2014)

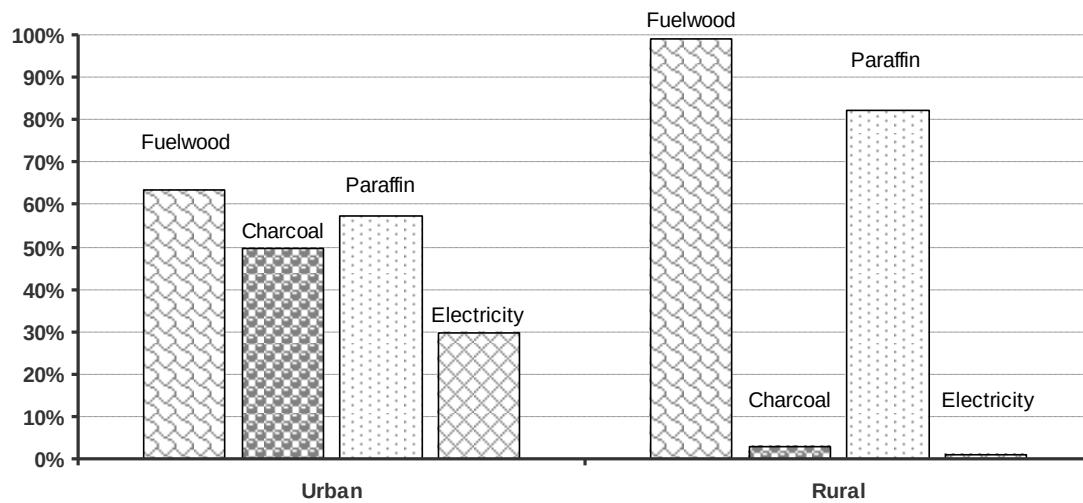
Figure 81 – Dust re-suspension from road traffic

Biomass combustion

An estimate 95% of the Malawian population uses biomass as their main source of domestic energy (Fullerton *et al*, 2009). The use of fuelwood and charcoal is spread out, especially in peri-urban and rural areas, posing a threat to indoor air quality, although with an influence also in local outdoor air.

A study developed in Malawi (rural Chikwawa and urban Blantyre; Fullerton *et al*, 2009) concluded that all sampled homes presented PM_{2.5} levels (24h period) above the recommended 25 mg/m³ limit and 80% had levels four times higher than the WHO level for outdoor air quality.

As observed during fieldwork and from the conclusions drawn from inquiries and contact with the local population and surveys, the study area reflects the national trend for rural households, as fuelwood is widely used as the main energy sources in households for cooking, with the use of paraffin as house lighting fuel, as shown in the following figure.



Source: Second Integrated Household Survey, 2004, in O'Sullivan&Fitzgerald (2006)

Figure 82– Energy use in Urban and Rural Lilongwe City

Other sources

Despite the low relevance and/or representativeness in the study area, other sources of air pollution were identified:

- Vegetation/crop residues combustion – associated with agricultural areas management and the setting/clearance for agricultural parceling;



Source: NEMUS (2014)

Figure 83 – Vegetation/crop residues burning



- Burnt bricks kilns – scattered near villages are some kilns or stoves for production of construction materials. In them, clay-bricks are stacked, covered with mud and burnt using wood. The emissions are characteristic of biomass combustion – CO, NO_x and PM;



Source: NEMUS (2013)

Figure 84 – Burnt clay bricks kiln

- Domestic waste combustion – as waste management is underdeveloped, domestic waste produced in residential areas is generally burnt in near surroundings or specified areas to that end. No landfill or waste concentration areas were identified, so its domestic waste combustion is assumed as an area source, responsible for typical emissions of CO, PM, NMVOC, NO_x and CH₄. Considering the low consumption profile of packaged market products, the domestic waste production is also very limited;
- Livestock – promotes residual emissions of NH₃ from decomposing manure (in grazing and housing areas – stables, barns or stalls).



Source: NEMUS (2014)

Figure 85 – Livestock grazing and manure



5.8.4. Atmospheric dispersion conditions

Pollutant's dispersion in the atmosphere is based on the advection concept and is essentially due to turbulent air mass movements influenced by thermal and/or mechanical forces. The pollutant's concentration in the atmosphere depends not only on the pollution sources emissions but also from its combined action with diffusion and transport phenomena (wind regime and thermal stratification), chemical reaction (in the atmosphere and at ground/emission source level) and removal mechanisms (such as precipitation and sinks).

The knowledge of the wind regime of a given region is a fundamental aspect to access the pollutant dispersion conditions, since it influences the horizontal transport patterns. In the local context, wind regime is the key interest factor among the ones mentioned above.

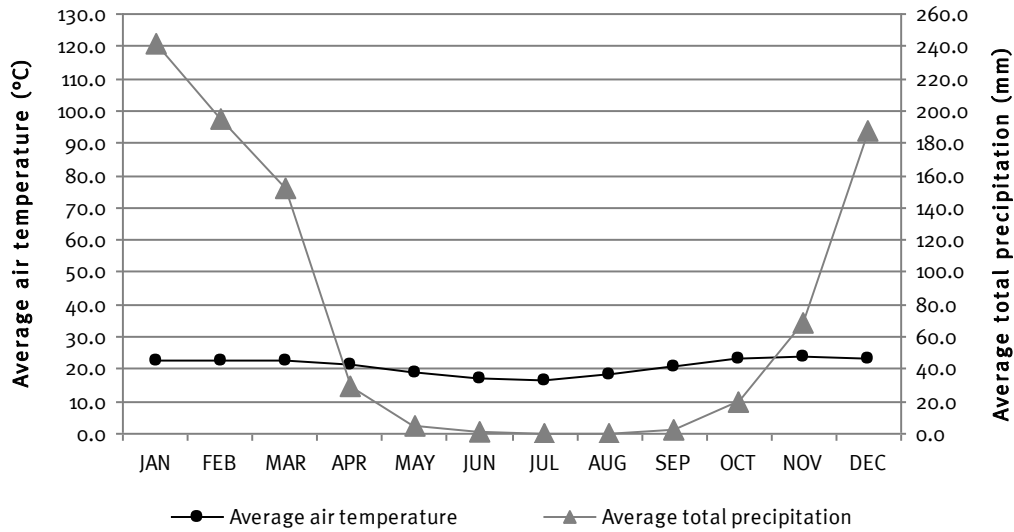
No meteorological data concerning wind direction, speed and frequency and scoping the project area/region is available for the Kamuzu Dam II meteorological station (LWB).

Nevertheless, regarding the wind regime for Malawi in general, bibliographic sources state the prevalence of south-eastern winds (Mandeville and Batchelor, 1990). Exception is made to the period from September to November, as the rapid increase of temperature induces a wind direction change to east and northeast (Venema & Lorkeers, 1991; Pegado, 2000).

The average intensity is higher in the dry season: 5.3 km/h contrasting with 4.4 km/h in the wet season, according to Chitedze weather station's 1985-2004 data (Wang *et al.*, 2011).

The analysis of monthly thermal-pluviometric regime for the Kamuzu Dam II meteorological station for the period between 1998 and 2012 (Figure 86; LWB, 2014) indicates the temporal concurrence of the rainiest months and with higher average temperatures – September to April (although the variation of the average temperature is of low significance).

Therefore, if on one hand the pollutant emission could be maximised (especially those related with combustion gases and biodegradable material decomposition), on the other hand the removal potential increases (wash-effect of suspended particulate matter).



Source: adapted from Kamuzu Dam II met station data provided by LWB (2014)

Figure 86 – Kamuzu Dam II station’s thermal-pluviometric monthly regime (1998-2012)

Lastly, rural characteristics favour the potential for pollutant’s sink. The occurrence of natural cover, forest areas (especially on the left margin of the Lilongwe River) and the extent of agricultural land indicates a not insignificant absorption/sink capacity, even if forested areas are of low significance compared with agricultural land (with less potential).

5.8.5. Air quality assessment

The available information indicates that no monitoring networks or data, public or private, are available in the study area.

RAPIDC – Regional Air Pollution in Developing Countries – is a programme coordinated by the Stockholm Environment Institute that aims to facilitate the development of agreements and/or protocols to implement measures which prevent and control air pollution through promoting international cooperation and developing scientific information for the policy process.



In what concerns the African region, the APINA – Air Pollution Information Network for Africa – collects the knowledge and data derived from the scientific programmes and existing research to influence policy and decision-makers in matters related to air pollution. Malawi is one of the APINA countries. According with the respective country fact sheet, there is an air quality monitoring station – the Lilongwe International Airport, which is not operational though.

Given the absence of quantitative data regarding air pollution, a qualitative assessment of the baseline situation is based on all the considerations above, as well as on specialised perception of local air quality conditions that was observed during the fieldwork.

The main pollution sources identified, along with other sporadic/irrelevant sources, the land use and the human settlement's dispersion all point to an emissions level that contribute to a very limited ambient air degradation. Notwithstanding, it could be expected that occasionally and in combination of high temperatures and low intensity winds, local/confined (in time and space) atmospheric contamination areas might occur. The human settlements adjacent to roads, for example, are particularly exposed to a local increase of traffic and dust emissions, as well as biomass combustion hotspots could affect residential areas (as mentioned, biomass combustion for example can exceed the WHO recommended standards for human well-being and health).



5.9. Terrestrial and Aquatic Ecology (Flora and Fauna)

5.9.1. Introduction

In the present section the occurring ecosystems in the study area will be characterised in terms of the existing habitats and flora and fauna communities; this analysis will allow the identification of sensitive ecological values.

The geographic scope of this analysis includes the estimated flooded area at the dam's full supply level (1,105 masl) and its immediate surroundings on a 100 m buffer zone, cumulative with a 50 m buffer zone around the dam infrastructures. Some potential impacts may have a superior area of incidence due to the ecosystems' continuity, therefore all of those cases are properly pointed out in the impact assessment phase.

The Project's site comprises terrestrial and aquatic environments, therefore the associated impacts are expected to occur over the following biological groups:

- Flora and vegetation;
- Aquatic macro-invertebrates;
- Ichthyofauna;
- Herpetofauna;
- Avifauna;
- Mammals.

The study area covers part of the Dzalanyama Forest Reserve, which has a total area of 98,934 ha. It was firstly protected in 1911 and gazetted in 1922 (Mauambeta *et al.*, 2010).

This Forest Reserve is also an Important Bird Area: IBA MW011 – Dzalanyama Forest Reserve. Covered with *Brachystegia–Julbernardia* woodland, part of the area (5%) is also occupied by forest plantations, dominated by *Eucalyptus* sp.

With 98,934 ha it is considered a key area for the miombo bird species and hosts several range and biome restricted species: *Apalis chapini* (restricted-range and biome-restricted species), *Pogonocichla stellata*, *Serinus hypostictus*, *Cryptospiza reichenovii*, *Estrilda melanotis*, *Pyrenestes minor*, *Falco dickinsoni* (biome-restricted species) (Dowsett-Lemaire *et al.*, 2001; Millington & Kaferawanthu, 2005).



The main threat over the Dzalanyama Forest Reserve is the illegal timber extraction. This area plays an important role as a catchment area for Lilongwe's water supply (Dowsett-Lemaire *et al.*, 2001).

To characterise the ecological component of the study area, a rigorous bibliographic research directed to the biological resources of the area was first conducted, and afterwards, the gathered data was crossed with the data collected during a fieldwork campaign in November, 2014.

5.9.2. Habitats

The natural and semi-natural habitats that occur in the study area include terrestrial habitats (woodlands, forest plantation and croplands), terrestrial habitats with aquatic affinities (wetlands) and aquatic habitats (Lilongwe and Katete Rivers). Each habitat has its own intrinsic ecological value, mainly reflected on the occurring floristic and faunistic values.

There are also artificial areas, mainly human settlements and other infrastructure areas, which due to their non-natural origin are not considered real "habitats" (excluding plantation areas, dealt separately).

The identification and description of the habitats occurring in the area was achieved through these actions:

- Preliminary mapping of the habitats and vegetation communities described for the area (based on bibliographic references) through orthophoto map interpretation;
- Fieldwork to assess the produced cartography and correct it if necessary;
- Characterisation of the identified habitats according to their ecological composition, current conservation status and human intervention level.

From this procedure resulted a cartographic representation of the several habitat types and vegetation communities occurring within the study area (Habitat Map, Appendix 1 – Map 7).

The areas occupied by each habitat in the study area are presented as follows.



Table 32 – Areas of each habitat within the study area

Habitat	Estimated Flooded area		Study Area	
	Area (ha)	Area (%)	Area (ha)	Area (%)
Croplands	83.01	20.41	313.55	37.50
Croplands – Cultivated lands	3.24	0.80	7.60	0.91
Croplands (total)	86.24	21.20	321.15	38.41
Wetlands – Riverine and lacustrine floodplains	86.06	21.16	87.15	10.42
Wetlands – Dambos	20.67	5.08	35.82	4.28
Wetlands – Permanent swamps and marshes	4.81	1.18	5.17	0.62
Wetlands (total)	111.53	27.42	128.14	15.33
Woodlands	106.10	26.08	212.44	25.41
Closed woodlands	24.36	5.99	31.72	3.79
Woodlands – Graveyards	0	0	0.21	0.03
Woodlands (total)	130.46	32.07	244.38	29.23
Forest plantation – <i>Eucalyptus</i> sp.	8.00	1.97	55.39	6.62
Forest plantation – Bamboos	0	0	0.93	0.11
Forest plantation – Gardens	1.88	0.46	11.76	1.41
Forest plantation (total)	9.88	2.42	68.09	8.14
Lilongwe and Katete Rivers	67.78	16.66	68.96	8.25
Human settlements and infrastructure area (total)	0.90	0.22	5.39	0.65
Total	406.79	100	836.11	100

From the analysis of Table 32 it is possible to conclude that croplands are the main habitat of the study area, occupying more than 38% of the total area. Woodlands are the second largest habitat, corresponding to almost 30% of the study area.

The identified habitats are described in the following topics. Their conservation value is properly assessed.

The area was characterised according to the macro-habitats existing, since each macro-unit may comprise one or more habitat units which have the same ecological functioning and functions, and thus do not justify to be represented by a different habitat. Nevertheless, the composition of the several habitats composing each macro-habitat is presented.



Croplands

This semi-natural biotope is the main habitat in the study area and includes non-original areas that were/are prepared for cultivation and cultivated areas.

Some cultivated species are seasonal: maize (planted upland), tobacco and groundnuts are the main cultures during the wet season; maize and vegetables are usually cultivated during all year (Figure 87 and Figure 88).

The species with higher water demands are planted near the river, so it is common to have patches of mixed species according to their water requirements (Figure 89 and Figure 90). Also, the close presence of water allows the plantation of some species during all year, mainly for families' subsistence consumption. This habitat frequently occupies a large band from the riverbank¹² up to more interior areas.

The fieldwork was developed immediately before the wet season (during November) and the registered cultivated species included: maize, tobacco, sweet potatoes, irish potatoes, pumpkins, tomatoes, beans, green beans, sugar cane, banana, cassava, mustard and lettuce.



Source: NEMUS (2014)



Source: NEMUS (2014)

Figure 87 – Cultivated lands in study area:

Figure 88 – Cultivated lands in study

¹² It should be noted that, downstream the Chaponda area to the dam site, LWB defined a protection buffer zone around the current water reservoir (demarked by a cactus line). Hence, croplands are upland of this protection buffer.



maize

area: tobacco



Source: NEMUS (2014)



Source: NEMUS (2014)

Figure 89 – Cultivated lands in study area:
patches of several crop species (1)

Figure 90 – Cultivated lands in study
area: patches of several crop species (2)

Several areas were already in preparation for cultivation (i.e., the soil was already tilled), whereas other areas were not yet tilled (farmers were expecting the rainy season to ease the soil tillage) (Figure 91 and Figure 92).



Source: NEMUS (2014)



Source: NEMUS (2014)

Figure 91 – Cultivated lands in study area:
tilled lands

Figure 92 – Cultivated lands in study
area: untillied lands

In some areas, the croplands occur in patches with human settlements and with remains of woodlands that used to be the original habitat in the area. As



mentioned before, cultivated lands are a semi-natural habitat, since the occurring flora and vegetation are anthropogenic and differ from original values.

In the study area, the most densely cultivated areas are the right and left banks of the Lilongwe River, downstream the confluence with Katete River.

In this habitat, the existing fauna is mainly human tolerant. Opportunist species can occur, drawn by the high food availability in these areas; animal husbandry is common practice, so cattle, goats, pigs and poultry are frequent, usually raised under free range near the villages.

Croplands represent a habitat of low ecological value, since the floristic and faunistic species occurring are mainly anthropogenic and thus differ from the original ones. Nevertheless, these areas are economically and socially relevant, since agriculture is the main subsistence activity in the area.

Wetlands

Wetlands is also a macro-habitat which include a variety of biotopes that share between them both the conservation interest and the ecological vulnerability. This habitat occurs in the riverbanks of the Lilongwe and Katete Rivers along all of the study area.

A systematic classification of the different occurring categories of wetlands does not exist in Malawi. Thus, in order to distinguish the types of wetlands occurring in the study area, one followed Hughes & Hughes (1992) and identified: riverine and lacustrine floodplains, dambos and permanent swamps and marshes.

Riverine and lacustrine floodplains are usually found in the lower part of the catchments where deposition of materials occurs. Dominated by grasses, these biotopes are frequently used as grazing sites in areas of animal husbandry due to the high primary production, to the higher water content of the plant species and to water abundance and availability (Frenken & Mharapara, 2002) (Figure 93, Figure 94, Figure 95 and Figure 96).

Common species include *Oryza barthii*, *Ischaemum afrum*, *Cynodon dactylon* and *Sporobolus* spp. (Kindt *et al.*, 2011).



Source: NEMUS (2014)

Figure 93 – Riverine and lacustrine floodplains in study area (1)



Source: NEMUS (2014)

Figure 94 – Riverine and lacustrine floodplains in study area (2)



Source: NEMUS (2014)

Figure 95 – Cattle grazing in floodplains in study area (1)



Source: NEMUS (2014)

Figure 96 – Cattle grazing in floodplains in study area (2)

Dambos are permanently or temporarily flooded wetlands located along drainage lines with herbaceous vegetation, mainly grasses and sedges, and absence of trees (FAO, 1996) (Figure 97).

Some grass species occurring are: *Brachiaria humidicola*, *Echinochloa pyramidalis*, *Entolasia imbricata*, *Hyparrhenia nyassae*, *Monocymbium ceresiiforme* (Kindt et al., 2011).



Cropping is very common in these palustrine systems because of the water availability and soil fertility, which gives them a high potential for agricultural use (Frenken & Mharapara, 2002; FAO) (Figure 98).



Source: NEMUS (2014)

Figure 97 – Dambo in study area



Source: NEMUS (2014)

Figure 98 – Agricultural use of dambo in study area

In permanent swamps and marshes the presence of *Phragmites mauritianus* and *Typha domingensis* is common, and sometimes associated with free floating species, like *Azolla nilotica*, *Pistia stratiotes* and *Utricularia* spp., depending on the water levels (Figure 99 and Figure 100).



Source: NEMUS (2014)

Figure 99 – Permanent swamps and marshes in study area



Source: NEMUS (2014)

Figure 100 – *Phragmites mauritianus*



In central Malawi this biotope has been lost due to crops cultivation and invasion by aquatic alien species, like *Eichhornia crassipes* (water hyacinth) (EAD, 2006).

Wetlands represent an important ecosystem to local communities and it is common to find human settlements near them, since they guarantee food (security against droughts), good grazing and hunting sites and water availability (Frenken & Mharapara, 2002). They are also ecologically relevant since they retain water levels in flood peaks, are responsible for the maintenance of riverbanks and for the organic matter input into the aquatic foodweb (through the leaves and branches) and regulate the water temperature and insolation of the river channel.

Faunistic species occurring in wetlands have ecological preferences that include proximity to water and in some cases some human tolerance, due to the frequent presence of cultivated lands, such as: amphibians and reptiles (as *Natriciteres olivacea*), aquatic avifauna (as *Cisticola njombe* and *Buggeranus carunculatus*), otters (*Aonyx capensis* and *Lutra maculicollis*) and some bats (like *Laephotis botswanae*) (Hughes & Hughes, 1992).

Human presence constitutes the main threat to these ecological systems, since it leads to habitat loss and fragmentation and biodiversity degradation (clearance for agriculture or settlement and introduction of invasive alien species) (EAD, 2006).

Woodlands

“Woodlands” is the designation for a type of forest-grassland formation. In the study area this biotope is represented by miombo, which is a particular type of forest dominated by the genera *Brachystegia* and *Julbernardia*. Other tree species occurring in the area include *Combretum* spp., *Piliostigma* spp. and *Khaya anthotheca* (Figure 101 and Figure 102).



Source: NEMUS (2014)

Figure 101 – *Piliostigma* spp.



Source: NEMUS (2014)

Figure 102 – Fruit of *Combretum* sp.

Woodlands have an understory generally of medium height grass and although the density may vary, usually there is a low ground cover (FAO).

Exotic tree species can also be found like *Gmelina arborea*, *Toona ciliata*, *Jacaranda mimosifolia* and *Acacia* spp. (Figure 12; Figure 13).



Source: NEMUS (2014)

Figure 103 – *Toona ciliata*



Source: NEMUS (2014)

Figure 104 – *Acacia polyacantha*



This biotope varies in the study area: areas with high diversity and complexity contrast (Figure 105 and Figure 106) with areas less diverse and with young individuals, simplifying the existing vegetation strata (Figure 107 and Figure 108).

These areas frequently develop close to the riverbanks and therefore may also function as riparian vegetation, since they help to maintain the riverbanks, provide organic input into the aquatic foodweb and regulate insolation of the water body. In some areas, the riparian woodland occurring is degraded due to anthropic pressure.



Source: NEMUS (2014)

Figure 105 – Woodlands within study area: high diversity and complexity (1)



Source: NEMUS (2014)

Figure 106 – Woodlands within study area: high diversity and complexity (2)



Source: NEMUS (2014)

Figure 107 – Woodlands within study area: low diversity and size (1)



Source: NEMUS (2014)

Figure 108 – Woodlands within study area: low diversity and size (2)



The potential occurring fauna include avifauna (like *Polemaetus bellicosus* and *Circus macrourus*), terrestrial mammals (like *Civettictis civetta*), bats (such as *Epomophorus anelli* and *Epomophorus labiatus*) and several reptile species.

In their original condition these habitats provide a relevant ecological, social and economic role, since they represent the preferential biotope of occurrence of several species of conservation concern and they provide feedstock to the well-being of human populations (construction material, biofuel and firewood) (Figure 109, Figure 110, Figure 111 and Figure 112).



Source: NEMUS (2014)

Figure 109 – Woodlands' vegetation as feedstock (1)



Source: NEMUS (2014)

Figure 110 – Woodlands' vegetation as feedstock (2)



Source: NEMUS (2014)

Figure 111 – Woodlands' vegetation as feedstock (3)



Source: NEMUS (2014)

Figure 112 – Woodlands' vegetation as feedstock (4)



Population growth and the human dependence of this habitat have lead to a decrease and degradation of woodland landscapes. Land clearing for agricultural expansion and intensive wood extraction (for timber, firewood and charcoal) result in the increasing of soil erosion and loss of habitat and biodiversity (Lowore, 2006) (Figure 113, Figure 114, Figure 115 and Figure 116). This habitat has generally a low productivity which further exacerbates the impact of the practised wood harvest (Fisher & Shively, 2006).



Source: NEMUS (2014)

Figure 113 – Wood harvest



Source: NEMUS (2014)

Figure 114 – Exploitation of *Gmelina arborea*



Source: NEMUS (2014)

Figure 115 – Wood and charcoal transportation (1)



Source: NEMUS (2014)

Figure 116 – Wood and charcoal transportation (2)



Currently, the areas that exhibit the true representative species of pristine woodlands are graveyards (*Manda*). They represent forest islands of unspoiled vegetation due to their sacred value and communities' beliefs (Mauambeta *et al.*, 2010) (Figure 117).



Source: NEMUS (2014)

Figure 117 – Graveyard in study area

Some woodland areas occur in patches with cultivated lands or with human settlements, which restricts their conservation status. Better conserved woodlands seem to occur in the left bank of the Katete River and scattered along the study area in patches with woodland areas less diverse and/or complex.

Forest plantation

As mentioned before, although natural woodlands provide important and valuable timbers, its intrinsic productivity is low. And a need for more available wood resources grows with the increase and expansion of the population.

Forest plantation is a semi-natural biotope originated from a human planted and/or seeded area, with either introduced or indigenous species, with the main purposes of reforestation (in case of indigenous species), minimising environmental degradation by deforestation of pristine woodlands and production for human exploitation as a sustainable supply of wood. When these plantations are intended for local communities' purposes and not industrial purposes, they are also called "woodlots".



In the study area, part of the area of Dzalanyama Forest Reserve is occupied by forest plantation of *Eucalyptus* sp. (55.39 ha), an exotic species to Malawi (Figure 118 and Figure 119). In several countries, this species is frequently planted because of its fast growth and high wood productivity (Chamshama *et al.*, 2010).



Source: NEMUS (2014)

Figure 118 – *Eucalyptus* sp. forest plantation in the study area (1)



Source: NEMUS (2014)

Figure 119 – *Eucalyptus* sp. forest plantation in the study area (2)

This area, due to its monospecific vegetation composition, has a low carrying capacity to fauna. Therefore more tolerant species are expected, like some avifauna species (*Buteo buteo*), rodents (*Dasymys incomtus*) and some bats (*Eidolon helvum*).



Source: NEMUS (2014)

Figure 120 – Planted garden areas in the study area (1)



Source: NEMUS (2014)

Figure 121 – Planted garden areas in the study area (2)



In the study area other small areas were identified as forest plantations and are mainly planted garden areas with both indigenous and exotic ornamental species, and with frequent human intervention (Figure 120 and Figure 121).

Lilongwe and Katete rivers

The study area includes the stretch of the Lilongwe River located immediately upstream Kamuzu Dam I, and the final stretch of the Katete River before reaching the Lilongwe River. Both stretches are non-natural due to the retention provided by the dam.

The Lilongwe River is a permanent freshwater course relevant to all biological populations, including human population. People use the river for economic, social and cultural purposes (fishing, bathing, washing, sand and clay digging) (Figure 122, Figure 123, Figure 124 and Figure 125).

According to local population, the Katete River is a seasonal riverine system. The strong influence of the dam downstream and several artificial and natural barriers heighten the intermittent nature of this stretch of river.

This habitat has an intrinsic low conservation status, considering its level of human intervention and existing pressure: the presence of the Kamuzu I dam and the water needs of the population affect the carrying capacity of this aquatic habitat profoundly, which is reflected on the biological communities that it supports.



Source: NEMUS (2014)

Figure 122 – Human uses and pressures on riverine habitats (1)



Source: NEMUS (2014)

Figure 123 – Human uses and pressures on riverine habitats (2)



Source: NEMUS (2014)

Figure 124 – Human uses and pressures on riverine habitats (3)



Source: NEMUS (2014)

Figure 125 – Human uses and pressures on riverine habitats (4)

The aquatic fauna includes invertebrate species, like aquatic insects and molluscs, and vertebrate species, such as fishes, amphibians and aquatic avifauna (Figure 126, Figure 127, Figure 128 and Figure 129). There has been no recent monitoring on the status and distribution of *Crocodylus niloticus* (Crocodile) in the area (Jenkins *et al.*, 2004) although bibliographic references confirm the presence of this species in the Lilongwe and Lingadzi rivers (IUCN, 1982).



Source: NEMUS (2014)

Figure 126 – Aquatic fauna occurring in the study area: bivalve molluscs



Source: NEMUS (2014)

Figure 127 – Aquatic fauna occurring in the study area: fishes



Source: NEMUS (2014)

Figure 128 – Aquatic fauna occurring in the study area: avifauna (1)



Source: NEMUS (2014)

Figure 129 – Aquatic fauna occurring in the study area: avifauna (2)

Human settlements and infrastructure areas

In the study area the artificial areas are represented by human settlements (Figure 130 and Figure 131).

Characterised by ruderal, opportunists and ubiquitous floristic and faunistic communities when occurring, the ecological value of these non-natural areas is null.



Source: NEMUS (2014)

Figure 130 – Human settlements and infrastructure areas within the study area (1)



Source: NEMUS (2014)

Figure 131 – Human settlements and infrastructure areas within the study area (2)

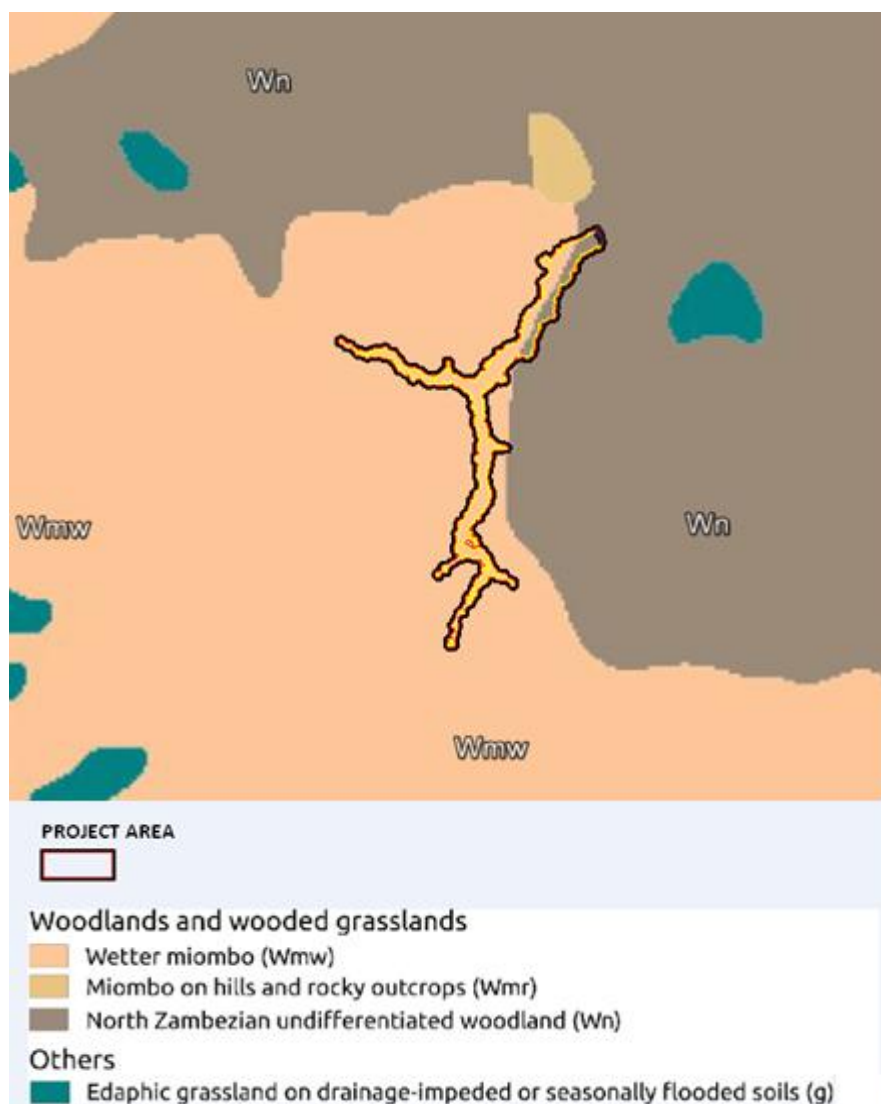


5.9.3. Vegetation and flora

5.9.3.1. Vegetation

Phytogeographically the study area is located in the North Zambezian unit, in the Zambezian Region, following White (1983).

The vegetation types of this Phytocoria are “Wetter Zambezian miombo woodland” and “North Zambezian undifferentiated woodland and wooded grassland” (Figure 132).



Source: adapted from VECEA

Figure 132 – Macro-scale vegetation framework of the study area



The first vegetation type is associated with the Zambezian dry evergreen forest and thicket, the Zambezian swamp forest, the Zambezian evergreen riparian forest and wet dambos. The second vegetation type is characterised by the nonexistence of the dominant species of miombo woodland and mopane woodland and scrub woodland, although it is composed of more tree species than those of miombo or mopane woodlands (White, 1983; Kindt *et al.*, 2011).

Wet miombo is characterised by moister soils due to the more than 1000 mm rainfall per year, which favours species growth and richness (Desanker *et al.*, 1997); the dominant genera are *Brachystegia*, *Julbernardia* and *Isoberlinia*, although in the study area the first two are the most common.

Some authors have distinguish between three types of miombo woodland: *Brachystegia* – *Julbernardia plateau* woodland; *Brachystegia* – *Isoberlinia plateau* woodland; and *Brachystegia* escarpment, hill and foothill woodland. However, according to Kindt *et al.* (2011), there is no substantive information that allows this differentiation. Moreover, in some areas there is a mixture between *Brachystegia* species and species from undifferentiated woodland or riparian forests, which hampers this distinction.

Dominant occurring species are: *Brachystegia floribunda*, *B. boehmii*, *B. glaberrima*, *B. taxifolia*, *B. wangermeeana*, *Julbernardia globiflora* and *J. paniculata* (Figure 133; Kindt *et al.*, 2011).



Source: NEMUS (2014)

Figure 133 – *Julbernardia globiflora*
identified during fieldwork



Source: NEMUS (2014)

Figure 134 – *Dichrostachys cinerea*
identified during fieldwork



Characteristic but not dominant species are: *Burkea Africana*, *Dombeya rotundifolia*, *Flacourtia indica*, *Parinari curatellifolia*, *Pericopsis angolensis*, *Pterocarpus angolensis* and *Terminalia sericea*. Other species frequently found are: *Antidesma venosum* (riverine species), *Combretum zeyheri*, *Dichrostachys cinerea*, *Kigelia Africana*, *Piliostigma thonningii* and *Vangueriopsis lanciflora* (Figure 134; Kindt et al., 2011).

According to White (1983), undifferentiated woodland has two main variants: “riparian woodland and wooded grassland” and “undifferentiated woodland on upper valley soils in Zambia”. In the study area only the first one occurs and is developed on alluvium fringing of permanent water courses (White, 1983).

Some species listed for these areas are: *Acacia polyacantha*, *Azelia quanzensis*, *Albizia harveyi*, *Burkea africana*, *Kigelia africana*, *Philenoptera violacea*, *Pseudolachnostylis maprouneifolia*, *Pterocarpus angolensis*, *Terminalia sericea*, *T. mollis*, *Trichilia emetica* and *Xeroderris stuhlmannii*, and also several species of *Combretum* (*C. adenogonium*, *C. collinum*, *C. imberbe* and *C. molle*) (White, 1983; Timberlake, 2010).

Undifferentiated woodlands in Malawi have numerous and overlapping species assemblages. Recent studies have proposed five subtypes on this vegetation type (Kindt et al., 2011), with the one occurring in the study area being “*Combretum-Acacia-Piliostigma* woodland and thicket”.

This vegetation type is described for the Central Plateau of Malawi with both miombo woodland and dambo grassland (Kindt et al., 2011). This data reiterates Shaxson’s vegetation/biotic communities map (1977), since the unit that encompasses the study area is “open canopy woodland of fertile areas”, with the three major genres being *Piliostigma*, *Acacia* and *Combretum*.

Characteristic species of *Combretum-Acacia-Piliostigma* woodland and thicket include: *Acacia polyacantha*, *Acacia sieberiana*, *Albizia amara*, *Albizia versicolor*, *Brachystegia bussei*, *Combretum collinum*, *Combretum zeyheri*, *Flueggea virosa*, *Ozoroa insignis*, *Piliostigma thonningii*, *Pseudolachnostylis maprouneifolia*, *Pterocarpus angolensis*, *Strychnos potatorum*, *Strychnos spinosa*, *Ziziphus abyssinica* (Figure 135; Kindt et al., 2011).



Source: NEMUS (2014)

Figure 135 – *Piliostigma thonningii* identified during fieldwork)

5.9.3.2. Flora

More than 6000 plant species are recorded in Malawi; 122 of these species are endemic and 248 are identified in the National Red Data List, of which more than half (128 species) are regarded as threatened (EAD, 2014; Malawi Government, s.d.).

The two vegetation types occurring in the study area are floristically rich units that include both ubiquitous and frequent species and species that have a more restrict distribution and/or exhibit some degree of threat.

Malawi's great flora diversity results from the distinct occurring habitats. In the study area the occurring diversity is also a reflection of the existing habitats. The alteration of some pristine areas due to habitat conversion and exploitation probably led to a decline of specialist species.

To list the threatened species potentially occurring in the study area, species' habitat requirements were crossed with species' distribution area, according to the Red Data List of the Southern African Botanical Diversity Network (SABONET).



Species that are Extinct or Threatened include: *Aloe bulbicaulis*, *Aloe cannellii*, *Aloe chabaudii* var. *chabaudii*, *Aloe cryptopoda*, *Aloe myriacantha*, *Aloe swynnertonii*, *Afzelia quanzensis*, *Dalbergia melanoxylon*, *Humularia descampsii*, *Pterocarpus angolensis*, *Ficus ottoniifolia* ssp. *ulugurensis*, *Milicia excelsa*, *Morus mesozygia*, *Aerangis distinct*, *Prunus Africana*, *Morinda asteroscepa* and *Rytigynia adenodonta* var. *reticulate* (Figure 136).



Source: NEMUS (2014)

Figure 136 – Fruit of *Pterocarpus angolensis* (1)

At Lower Risk are the following species: *Aloe duckeri*, *Aloe zebrina*, *Ceropegia paricyma*, *Asplenium unilateral* and *Pteleopsis myrtifolia*.

As Data Deficient the following species are registered: *Fuirena nyasensis*, *Monadenium parviflorum*, *Lotus mlanjeanus*, *Rhynchosia clivorum* var. *fulvida*, *Habenaria pubipetala*, *Polystachya goetzeana*, *Solenangis conica*, *Platyserium elephantotis* and *Coffea mufindiensis* ssp. *australis*.

Aquatic vegetation comprises many forms: vascular macrophytic species, filamentous attached algae, phytoplankton and unicellular demersal algae. The aquatic vascular species are classified according to their life-forms as: rooted emergent macrophytes (like *Phragmites mauritianus*), rooted macrophytes with floating leaves (like *Eichhornia crassipes*), rooted submerged with floating leaves (as *Potamogeton* spp.) and free-floating macrophytes (EAD, 2006).

From the estimated 6000 plant species in the country, almost 10% (555 species) represent food resources and some also represent economic



resources since they may be exploited as such. Some examples are: *Zea mays* (maize), *Manihot esculentum* (cassava) and *Vigna subterranea* (bambara groundnuts) (Malawi Government, s.d.).

In Malawi more than 75 species of edible fruits are described, like *Uapaca kirkiana*, *Parinari curatellifolia*, *Strychnos cocculoides*, *Flacourtia indica*, *Diospyros mespiliformis* and *Azanza garkceana* (Shackleton *et al.*, 2010).

Other species are harvested for fuelwood or show potential for timber plantations, due to their fast growth and high quality wood, like *Azanza garkceana* and *Pteleopsis myrtifolia* (Malawi Government, 1995).

Some species become relevant due to their medicinal use: about 131 plant species of Malawi are used for medical purposes, and most of them grow as wild plants (Malawi Government, s.d.; Baumann, 2005; Morris, 2009; SABONET), like *Prunus africana*.

Alien plant species are frequently harmful agents that may compete or hybridize with native species, affecting the entire ecosystem. In the study area, *Eucalyptus* sp. and *Gmelina arborea* are common species occurring, frequently planted as fuel wood (as previously mentioned in section 5.9.2 – woodlands and forest plantations; Figure 114, Figure 118 and Figure 119).

Recently, new alien species have been introduced in the country as biofuel, namely *Acacia mearnsii* (black wattle), from Australia, and *Jatropha curcas*, from South America (CHM).

Other alien species are registered in the country such as *Eichhornia crassipes* (water hyacinth), *Prosopis glandulosa* (mesquite), *Lantana camara* (lantana), *Rubus* spp., *Salvinia molesta* (kariba weed) and *Pistia stratiotes* (water lettuce) (Macdonald *et al.*, 2003; EAD, 2006).

5.9.4. Fauna

The raising of the dam will directly affect the aquatic environment and the terrestrial environment in its surroundings, and indirectly the terrestrial habitats



located further inland, which justifies the analysis of both aquatic and terrestrial fauna.

Existing information on the fauna groups occurring specifically in the study area is scarce; nevertheless, the analysis was based on the carrying capacity of the existing habitats, cross-checked with the habitat preferences of the faunistic species described for the area.

5.9.4.1. Aquatic macro-invertebrates

At the present time there is no certainty on the existing aquatic macro-invertebrates' richness of Malawi. Several studies undertaken in the country have registered 280 species of non-insect aquatic invertebrates, distributed among Molluscs, Nematodes, Crustaceans, Annelids and others (Figure 137; EAD, 2006; CHM). The total encompasses over 9,197 species, including insects (Dudley, 1998; Kamwendo *et al.*, 2005).



Source: NEMUS (2014)

Figure 137 – Riverine bivalve mollusc and gastropod shells

The relevance of this faunistic group lies on the fact that it constitutes an important food resource to other faunistic communities such as fishes and avifauna.

In Malawi, eight species of invertebrates were assessed with a Red List category above “Least Concern” according to IUCN (2014): two species are “Critically Endangered”; one species is “Endangered”; four species are



“Vulnerable” and one species is “Near Threatened”. Some of these species are restricted to specific areas (like *Allocnemis macleayi*, *Allocnemis montana* and *Oreocnemis phoenix*), while others have montane or dense forest habitats as preferential sites of occurrence (like *Chlorocypha jacksoni*, *Chlorolestes elegans*, *Nepogomphoides stuhlmanni*, *Teinobasis alluaudi* and *Umma declivium*); therefore their presence in the study area is unlikely.

5.9.4.2. Ichthyofauna

In Malawi, 800 fish species from the 850 species described for the country occur in Lake Malawi, and about 95% of these species are cichlids and 99% are endemic to the Lake (EAD, 2014). In riverine habitats cyprinids and some species of catfish can occur and represent important fishing resources.

According to the IUCN Red List (2014), 119 fish species occurring in Malawi have a conservation status above “Least Concern”: nine species were assessed as “Endangered”, 89 as “Vulnerable” and three as “Near Threatened”; 18 species are “Data Deficient”. Many species are endemic to Lake Malawi (like *Aulonocara ethelwynnae*, *Aulonocara nyassae*, *Buccochromis atritaeniatus*, *Cynotilapia zebroides* and *Labidochromis pallidus*) or occur exclusively in lacustrine habitats, whilst other species have lotic habitat preferences (like *Pangio filinaris*) or a more ubiquitous distribution (like *Megalops cyprinoides* and *Oreochromis mossambicus*).

Species potentially occurring in the study area include both species with lotic and lentic habitat preferences. During the fieldwork several fishermen mentioned as common species occurring (in decreasing order of abundance): kambuzi (or akachakwa), nkhalala and mphondo (or mphuta).

Tilapia rendalli (matemba) and *Clarias gariepinus* (mlamba) are also described for the study area. These are native species with a wide range and ubiquitous habitat demands and preferences, which justifies a “Least Concern” assessment to both according to the IUCN Red List (Figure 138; IUCN, 2014).



Source: NEMUS (2014)

Figure 138 – *Clarias gariepinus* (mlamba)

Cyprinus carpio is an alien species frequently introduced as food resource. *Oreochromis* is a genus that includes native species like *O. mossambicus* and *O. squamipinnis*, and alien species like *O. niloticus* and *O. leucostictus*, already registered in the Lake Malawi according to Genner *et al.* (2013).

In the study area, fish fauna is a relevant food resource to local human populations as well as an economic resource (Figure 139). To prevent the overexploitation of fish species there are laws that regulate the seasonal closures of some species. Nevertheless, overfishing is one of the main causes of decline of the existing fish species.



Source: NEMUS (2014)

Figure 139 – Informal fish sale in the study area



Habitat deterioration and introduction and proliferation of invasive alien species are the other two main threats to native ichthyofauna. Water quality degradation and altered flow regimes that do not mimitise the natural flow regimes promote the maintenance and proliferation of tolerant fish spices. Hybridization of exotic species with native species leads to fish genetics' erosion (EAD, 2006). Moreover, exotic species are usually aggressive and voracious and compete with native species for food and space resources.

Fishing is done throughout the study area, but the bigger specimens are expected to be caught in the lacustrine habitat provided by Kamuzu Dam I. River sections in the upstream areas frequently show a small support capacity to fish species, consequence of the reduced river flow and human pressure, which may limit the occurring fish diversity (Figure 140, Figure 141, Figure 142 and Figure 143).



Source: NEMUS (2014)

Figure 140 – Fishing in the study area (1)



Source: NEMUS (2014)

Figure 141 – Fishing in the study area (2)



Source: NEMUS (2014)

Figure 142 – Fish trap in the study area (1)



Source: NEMUS (2014)

Figure 143 – Fish trap in the study area (2)



5.9.4.3. Herpetofauna

There are no accurate numbers for the total number of amphibian species in Malawi but according to the last National Report to the Convention on Biological Diversity 83 species are described, of which six species are endemic and nine were assessed in the IUCN Red List in a category different from “Least Concern” (EAD, 2014; IUCN, 2014).

From the nine species assessed into the IUCN Red List (2014):

- *Nothophryne broadleyi*, *Amietia johnstoni*, *Arthroleptis franciei* and *Ptychadena broadleyi* are “Endangered” and occur mainly in Mount Mulanje, the last three are endemic (*Ptychadena broadleyi* also exists at the Zomba Plateau);
- *Mertensophryne nyikae* is “Vulnerable” and in Malawi occurs specifically on Nyika Plateau;
- *Arthroleptis reichei* is “Near Threatened” and is a montane species with described occurrence for Misuku Hills;
- For the other three species, *Amietia viridireticulata*, *Phrynobatrachus stewartae* and *Phrynobatrachus ukingensis*, the lack of information does not allow a grounded assessment, thus they were classified as “Data Deficient”.

The assessed species are described for a specific spatial range that does not include the study area, even though for some species the preferential habitats of occurrence are habitats similar to those found in the study area.



Source: NEMUS (2014)

Figure 144 – *Agama* sp. sighted during fieldwork



Also for reptile species there is a lack of accuracy in terms of total diversity. There are 145 reptile species described for Malawi, from which eight are endemic and four are identified with a relevant conservation status in the IUCN Red List (Figure 144; EAD, 2014; IUCN, 2014).

The chameleon *Rhampholeon chapmanorum* is “Critically Endangered” due to the intense pressure over its small and fragmented occurrence area. *Nadzikambia mlanjensis* and *Rhampholeon platyceps* are also chamaeleonidae species and are endemic to Mount Mulanje; both are “Endangered”. *Cycloderma frenatum*, a freshwater tortoise, is assessed as “Near Threatened” although the updating of the available data is advised (IUCN, 2014). For the species *Crocodylus niloticus* (Crocodile), *Pelusios castanoides* and *Pelusios rhodesianus*, currently assessed as “Least Concern”, it is also advised to update the available data.

There has been no recent monitoring on the status and distribution of *Crocodylus niloticus* (Crocodile) in the area (Jenkins *et al.*, 2004) although bibliographic references confirm the presence of this species in the Lilongwe and Lingadzi rivers (IUCN, 1982). During the field work a fisherman confirmed the existence of one identified specimen in the Katete River and another in the Kamuzu dam II area. This fisherman claimed to have seen the Katete River specimen recently (early November) when collecting his own fishing nets.

5.9.4.4. Avifauna

According to the last National Report to the Convention on Biological Diversity (EAD, 2014) there are over 630 bird species in Malawi, comprising migrant species and species that at least for part of their life cycle live in close association with aquatic habitats. Only one endemic species is described for the country, *Apalis flavigularis* (EAD, 2014).

A total of 36 species are listed in the IUCN Red List (2014) with a category different from “Least Concern”: eight species are listed as “Endangered”; 10 species are listed as “Vulnerable”; and 18 species are listed as “Near Threatened”.



Several species can potentially occur in the study area, depending on the available habitats and species' habitat needs and preferences: *Anthreptes anchietae* (Anchieta's Sunbird), *Accipiter melanoleucus* (Black Sparrowhawk), *Ardea melanocephala* (Black-headed Heron), *Bubo lacteus* (Verreaux's Eagle-owl), *Bugeranus carunculatus* (Wattled Crane), *Buteo buteo* (Eurasian Buzzard), *Ceryle rudis* (Pied Kingfisher), *Circus macrourus* (Pallid Harrier), *Coracias caudatus* (Lilac-breasted Roller), *Motacilla aguimp* (African pied wagtail), *Platalea alba* (African Spoonbill) and *Polemaetus bellicosus* (Martial Eagle) (Figure 145, Figure 146 and Figure 147).



Source: NEMUS (2014)

Figure 145 – *Ceryle rudis* (Pied Kingfisher) identified during fieldwork



Source: NEMUS (2014)

Figure 146 – *Ardea melanocephala* (Black-headed Heron) identified during fieldwork



Source: NEMUS (2014)

Figure 147 – *Motacilla aguimp* (African pied wagtail) identified during fieldwork



The proximity of the Dzalanyama Forest Reserve also guarantees a relevant habitat for several bird species, since it is considered a hotspot for this fauna group (African Bird Club, 2014). Species described for this area include: *Dendropicos stierlingi* (Stierling's Woodpecker) and *Ploceus olivaceiceps* (Olive-headed Weaver) (as “Near Threatened”); *Poicephalus robustus* (Brown-necked Parrot), *Elminia albicauda* (White-tailed Blue-flycatcher), *Monticola angolensis* (Miombo Rock-thrush), *Hyliota australis* (Southern Hyliota) and *Terpsiphone viridis* (African Paradise-flycatcher) (as “Least Concern”) (African Bird Club, 2014; EAD, 2014).

The species *Balearica regulorum* (Grey Crowned-crane) was occasionally sighted in Lilongwe, but there are no present records. This fact was supported by local inquiries to village chiefs who identified this species as extinct in the study area (Figure 148).



Source: NEMUS (2014)

Figure 148 – Interviews with the village chiefs to survey about some species

Habitat degradation and loss as a result of clearing, drainage and conversion to agro-pastoral systems are the major threats to bird species that occur in the study area. These threats restrict the preferential areas of occurrence of the species, which may lead to the populations' decline.



5.9.4.5. Mammals

At least 192 mammal species are recorded for Malawi, according to the Malawi Report to the Convention of Biological Diversity (EAD, 2014). Several of these species with terrestrial and aquatic affinities may occur in the study area.

A total of 24 species have been assessed with a concern category in the IUCN Red List (2014). While some of these species are not described for the area, like *Diceros bicornis* (Black Rhinoceros) (extinct but was recently reintroduced in some protected areas) (“Critically Endangered”), *Acinonyx jubatus* (Cheetah), *Panthera leo* (Lion) and *Loxodonta Africana* (African Elephant) (all as “Vulnerable” species), others may potentially occur in the study area or its vicinity, like *Hippopotamus amphibius* (Hippopotamus) and *Otomys lacustris*, as “Vulnerable”, and *Kobus vardonii*, as “Near Threatened”. A fisherman claimed that nowadays hippopotamus do not occur in the study area but they used to; according to him, currently a known specimen occurs at Kamuzu Dam II (Figure 149).



Source: NEMUS (2014)

Figure 149 – Informal interview with a fisherman

Amongst the species assessed as “Low Concern” many may potentially occur in the study area, since their habitat requirements match with the occurring biotopes in the study area: *Aonyx capensis* (African Clawless Otter), *Civettictis civetta* (African Civet), *Dasymys incomtus* (African Marsh Rat) and *Thryonomys swinderianus* (Greater Cane Rat).



The species *Lutra maculicollis*, *Atilax paludinosus* and *Kobus ellipsiprymnus* should be highlighted since their populations are in decline. Major threats over these species include alteration or degradation of freshwater habitats and riparian vegetation, and the loss of habitat as a consequence of conversion to agro-pastoral systems (IUCN, 2014).

Happold & Happold (1998) registered for the Dzalanyama Forest Reserve the presence of the rodents *Dendromus melanotis*, *Aethomys chrysophilus*, *Dasymys incomtus* and *Grammomys cometes*.

Domesticated livestock like goats, cattle, poultry, donkeys and swine represent a relevant economic and food resource to human populations (Morris, 2009). During the fieldwork livestock and farm animals were frequently seen under free range near the human settlements (Figure 150, Figure 151, Figure 152 and Figure 153).

Bats represent a particular group inside the mammals. The total number of species has been updated from 55 (recorded by Happold *et al.* in 1987), to 59 (Happold & Happold, 1997) and currently to 66 species, according to the African Chiroptera Report (AfricanBats, 2014).



Source: NEMUS (2014)

Figure 150 – Domesticated livestock identified in settlements within the study area: goats



Source: NEMUS (2014)

Figure 151 – Domesticated livestock identified in settlements within the study area: cattle



Source: NEMUS (2014)

Figure 152 – Domesticated livestock identified in settlements within the study area: pigs



Source: NEMUS (2014)

Figure 153 – Domesticated livestock identified in settlements within the study area: poultry

58 bat species are assessed in the IUCN Red List, eight of them are in categories different from “Least Concern”: *Eidolon helvum*, *Otomops martiensseni* and *Hipposideros vittatus* are assessed as “Near Threatened”; *Epomophorus anelli*, *Neoromicia flavescens*, *Plerotes anchietae*, *Scotoecus albobfuscus* e *Tadarida ventralis* are assessed as “Data Deficient” (IUCN, 2014).

Some species are widespread and adaptable (like *Eidolon helvum*, *Epomophorus labiatus* and *Epomophorus crypturus*), thus there are no major threats to their populations; others have a more restrict or scattered distribution and threats like deforestation, agricultural development and collection of timber and firewood may compromise populations’ size and structure (like in *Plerotes anchietae* and *Rousettus lanosus*).

Several species have aquatic affinities since they use rivers and lakes as main hunting biotopes, like *Laephotis botswanae*; others are usually recorded from miombo woodlands, like *Epomophorus anelli* and *Epomophorus labiatus* (AfricanBats, 2014); these species represent potential occurrences in the study area.

Happold & Happold (1998) have registered for the Dzalanyama Forest Reserve (following the nomenclature of ACR, 2014): *Epomophorus crypturus*, *Rhinolophus clivosus*, *Rhinolophus fumigatus*, *Scotoecus* sp., *Neoromicia capensis*, *Scotophilus viridis* and *Pipistrellus* sp. (probably *P. hesperidus*).



5.10. Land Use and Spatial Planning

5.10.1. Land use

5.10.1.1. Quantitative results

In the present section the Land Cover Map provided by the Lilongwe Water Board (LWB) for the Lilongwe District area was analysed and shaped in Geographic Information System (GIS). The main goal was to know the land uses by area (in km²) considering the district, TA and study area level. Afterwards, the land use percentage to each class was calculated.

In the Lilongwe District, the predominant land uses are *Rainfed Herbaceous Crop(s) Small (<2ha)* (62.4%), *Woodland Open General (15-65%) with Herbaceous Layer* (12.3%) and *Cultivated Dambo* (10.7%). In TA Chiseka, the dominant land uses are the same, but with different proportions (44.2%, 38.1% and 12.7%, respectively) (Table 33).

Table 33 – Land uses in Lilongwe District in and TA Chiseka

Land Uses	Area Lilongwe District		TA Chiseka	
	Area (km ²)	%	Area (km ²)	%
ARTIFICIAL AREAS	239.9	3.8	3.3	0.2
<i>Built Up, Urban/ Built Up, Non-Urban</i>	169.2	2.7	-	-
<i>Built up Urban Non-Urban/ Rainfed Herbaceous Crop(s) Small (<2 ha)</i>	70.7	1.1	3.3	0.2
AGRICULTURAL LAND	4,689.1	76.1	890.2	57.4
<i>Cultivated Dambo</i>	660.2	10.7	192.6	12.4
<i>Rainfed Herbaceous Crop(s) Small (<2 ha)/ Woodland Open General (15-65%) with Herbaceous Layer</i>	22.4	0.4	1.3	0.1
<i>Rainfed Herbaceous Crop(s) Large to Medium Field(s) (>2 ha)</i>	127.1	2.1	10.3	0.7
<i>Rainfed Herbaceous Crop(s) Small (<2 ha)</i>	3,847.7	62.4	686	44.2
<i>Rainfed Herbaceous Crop(s) – Small Field(s) (<2 ha) with a layer of Sparse Trees</i>	2.1	0.0	-	-
<i>Rainfed Herbaceous Crop(s) Small (<2 ha)/ Built up Urban Non-Urban</i>	3.3	0.1	-	-



Land Uses	Area Lilongwe District		TA Chiseka	
	Area (km ²)	%	Area (km ²)	%
<i>Rainfed Herbaceous Crop(s) Small (<2 ha)/ Shrubland Closed to Open (Thicket) (100-15%)</i>	26.3	0.4	-	-
WATER BODIES	7.1	0.1	4.2	0.3
<i>Perennial Artificial Waterbodies (Standing)</i>	2.7	0.0	2.7	0.2
<i>Perennial Natural Waterbodies (Standing)</i>	0.8	0.0	0.8	0.1
<i>Permanent Marsh</i>	3.6	0.1	0.7	0.0
WOODLANDS AND INDIGENOUS VEGETATION	1,231.1	19.9	652.8	42.1
<i>Bare Rock And/ Or Coarse Fragments</i>	4.4	0.1	-	-
<i>Broadleaved Deciduous Trees, Closed > (70-60)%</i>	14.8	0.2	1.1	0.1
<i>Dambo Herbaceous Vegetation On Temporarily Flooded Land</i>	208.9	3.4	10.4	0.7
<i>Forest Plantation</i>	60.4	1.0	45.1	2.9
<i>Herbaceous closed vegetation (15-100%)</i>	21	0.3	5	0.3
<i>Shrubland Closed to Open (Thicket) (100-15%)</i>	10	0.2	-	-
<i>Shrubland Closed to Open (Thicket) (100-15%)/ Rainfed Herbaceous Crop(s) Small (<2 ha)</i>	112.6	1.8	-	-
<i>Tree and Shrub Savannah</i>	13.7	0.2	-	-
<i>Woodland Open General (15-65%) with Herbaceous Layer</i>	755.9	12.3	591.2	38.1
<i>Woodland Open General (15-65% with Herbaceous Layer/Built Up Urban Non-Urban</i>	1.8	0.0	-	-
<i>Woodland Open General (15-65%) with Herbaceous Layer/ Rainfed Herbaceous Crop(s) Small (<2 ha)</i>	27.6	0.4	-	-
TOTAL	6,167.3	100.0	1,550.3	100.0

Additionally, the results show that agricultural and forestry production have a great relevance for regional social and economic development and, as consequence, in the occupied area. Note that *Agricultural Land* and *Woodlands and Indigenous Vegetation* groups represent 96.0% of the total area in the Lilongwe District and 99.5% in TA Chiseka.

To back up this assertion, the percentage of artificial areas is residual (3.8% in the Lilongwe District and only 0.2% in TA Chiseka). The results also show that artificial areas are mostly concentrated in Lilongwe City.



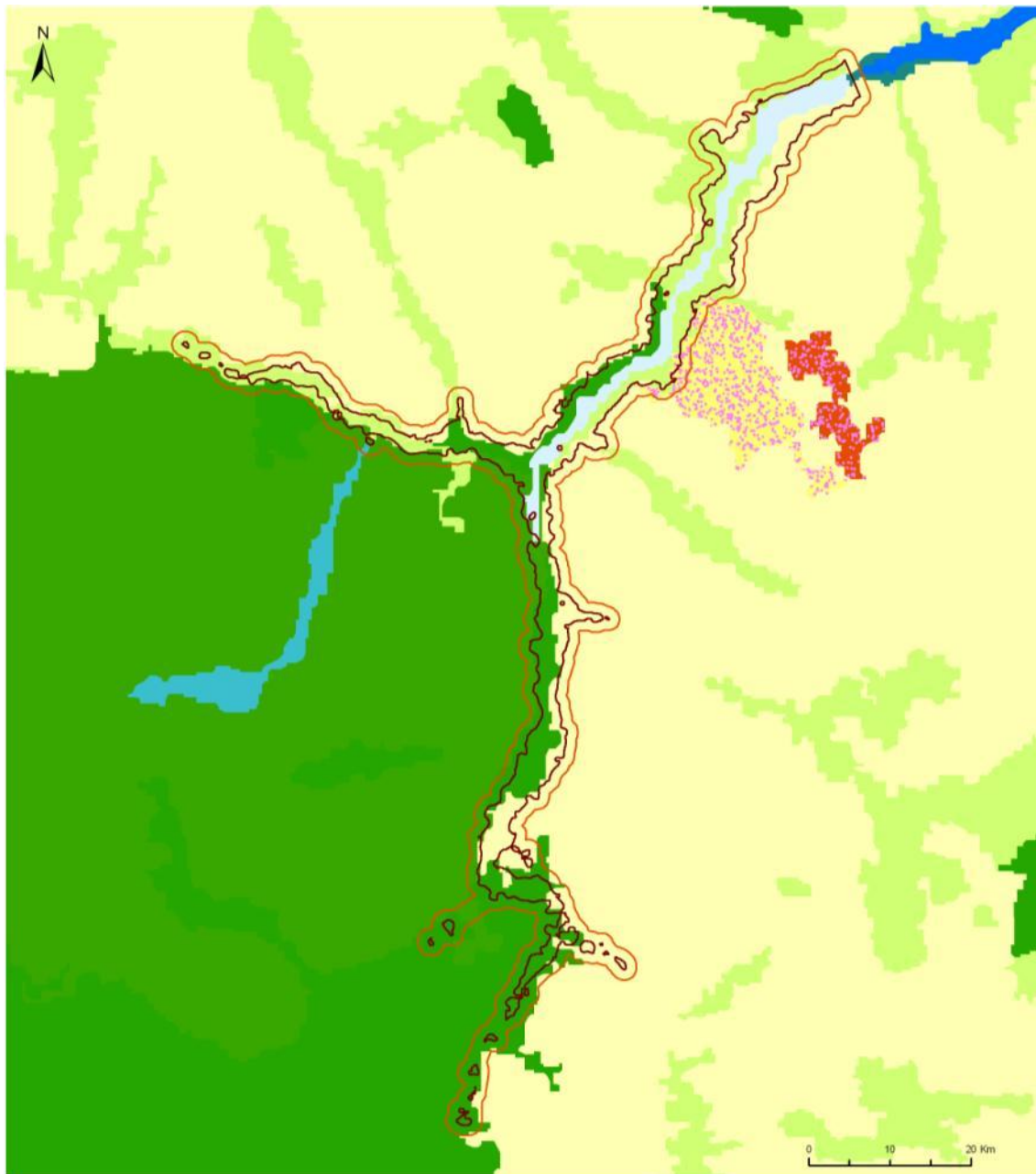
Table 34 and Figure 154 show the analysis of the major groups of land uses within the study area.

Table 34 – Land uses within the study area

Land Uses	FSL at 1,105 masl		100 m study buffer area		Cumulative	
	Area (km ²)	%	Area (km ²)	%	Area (km ²)	%
AGRICULTURAL LAND	2.0	49.3	2.7	62.6	4.7	56.1
<i>Cultivated Dambo</i>	<i>1.0</i>	<i>24.1</i>	<i>0.6</i>	<i>14.4</i>	<i>1.6</i>	<i>19.1</i>
<i>Rainfed Herbaceous Crop(s) Small (<2 ha)/ Woodland Open General (15-65%) with Herbaceous Layer</i>	<i>0.0</i>	<i>0.5</i>	<i>0.1</i>	<i>2.5</i>	<i>0.1</i>	<i>1.5</i>
<i>Rainfed Herbaceous Crop(s) Small (<2 ha)</i>	<i>1.0</i>	<i>24.7</i>	<i>2.0</i>	<i>45.6</i>	<i>3.0</i>	<i>35.4</i>
WATER BODIES	0.8	19.0	0.0	0.3	0.8	9.4
<i>Perennial Natural Waterbodies (Standing)</i>	<i>0.8</i>	<i>19.0</i>	<i>0.0</i>	<i>0.2</i>	<i>0.8</i>	<i>9.3</i>
<i>Permanent Marsh</i>	<i>0.0</i>	<i>0.0</i>	<i>0.0</i>	<i>0.1</i>	<i>0.0</i>	<i>0.1</i>
WOODLANDS AND INDIGENOUS VEGETATION	1.3	31.7	1.6	37.1	2.9	34.5
<i>Dambo Herbaceous Vegetation On Temporarily Flooded Land</i>	<i>0.0</i>	<i>0.1</i>	<i>0.0</i>	<i>0.2</i>	<i>0.0</i>	<i>0.2</i>
<i>Forest Plantation</i>	<i>0.2</i>	<i>5.5</i>	<i>0.6</i>	<i>14.3</i>	<i>0.8</i>	<i>10.0</i>
<i>Woodland Open General (15-65%) with Herbaceous Layer</i>	<i>1.1</i>	<i>26.1</i>	<i>1.0</i>	<i>22.6</i>	<i>2.0</i>	<i>24.3</i>
TOTAL	4.1	100.0	4.3	100.0	8.4	100.0

From this, it is possible to conclude that:

- There are no affected artificial areas;
- Water bodies have a relative importance in the future flooded area (19.0%, considering the current reservoir FSL at 1,100 masl and Lilongwe River), but their importance decreases in the 100 m study buffer area (0.3%);
- Agricultural Land and Woodlands and Indigenous Vegetation are the most representative groups of land uses in the future flooded area (49.3% and 31.7%, respectively), increasing their relative importance in the 100 m study buffer area (62.6% and 37.1%).



Legend

Estimated future FSL at 1,105 masl

100 m study buffer area

Land Cover

RAINFED HERBACEOUS CROP(s) Small (< 2ha) (1Hcs)

RAINFED HERBACEOUS CROP(s) Small (< 2ha)/Woodland Open General (15-65%) with Herbaceous Layer (1Hcs/2TO)

CULTIVATED DAMBO (1HcMspf)

Forest Plantation (1Tcfp)

Woodland Open General (15-65%) with Herbaceous Layer (2TO)

Permanent Marsh (4Hcpf)

DAMBO Herbaceous Vegetation On Temporarily Flooded Land (4HcpfD)

Perennial Natural Waterbodies (Standing) (8Ws)

Source: adapted from data provided by LWB

Figure 154 – Land cover in study area and immediate surroundings



A detailed analysis of the affected area by the rehabilitation and raising of Kamuzu Dam I project allows to verify that:

- Within the estimated FSL area, Woodland Open General (15-65%) with Herbaceous Layer (26.1%), Rainfed Herbaceous Crop(s) Small (<2 ha) (24.7%) and Perennial Natural Waterbodies (Standing) (19.0%) are the most representative land uses;
- Within the 100 m study buffer area, the most significant land uses are Rainfed Herbaceous Crop(s) Small (<2 ha) (45.6%), Woodland Open General (15-65%) with Herbaceous Layer (22.6%) and Cultivated Dambo (14.4%);
- Additionally, Figure 154 and Table 34 show the cumulative sum of areas affected considering the estimated FSL and the 100 m study buffer area. The dominant land uses are Rainfed Herbaceous Crop(s) Small (<2 ha) (35.4%), Woodland Open General (15-65%) with Herbaceous Layer (24.3%) and Cultivated Dambo (19.1%).

5.10.1.2. Qualitative results

Qualitative analysis aims to describe the major groups of land uses (Artificial areas, Agricultural land, Water bodies and Woodlands and indigenous vegetation) in the aforementioned geographical areas, with more detail in the study area. Bibliographic review and fieldwork were the main sources of information to carry out the qualitative analysis.

Artificial areas

An important percentage of identified artificial areas is due to settlements. Typical built up areas in the Lilongwe District and TA Chiseka are unplanned settlements, with medium density housing (urban areas) or indigenous villages (rural areas, with low density) (Figure 155).



According to Table 33, built up areas (in urban or non-urban areas) represent 2.7% of the total area in the Lilongwe District, but it doesn't play any role in TA Chiseka. However, built up (in urban or non-urban areas) with small rainfed herbaceous crop(s) (<2 ha) already has some expression in TA Chiseka (0.2%). Despite this value, the Lilongwe District continues to have higher percentage of such land uses (1.1%).

In the study area itself the presence of artificial areas is residual – most of low density human settlements (villages) are located upland of the study area. Some houses and other human structures are scattered in agricultural and forest lands within the study area, mainly concentrated near KD1 and at the Katete area (settlement of Department of Forests).



Source: NEMUS (2014)

Figure 155 – Low density housing area

In section 5.11.7 it is possible to find detailed information about housing conditions in the Lilongwe District (urban and rural areas), as well as in the study area.

Another part of the artificial areas are institutional entities and facilities (e.g., education; Figure 156) or health and retail activities (e.g., markets). However, in rural areas, this type of land use can be included in other land uses, due to the scarce area occupied by infrastructures or buildings.



Source: NEMUS (2014)

Figure 156 – School at Chisauka

Lastly, infrastructures are usually developed with rudimentary/ local construction materials – especially wood and clay. For example, there are no paved roads (Figure 157) and river crossings are made either with cement culverts (e.g., at Sinyala, Chisauka and Katete – Figure 158) or local materials such as wood (Figure 159). For this reason, some infrastructures can be included in other groups.



Source: NEMUS (2014)

Figure 157 – Earth road



Source: NEMUS (2014)

Figure 158 – Bridge made with cement culverts



Source: NEMUS (2014)

Figure 159 – Wood pedestrian bridge

Agricultural land

As shown in section 5.10.1.1 and Table 33, agricultural land and activities have an important role in the Lilongwe District, particularly in rural areas.

Subsistence farming is the major occupation of the communities at a district level. The main cultures produced are maize, groundnuts and tobacco. There is limited irrigated cultivation on the riverbanks producing mainly vegetables and bananas.



In rural areas at a district level, some land classified as *Agricultural* can include subsistence farming areas/ gardens (developed near the houses), small scale industries, small grocery shops, market centers and institutional uses (e.g., prayer houses and schools).

In the study area and immediate surroundings, agriculture is developed in small holder farms based on rainfed maize production and tobacco. Other important planted crops are groundnuts and vegetables and other subsistence and consumption products within households (like irish and sweet potatoes, green beans, soyabeans, tomatoes, pumpkins, sugarcane, among others) – Figure 160.



Source: NEMUS (2014)

Figure 160 – Agricultural land

Water bodies

Kamuzu Dam I (Figure 162) and Kamuzu Dam II reservoirs are the main water bodies in (or near) the study area.

The Lilongwe River and the Katete River are the two main watercourses in the area, upstream Kamuzu Dam I.

Water bodies also include intermittent flooding areas, which are generated along small tributary streams affluent to Kamuzu Dam I water reservoir and the Lilongwe and Katete Rivers.



Source: NEMUS (2014)

Figure 161 – Kamuzu Dam I and tailwater from Kamuzu Dam II reservoir



Source: NEMUS (2014)

Figure 162 – Kamuzu Dam I reservoir

Fishing and livestock grazing are common activities in and around the reservoir margins. Agriculture, while respecting the reservoir's protection buffer demarked by the LWB, is developed along the riverbanks in the upstream area and along the Katete and Lilongwe Rivers.



Woodlands and indigenous vegetation

Despite the impact on natural vegetation cover caused by extensive deforestation over the last decades and intensive wood extraction, there are still some woodland and indigenous vegetation areas – represented by miombo in the study area. These areas frequently develop close to the riverbanks and therefore may also function as riparian vegetation. Currently, the areas that exhibit the true representative species of pristine woodlands are graveyards.

The left margin of the Lilongwe River (limited by the Katete River north) – within the Dzalanyama Forest Reserve – is occupied by forest plantation of *Eucalyptus* sp.

More detailed information in *Terrestrial and Aquatic Ecology* section (see 5.9).

5.10.2.Spatial Planning

5.10.2.1. Land and water management

In the Lilongwe District, urban land is under the jurisdiction of the Lilongwe City Council. The Planning and Development Department is responsible for all territorial planning and development. Usually, it works in articulation with other departments. Some territorial plans and strategies are produced or coproduced by the Planning and Development Department (e.g., revision of Lilongwe City Master Plan, in 2010).

Although the Town and Country Planning Act of 1988 provides the enabling authority for designating planning areas prior to the preparation of any land use planning schemes, territorial planning has been fundamentally on an *ad-hoc* basis in Malawian rural areas.

The Lilongwe City Master Plan is the main territorial plan in force in Lilongwe. Revised in 2010, the Lilongwe City Master Plan objectively defined the land use pattern in urban areas. However, in rural areas, land use patterns aren't defined, with rural settlements scattered into large agricultural fields.

In respect to water management, the *Water Resources Board* is the governmental entity responsible for its management. According to the Water



Resources Act in force until 2013, human settlements or agricultural production may be developed only at more than 50 metres of distance from the water body. So, the *Water Resources Board* had as mission to ensure that catchment areas weren't utilized for referred uses. However, in practice, the Water Resources Act was poorly enforced and, as a consequence, some catchment areas are occupied with houses and agricultural activities and water pollution problems are increasing.

The New Water Resources Act currently (published 19th April, 2013) doesn't define a minimum distance from the water body to human activities. According to section 86, "The Minister may, in relation to any water source, where the situation so requires due to shortage or anticipated shortage of water, by notice published in the Gazette and in such other manner appropriate for such areas as the Minister may see fit, on the advice of the Authority, declare any part of Malawi to be a controlled area and establish a comprehensive and integrated plan for managing land, water and other natural resources within that area." Section 87 defines controlled activities.

In conclusion, urban and rural areas in Lilongwe currently face different challenges. In the city, the absence of housing policies and upgrading strategies are the main challenges. As a consequence, housing development and urban sprawl is very active, including illegal and unplanned settlements, without urban facilities (e.g., urban water supply, and sewerage/on-sanitation). In rural areas, the main challenge is the correct land use's planning, without in any way prejudicing the sustainable development. In common, urban and rural areas also have similar challenges, such as the water management.

5.10.2.2. Territorial plans and strategies

Table 35 shows the main territorial plans and strategies in force in Malawi in general and in the Lilongwe District in particular, identifying their objectives.



Table 35 – Main territorial plans and strategies in force in Malawi and Lilongwe District

National Physical Development Plan (NPDP)	Geographical area	Malawi.
	Timeframe	Since 1987.
	General Objectives	Master document for land-use planning in rural areas.
	Natural Resources and Territorial Management Objectives	NPDP provides a spatial framework for the co-ordination and implementation of development programs and projects; NPDP assists with the development of an ordered hierarchy of rural growth centres and to encourage a balanced pattern of economical use of resources; NPDP sets appropriate standards for the development of services and facilities, as a guide for rural and urban land use and development decisions.
Lilongwe District Development Plan (LDDP)	Geographical area	Rural area in Lilongwe District.
	Timeframe	Bi-annual or tri-annual plan.
	General Objectives	LDDP contains a list of proposed development projects in various traditional authorities.
Lilongwe Master Plan (LMP)	Geographical area	Lilongwe City.
	Timeframe	2010-2030.
	General Objectives	LMP defines the principles for the long-term land use of Lilongwe City. LMP formulates the sector plans on transport and urban facilities.
	Natural Resources and Territorial Management Objectives	In accordance with Malawi Vision 2020, Urban Development studies to LMP expects that Lilongwe will be the Malawian city model. The main goals of LMP are: definition of Lilongwe as a primary city of Malawi; developing an environment, economic, and social harmonization; definition of Lilongwe as gateway to neighbouring countries.



5.10.2.3. Socioeconomic development strategies

Table 36 shows the main socioeconomic development strategies in force in Malawi and the Lilongwe District, identifying their objectives.

Table 36 – Main socioeconomic development strategies in force in Malawi and Lilongwe District

Malawi Vision 2020 (MV)	Geographical area	Malawi.
	Timeframe	(---)-2020
	General Objectives	MV is a strategic document, which provides a framework to formulate, to implement and to evaluate short and medium-term plans, managed by public and private sectors. MV aims to create the economic competitive advantage that can lead to significant economic growth and consequently improved material well being of inhabitants.
	Natural Resources and Territorial Management Objectives	In natural resources and environmental management: sustainably managed natural resources and environment, namely through the availability of adequate and clean water resources, and of restored and well conserved biodiversity and ecosystems In preservation of degradation and depletion of water resources: conservation of catchment areas and improvement of water supply systems In restoration and conservation of biodiversity: control deforestation, pollution, siltation, invasive species, overgrazing, population growth, and bush fires and to prevent illegal access to biological resources and the loss of indigenous knowledge.
Malawi Growth and Development Strategy (MGDS II)	Geographical area	Malawi.
	Timeframe	2011-2016.
	General Objectives	MGDS II aims to continue reducing poverty through sustainable economic growth and infrastructure development. MGDS II included <i>Infrastructure Development</i> and <i>Sustainable Economic Growth</i> as major themes
	Natural Resources	MGDS II identifies as key priority areas:



	and Territorial Management Objectives	<i>integrated rural development; green belt irrigation and water development; climate change, natural resources and environmental management; public health; sanitation; and agriculture and food security.</i>
Lilongwe City Development Strategy (LCDS)	Geographical area	Lilongwe City.
	Timeframe	2010-2015.
	General Objectives	LCDS aims to deal with development strategies and policies for Lilongwe as the capital city, in themes as governance, housing/land, community development, public service and environment, and economic development.

As shown in Table 36, socioeconomic development strategies have the natural resources management as their prime concern and their relation with medium-term economic growth.

5.10.2.4. Sector and institutional plans and strategies

Table 37 shows the main sector and institutional plans and strategies in force in Malawi and the Lilongwe District, identifying their objectives.

Table 37 – Main sector and institutional plans and strategies in force in Malawi and Lilongwe District

Second National Water Development Project (NWDP II)	Geographical area	Malawi.
	Timeframe	2007-2015
	General Objectives	SNWDP is a program for sustainable water resources management and development, in accordance with national and international development objectives.

Water Resources Investment Strategy (WRIS) is created from NWDP II. WRIS aims to meet a range of water needs for productive purposes, such as economic development (in agriculture, industrial/commercial, energy etc.), and at the same time help to deliver water supply requirements; to identify key water-related challenges for the country's economic development in the medium and long-term; to set-up priorities for water sector interventions in time and geographically; and to identify priority water resources sector investments.



Other medium and small water management and agricultural related projects with approved by the World Bank and that are currently active, are:

- Irrigation, Rural Livelihoods and Agricultural Development Project (Approved in 2005);
- Agricultural Development Programme Support Project SIL (FY08) (Approved in 2008);
- Irrigation, Rural Livelihoods and Agricultural Development Project (Approved in 2010);
- Additional Financing to the Malawi Agricultural Development Program Support Project (Approved in 2012);
- Irrigation Rural Livelihoods and Agricultural Development Project AF II Project (Approved in 2012);
- Second Additional Financing to the Malawi Agricultural Sector Wide Approach – Support Project (Approved in 2014).

5.11. Socioeconomics and Public Health

5.11.1. Administrative and community structures

Malawi has an area of 118,484 km² and the country is divided into twenty eight districts within three regions (Table 38). According to Benson (2008), the Malawian districts are structured in Traditional Authorities (TA) in rural areas and administrative wards in urban areas (approximately 250 and 110, respectively).

Table 38 – Main characteristics of three regions of Malawi

	Northern Region	Central Region	Southern Region
Population (2008)	1,708,930	5,510,195	5,876,784
Area (km ²)	26,931	35,592	31,753
City	Mzuzu	Lilongwe	Blantyre
Number of districts	6	9	13

Source: Benson (2008) & NSO (2008)



The Lilongwe District has an area of 6,130 km², which is divided into two areas (NSO, 2008):

- Lilongwe City (432 km², about 7.0% of Lilongwe District's total area) – subdivided into 58 subareas, Lilongwe is the Malawian capital since 1975 and it is one of the four major cities in the country, as well as the main administrative urban centre;
- Lilongwe Rural (5,698 km², 93.0% of District's total area), subdivided into eleven TA and four Sub-Traditional Authorities (STA).

The study area is inserted in Lilongwe Rural. As the designation indicates, it corresponds to land use and geographical distribution of population and settlements characteristic of rural areas. Usually, and as it can be observed in the study area, settlements are dispersed, with low population density, interspersed with agricultural land.

According to the description, the community and local government structures are supported by the Traditional Authority boundaries and correspondent chiefs. Lower in the local structure hierarchy are Group Villages, and respective leaders, followed by Villages and Village Leaders.

From the set of consultation actions performed (workshop, public meetings, individual contacts with TA chiefs and population) and the fieldwork undertaken, it was possible to identify the villages (or group villages) that directly or indirectly are likely to be affected by the rehabilitation and raising of Kamuzu Dam I:

- TA Masula – Kapininga, Mbalame, Mbowela, Katopeka, Manyenje, Chaponda, Simalambo, Mamina, Chisauka and Jasoni;
- TA Masumbankhunda – Malingunde, Sinyala, Kaweche, Manuele, Bukatantha, Ntchontcho, Mafupa and Katete (along with isolated households within the Dzalanyama Forest Reserve).



5.11.2. Demographic dynamics

In 2008, Malawi had 13,077,160 inhabitants and the Lilongwe District had 1,905,282 inhabitants (14.6% of the Malawian population).

Lilongwe is the second most populated Malawian city, with 674,448 inhabitants (35.4% of Lilongwe District's population). Lilongwe Rural had 1,230,834 inhabitants (64.6%) (Table 39).

Between 1998 and 2008, the Lilongwe District's population average annual growth rate was of 3.5%, while the population in Lilongwe City and Lilongwe Rural increased 4.3% and 3.1% per year, respectively.

With a smaller area and a greater population in 2008, Lilongwe City had a density of 1,561 persons per square km, far from the Lilongwe District and Lilongwe Rural averages (311 and 216 inhabitants per square km, respectively).

The age structure of the Malawian population is relatively young. In 2008, the Lilongwe District had just 3.1% of the population aged over 64 years old (in the city area, the value is smaller – 1.3% – and in rural areas it is higher – 4.1%). However, in city and rural areas different population age-groups predominate: 15-64 years old in Lilongwe City (57.7%) and under 15 years old in Lilongwe Rural (46.5%).

Table 39 – Key demographic indicators for Malawi and Lilongwe (1998-2030)

Indicator	Year	Malawi	Lilongwe District		Lilongwe City		Lilongwe Rural	
		Total	Total	%	Total	%	Total	%
Population	1998	9,933,868	1,346,360	13.6	440,471	32.7	905,889	67.3
	2008	13,077,160	1,905,282	14.6	674,448	35.4	1,230,834	64.6
Population (projected)	2015	15,316,860	2,427,501	15.8	972,000	40.0	1,455,501	60.0
	2020	19,104,275	2,803,430	14.7	1,160,000	41.4	1,643,430	58.6
	2030	26,090,975	3,698,163	14.2	1,580,000	42.7	2,118,163	57.3
Pop. <15 years old	2008	6,008,701	849,012	44.6	277,006	41.1	572,006	46.5
Pop. 15-64 years old	2008	6,567,822	997,186	52.3	388,835	57.7	608,351	49.4
Pop. ≥64 years old	2008	500,637	59,084	3.1	8,607	1.3	50,477	4.1

Source: NSO (2008)



In 2030, a population increase to 26,090,975 inhabitants in Malawi and to 3,698,163 inhabitants in the Lilongwe District is expected, both with an average annual increase rate of 3.1%. However, in the Lilongwe District the urban population will increase at an average annual growth rate higher than the rural population (3.9% and 2.5%, respectively).

In the analysed time period (1998-2008), the relative weight of the urban population considering the Lilongwe District's total population grew from 32.7% to 35.4%. In 2030, Lilongwe City will represent about 42.7% of the Lilongwe District's inhabitants.

The statistical data available for the villages of the study area and immediate surroundings are scarce. Additionally, in the 2008 Population and Housing Census Malawi, TA Masula is included in TA Chiseka and TA Masumbankhunda is included in TA Kalolo (NSO, 2008).

Considering that administrative distribution, in 2008, TA Chiseka had 229,184 inhabitants (average annual increase rate of 2.8%, between 1998 and 2008) and TA Kalolo had 141,624 inhabitants (3.0%). The distribution of the population by age is very similar to the Lilongwe Rural's indicators performance.

5.11.3. Internal migration pattern

The Lilongwe District attracted 188,084 inhabitants in 2008. However, the net migration of urban and rural areas showed different patterns – in total, rural areas lost 87,798 inhabitants and the city had 275,882 new inhabitants (Table 40).

Table 40 – Internal Migration, in Malawi and Lilongwe (2008)

	Malawi	Lilongwe District	Lilongwe City	Lilongwe Rural
In migrants	2,111,181	420,813	349,213	71,600
Out-migrants	2,111,181	232,729	73,331	159,398
Net migration	0	188,084	275,882	-87,798

Source: NSO (2008)



As mentioned in the 2008 Population and Housing Census Malawi (NSO, 2008), the main origins of the new Lilongwe City inhabitants are: Lilongwe Rural (about 39,000 inhabitants), Dedza (about 36,000 inhabitants) and Ntcheu (about 29,000 inhabitants).

5.11.4. Education

The 2010 Malawi Demographic and Health Survey results (NSO & ICF Macro, 2011) suggest that educational attainment of women is (slightly) lower in the Lilongwe District than in Malawi, with male indicators performing better (Table 41).

Table 41 – Educational attainment, in Lilongwe District and Malawi (2010)

Indicator	Lilongwe District		Malawi	
	Women	Men	Women	Men
Educational attainment (median years completed)	2.4	3.7	2.5	3.5

Source: NSO & ICF Macro (2011)

Additionally, according to the Population and Housing Census Malawi (NSO, 2008), the literacy rate in Lilongwe City was 84.1% and 57.0% in Lilongwe Rural.

From the information collected for TA Masula and TA Masumbankhunda it is evident that TA Masula had more schools and pupils across all levels of education (pre-school, primary and secondary), as well as in adult literacy centres (Table 42). However, according to the Census population data, TA Chiseka (which includes TA Masula) had more inhabitants. So, the analysis of such indicators as enrolment of school-age population should take into consideration the relative proportion between TA Masula and TA Masumbankhunda's population.



Table 42 – School and pupils, by level of education, in Lilongwe Rural, TA Masula and TA Masumbankhunda (2005 and 2006)

Administrative division	Pre-school (2006)		Primary (2005)		Secondary (2005)		Adult Literacy Centres (2005)	
	S	P	S	P	SE	P	CE	P
Lilongwe Rural	304	24,015	411	320,212	270	11,637	161	*
TA Masula	54	6,744	28	21,642	4	533	18	*
TA Masumbankhunda	19	1,865	24	13,138	12	402	8	*

C = Classes; CE = Centres; P = Pupils; S= Schools; * No data.

Source: Scotland Malawi Partnership (2006)

5.1.1.4.1. Education facilities

In Malawi, education services are provided by the government, private sector and religious schools (Church of Central Africa, Presbyterian – CCAP – and Catholic, provided by the Lilongwe Diocese).

Lilongwe City had, in 2008, 104 primary schools (66 public¹³ and 38 private) and 29 secondary schools¹⁴. In the tertiary education area, Lilongwe had the University of Malawi and its colleges (College of Medicine, Lilongwe University of Agriculture and Natural Resources, Kamuzu College of Nursing), College of Health Sciences, Natural Resources College, another technical college and private institutions.

The educational facilities for Lilongwe Rural are referred to in Table 42. According to the data about primary schools collected by Scotland Malawi Partnership (2006), the public sector had 6 schools in TA Masula and 4 in TA Masumbankhunda; the CCAP had 16 schools in TA Masula and 13 in TA Masumbankhunda; Lilongwe Diocese had 6 schools in TA Masula and 7 in TA Masumbankhunda; and the private sector had 2 schools in TA Masumbankhunda.

¹³ In 2008, with 135,026 pupils and 2,474 teachers (UN-HABITAT, 2011).

¹⁴ In 2008, with 30,795 pupils (UN-HABITAT, 2011).



5.11.5. Social conditions and public health

The access to drinking water is a significant issue in the Lilongwe District. The indicators about drinking water sources' quality were below the national average (Table 43), in contrast to sanitation and access to electricity indicators.

Table 43 – Key indicators of social condition (2010)

Indicator	Malawi	Lilongwe District
Drinking water (% of improved source)	79.3	72.9
Drinking water (% using an appropriate treatment method)	32.6	30.2
Sanitation facilities (% of improved, not shared facility)	8.9	14.6
Access to electricity (%)	9.1	12.4

Source: NSO & ICF Macro (2011)

Despite some statistical inconsistent data, the following table shows that the crude death rate is bigger in Malawi than in Lilongwe and Lilongwe Rural, which is also reflected in the lowest percentage of orphan children in the Lilongwe District.

However, in general, indicators related with the infant mortality (e.g., neonatal mortality, infant mortality rate and under five mortality rate) in the Lilongwe District had a worse performance than the national average, with a higher proportion of deceased children (Table 44).

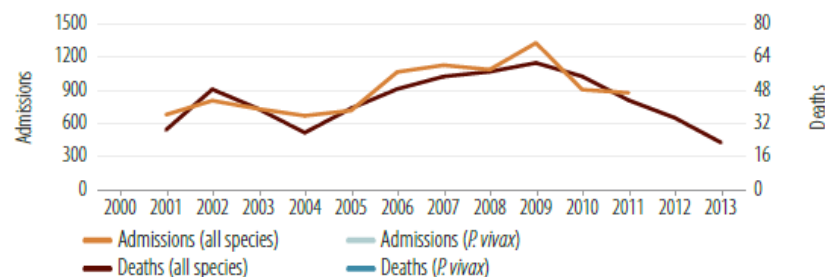
Table 44 – Key health conditions indicators for Malawi and Lilongwe District

Indicators	Year	Malawi	Lilongwe District		
			Total	Lilongwe	Rural
Crude birth rate (‰)	2008	39.5	-	-	39.6
Crude death rate (‰)	2008	10.4	-	7.6	8.5
Neonatal mortality (‰)	2011	33.0	35	-	-
Infant mortality rate (‰)	2008	87.0	-	101.0	63.0
	2011	73.0	69.0	-	-
Under five mortality rate (‰)	2008	140.0	-	166.0	96.0
Total fertility rate (‰)	2008	-	-	4.9	6.6
Orphan children (%)	2011	12.6	9.1	-	-

Source: NSO (2008) and NSO & ICF Macro (2011)



Malawi is considered a country of high Malaria transmission risk (>1 case per 1,000 population). According to the 2014 World Malaria Report (WHO, 2014), the number of deaths per admissions has declined since 2009 (Figure 163).



Source: WHO (2014)

Figure 163 – Malaria admissions and deaths (per 100,000), in Malawi

The 2010 UNAIDS Global Report on the AIDS Epidemic (UNAIDS, 2010) refers that HIV prevalence in Malawi was of 11% at the end of 2010, with 920,000 adults and children living with HIV.

The overall HIV incidence has decreased by more than 25% since 2001, although the HIV prevalence has remained relatively stable. The Malawi Demographic and Health Survey 2010 (NSO & ICF Macro, 2011) states that HIV prevalence for 15–49 year olds is higher in urban areas (17.4%) compared to rural areas (8.9%). In both rural and urban settings, HIV prevalence is higher in women than in men (12.9% compared to 8.1%). Prevalence is also roughly three times higher among young women aged 15–24 than young men of the same age.

The malaria prevention and HIV awareness indicators, shown in Table 45, are lower at a District level, compared to the national level. Within District values, it should be highlighted that men, although more aware than women about the use of condoms as a prevention measure, also have more risk behaviours (e.g. multiple sexual partners).

Table 45 – Key indicators about public health (2010)

Indicator	Malawi		Lilongwe District	
	Women	Men	Women	Men
Malaria prevention (% slept under an Insecticide-Treated Net last night)	29.0		26.2	



Indicator	Malawi		Lilongwe District	
	Women	Men	Women	Men
Malaria prevention (% children under 5 slept under an ITN last night)	39.4		37.8	
Prophylactic use of antimalarial drugs during pregnancy (% women 15-49)	88.7	-	90.7	-
Knowledge of HIV prevention by using condoms (% pop 15-49)	72.0	72.6	65.6	72.0
Multiple sexual partners in last 12 months (% pop 15-49)	0.7	9.2	1.0	3.6

Source: NSO & ICF Macro (2011)

5.11.5.1. Health facilities

Lilongwe City has 4 hospitals (Kamuzu Central, Bwaila/Bottom, Likuni Mission and Daye Yong) and 33 public and private health centres.

In 2005, Lilongwe Rural had 85 health care facilities (10 in TA Masula and 4 in TA Masumbankhunda), with over 659 facilities required (60 in TA Masula and 36 in TA Masumbankhunda). The majority of health facilities correspond to health posts and health centres (Table 46).

Table 46 – Health care facilities, in Lilongwe Rural, TA Masula and TA Masumbankhunda (2005)

Health Facilities	Lilongwe Rural	TA Masula	TA Masumbankhunda
Health Posts	32	4	1
Dispensaries	7	0	1
Health Centres	32	4	2
Hospitals	5	1	0
Private Clinics Reg. With Medical Council	9	1	0
Total Existent	85	10	4
Health Posts Required	546	50	30
Health Centres Required	113	10	6
Total Required	659	60	36

Source: Scotland Malawi Partnership (2006)



5.11.6.Land Ownership

According to the 1965 and 2002 Land Acts, ownership of the land can be of three types:

- Public (15-20% of Malawian land ownership): land occupied, used, acquired or held by the government in the public interest (e.g., national parks, conservation and historical areas) or public purposes (e.g., schools and government offices);
- Private (10-15%): land owned, held or occupied under freehold title, lease, Certificate of Claim (legal instrument created by colonial administration of the British Central Africa Protectorate, to grant the title to individuals, companies and others who claimed to have acquired land within the protectorate by grant or purchase) or registered as private land under the Registered Land Act of 1967 (includes privately owned freehold land and customary land registered by communities or individuals; upon registration, the land loses its characteristic as a customary land);
- Customary (65-75%): land held, occupied or used by a community, according to customary law (the management is realized by a community leader). Customary land can be held communally (e.g., lineage) or individualized (family or individual).

The land tenure can be as follows:

- Freehold¹⁵ (application to private land): Private sector manages the rights, use and alienation of lands;
- Leasehold (application to public, private and customary land): Lease conditions vary by the use – 21 years to agricultural land and 22 to 99 years to development properties and infrastructures. Public and customary lands are managed by the government or TA leader. When the leasehold time expires, the land reverts to the ownership;
- Customary: Land held as a whole by a group or individual person or family. If the land has been held individually, it is a presumption that the

¹⁵ In freehold case, the use and management of land is regulated by 1965 Land Act and the 1967 Registered Land Act. Some of the land was customary land, in the meantime converted to freehold land at Independence by the government to develop the agricultural sector.



use is exclusive and perpetual and that the land can be leased or bequeathed.

The information about land ownership, land tenure and use of land is scarce in the Lilongwe District. The only available information regards Lilongwe City.

According to the City Development Strategy for 2010-2015 developed by the Lilongwe City Council (2009), 35% of the land was designed for residential use. Other uses include commercial, industrial and agricultural use. The major land owners in Lilongwe City are the Ministry of Lands, Housing and Urban Development, Malawi Housing Corporation, Airports Development Limited and Press Corporation Limited. Chiefs also take part in land administration within the city.

According to the local government structure in the study area – sustained in Traditional Authority chiefs and Group Village and Village Leaders –, consultation actions performed and land use observed in the fieldwork surveys, most of the land in the study area is either:

- Public – KD1 infrastructures and reservoir area, along with its protection buffers – LWB; Dzalanyama Forest Reserve – Department of Forests; agricultural development areas (Ministry of Agriculture, Irrigation and Water Development and/or ADMARC);
- Customary;
- Private – infrastructures at Malingunde and Kapininga, near KD1.

5.11.7. Housing conditions

In peri-urban and rural areas, most people live in informal settlements, where the living conditions are underdeveloped and inhabitants have little or no access to social infrastructures and basic urban services. The houses, with their poor conditions, are also vulnerable to disasters (e.g., fire and flood).

Table 47 – Houses by type (2008)

House type	Lilongwe District (N.º)	Lilongwe City (N.º)	Lilongwe Rural (N.º)
Regular	416,908	147,063	269,845
Hospital/Hotel/Lodge	212	124	88



House type	Lilongwe District (N.°)	Lilongwe City (N.°)	Lilongwe Rural (N.°)
Other collective	710	176	534
Total	418,231	147,379	270,852

Source: NSO (2008)

The access to drinking water in households was obtained through piped water into the dwelling plot or yard (61.9%) and public tap/stand pipe (30.3%) in Lilongwe City. The Tube well/borehole (57.1%) and Unprotected dug well (25.0%) was most commonly used in Lilongwe Rural (Table 48).

Table 48 – Distribution of houses by main source of drinking water (2011)

Water source	Lilongwe City (%)	Lilongwe Rural (%)
Bottled water	0.0	0.2
Cart with small tank/drum	0.0	0.1
Piped water into dwelling plot or yard	61.9	2.3
Protected dug well	2.4	8.1
Protected spring	0.0	0.6
Public tap/stand pipe	30.3	2.4
Rain water collection	0.0	0.0
Surface water (river, dam, lake, pond, stream, canal) irrigation channel	0.0	2.1
Tanker/truck	0.0	0.0
Tube well/borehole	3.5	57.1
Unprotected dug well	1.9	25.0
Unprotected spring	0.0	1.9

Source: NSO (2012)

During fieldwork surveys the use of water piped from the Lilongwe River wasn't identified as common, information confirmed in meetings held with TA chiefs and local leaders. Nevertheless, sporadic cases of private owners (near KD1) pumping water from the dam (according to respective water abstraction licenses) and isolated households near the river using untreated river water, or dug holes (Figure 165), for drinking water, were identified.

Most of the drinking water is abstracted from boreholes in the study area and its immediate surroundings, following the tendency from Lilongwe Rural (Table 48).



Groundwater consumption is available at villages located in the study area and/or immediate surroundings especially through communal hand-pumps in villages (Figure 164) or individual boreholes/wells (Figure 166).

In Katete, water is piped and distributed through communal water taps from a lake for rain water collection at the Dzalanyama Mountains (Figure 167).

As previously mentioned, private owners near KD1 usually abstract dam reservoir water (as well as groundwater, in some cases), pump it to elevated reservoirs and pipe water to water taps within its premises (including inside buildings in some cases)..

In summary, most households within the study area use tapped water, with the main water source being groundwater (upstream villages), rain water collected at the Dzalanyama Mountains (Katete) and dam reservoir water (licensed abstraction near KD1 – Malingunde and Kapininga). It should be noted that most of the households/properties are located near KD1 and in Katete.



Source: NEMUS (2014)

Figure 164 – Borehole hand-pump



Source: NEMUS (2014)

Figure 165 – Dug hole



Source: NEMUS (2014)



Source: NEMUS (2014)

Figure 166 – Manual borehole

Figure 167 – Water tap at Katete



Source: NEMUS (2014)

a)

b)

c)

a) Pump-house; b) Water Reservoir; c) Water-tap

Figure 168 – Water abstraction from dam:

The 2011 Welfare Monitoring Survey data (NSO, 2012) refers that 28.9% of Lilongwe Rural's houses and 14.6% of Lilongwe City's houses treated their own drinking water.

The treatment provided to the drinking water is very similar in Lilongwe City and Lilongwe Rural – water guard, addition of chlorine and boiling – as shown in Table 49.

Table 49 – Distribution of houses which treated their drinking water(2011)

Treatment method	Lilongwe City (%)	Lilongwe Rural (%)
Chlorination	36.0	25.7
Boiling	20.0	13.7
Filtration	0.0	0.0



Treatment method	Lilongwe City (%)	Lilongwe Rural (%)
Other	2.0	14.3
Use water guard	42.0	46.3

Source: NSO (2012)

To carry drinking water from water points to households, the covered pail/container is mostly used in Lilongwe City (47.8%), while the open pail/container is mainly used in Lilongwe Rural (66.3%) (Table 50). Nevertheless, the use of open pail/container is still very expressive in Lilongwe City (about 35.0%).

Table 50 – Houses which reported methods of carrying drinking water from water point to their house (2011)

Water transport	Lilongwe City (%)	Lilongwe Rural (%)
Bucket with cover	9.2	1.2
Covered pail/container	47.8	30.8
Open pail/container	34.9	66.3
Other	5.7	0.7
Zigubu	2.4	1.0

Source: NSO (2012)

The water storage in houses was predominantly performed with covered pail/container (54.7% in Lilongwe City and 48.1% in Lilongwe Rural). However, in Lilongwe Rural 34.8% of houses still storage the water in open pail/container (Table 51).

Table 51 – Houses which reported methods of water storage (2011)

Water storage	Lilongwe City (%)	Lilongwe Rural (%)
Bucket with cover (with/without Tap)	16.3	4.0
Clay pots with/without cover	2.7	11.6
Covered pail/container	54.7	48.1
Drums	2.4	1.0
Open pail/container	17.9	34.8

Source: NSO (2012)

In Lilongwe City's and Lilongwe Rural's houses, the main source of energy for cooking and for lighting is firewood and paraffin (Table 52), respectively. Nonetheless, in Lilongwe City the charcoal is emerging as the main source of energy for cooking and the electricity as the main source of energy for lighting.



In the study area and surroundings, firewood is the dominant source of energy for cooking; charcoal production is predominantly for sale purposes.

Table 52 – Houses by main source of energy for cooking and for lighting (2011)

Energy source	For cooking			For lighting		
	Lilongwe District	Lilongwe City	Lilongwe Rural	Lilongwe District	Lilongwe City	Lilongwe Rural
Candles	0	0	0	32,959	29,777	3,182
Charcoal	65,083	60,773	4,310	0	0	0
Electricity	23,472	22,552	920	49,272	46,006	3,266
Firewood	319,639	60,929	258,710	9,124	700	8,424
Gas	115	95	20	0	0	0
Other	667	396	271	5,691	788	4,903
Paraffin	4,519	1,075	3,444	319,862	69,792	250,070
Straw	3,413	1,243	2,170	0	0	0
Total	416,908	147,063	269,845	416,908	147,063	269,845

Source: NSO (2012)

According to the Welfare Monitoring Survey, in 2011, 95.7% of Lilongwe City's houses and 82.8% of Lilongwe Rural's houses were located at a distance less than 15 minutes away from drinking water sources. However, this is not the case for the access to the food market: 30.9% of Lilongwe Rural's houses were up to 60 or more minutes away; in Lilongwe City, 49.7% of the houses were at 14 or less minutes away (Table 53).

Table 53 – Time taken to get to the nearest supply of drinking water and food market (2011)

Minutes	Drinking water		Food market	
	Lilongwe City	Lilongwe Rural	Lilongwe City	Lilongwe Rural
0-14	95.7	82.8	49.7	15.0
15-29	3.8	12.8	35.7	17.7
30-44	0.3	2.6	11.9	24.7
45-59	0.3	1.2	1.6	11.7
60+	0.0	0.6	1.1	30.9

Source: NSO (2012)

Agricultural crops, charcoal and wood products and farm animal's production for sale are usually purchased by vendors at the production sites/villages. For producers who sell their products directly in markets, Malingunde, Sinyala and Likuni are the main destination markets, but also Chinsapo and Lilongwe.



Nevertheless, local populations in the study area focus mainly in subsistence agriculture, limiting the influence of the distance to markets.

5.11.8. Economic activity

Malawi is one of poorest countries in the world (ranking 174 out of 187 countries on the 2014 Human Development Index), where 70% of the population lives with less than \$1.25 per day (UNDP, 2014).

As the UN-HABITAT (2011, p. 14) refers, “Lilongwe was mainly an administrative centre until 2005 when many head offices of institutions located in Blantyre moved to the city. This movement attracted economic activities to the town which resulted in increased employment opportunities and population growth. Finance, banking, retail trade, construction, transport, public administration, tourism, and tobacco manufacturing are the main economic activities in Lilongwe”.

The largest employing sectors in Lilongwe City were the family business (29.7%), the private sector (26.1%) and self-employment (17.9%). In Lilongwe Rural, the main inhabitants’ professional occupation is the subsistence farming (84.7%) (Table 54).

Table 54 – Currently employed persons aged 15 years and above by sector (2011)

Employing sectors	Lilongwe City (%)	Lilongwe Rural (%)
Estate	0.0	0.6
Family business	29.7	7.6
Missions NGO	5.5	0.3
Mlimi (Subsistence farming)	6.2	84.7
Parastatal	1.3	0.0
Private sector	26.1	2.8
Public sector	13.4	2.3
Self employed	17.9	1.6

Source: NSO (2012)

Bibliographic sources refer that the informal sector is employing a significant proportion of the labour force.



An analysis focused on the economic activities in Lilongwe City shows that the most prominent ones are social and community services (35.0%) and wholesale/retail marketing (26.0%).

In Lilongwe Rural, activities related with agriculture, forestry and fishing represent nearly 90% of the economic activities (Table 55), especially in the case of rural women.

Table 55 – Currently employed persons aged 15 years and above by main activity (2011)

Economic activities	Lilongwe City (%)	Lilongwe Rural (%)
Agriculture, forestry, fishing	13.4	89.6
Construction	6.6	3.0
Electric, water other utilities	2.2	0.2
Finance and Business	3.3	0.7
Hotels	5.4	0.2
Manufacturing	1.9	0.5
Mining and quarrying	0.5	0.2
Social and community services	35.0	2.9
Transport/communication	5.8	0.2
Wholesale, retail marketing	26.0	2.6

Source: NSO (2012)

As FAO (2013a, p. 1) refers, “while mining and construction are growing in importance, agriculture continues to be the main economic activity, and employs about 80 percent of the labour force. Malawi’s agriculture sector is characterized by a dual structure, consisting of smallholder farms and estates. The estate sector mainly produces tobacco, which accounts for more than half of all exporter venues, as well as tea, sugar and coffee, and is the main provider of wage labour in the country. Small holders are mostly engaged in rain-fed maize production, cultivating on average around one hectare of land. They also contribute significantly to cash crop and export production of burley tobacco, accounting for over 80 percent of total production.”.

According to FAO (2013b), the small holders’ agricultural production is focused in maize (represents about 86.4% of all production and 79.3% of area harvested), groundnuts and soybeans, as shown in Table 56.



Despite the fact that production value is more expressive for maize, a producer Prices per MWK/kg analysis shows that groundnuts and soybeans production is more profitable (cost-effectively).

Table 56 – Production quantity, area harvested and average productivity in Lilongwe District (2008) for primary crops

Primary Crops	Production Quantity	Area Harvested	Average Productivity	Producer Prices	Production in Value
	tones	ha	kg/ha	MWK/kg	10 ⁶ MWK
Maize local	142,214	153,688	925	46.40	6,598.72
Maize composite	202,140	112,750	1,793	46.40	9,379.28
Maize hybrid	269,286	109,032	2,470	46.40	12,494.84
Chalimbana Groundnuts	32,597	39,182	832	168.03	5,477.32
Other local variety of groundnuts	44,238	35,790	1,236	168.03	7,433.38
Soybeans	19,806	23,072	858	106.30	2,105.31
Total	710,281	473,514	1,500	-	43,488.85

Source: FAO (2013b)

The study area follows the national trend regarding agricultural activities: the vast majority of the rural population relies on subsistence agriculture, with small holder farms based on rainfed maize production and tobacco. Other important planted crops are groundnuts and vegetables and other subsistence and consumption products within households (like irish and sweet potatoes, green beans, soyabeans, tomatoes, pumpkins, sugarcane, among others).

In TA Masula, according to local chiefs and leaders, all year long people plant maize and vegetables crops in small agricultural parcels, near the river/reservoir; upland, where land moisture is lower, only during the wet season (December to March) is the land cultivated, usually between maize, tobacco and groundnuts (in larger areas). By order of importance, maize is the main crop, followed by groundnuts and tobacco.

In TA Masumbankhunda, also according to local chiefs and leaders, the estimated agricultural mosaic is very similar to TA Masula, with maize being dominant (70%), followed by groundnuts (15%) and tobacco, as well as other other vegetables and subsistence crops planted near the river/reservoir.



5.11.9. Survey of houses, edifications and infrastructures

Although it is not a recurrent situation, a set of human infrastructures and other areas of interest to local populations are located within the study area, nevertheless most of the human settlements are located upland the river and/or reservoir boundaries.

Considering the previously mentioned land use, and excluding the LWB protection buffer area around the dam reservoir, local populations tend to use riverbanks land mainly for agriculture.

Hence, most of the human structures enclosed by the estimated future FSL at 1,105 masl and the 100 m buffer study area are located near KD1 and in Katete.

According to fieldwork surveys, 29 buildings are included by the FSL at 1,105 masl, and 60 buildings are framed by the 100 m study buffer, with the distribution shown in Table 57.

Table 57 – Houses, edifications, infrastructures and other human structures within the study area

Structures	FSL at 1,105 masl	100 m study buffer	FSL + 100 m buffer
Edifications (20 ownerships/properties*)	12	79	91
<i>Habitation</i>	5	54	59
<i>Agricultural support</i>	1	2	3
<i>Commerce and Tourism</i>	3	15	18
<i>Schools</i>	-	6	6
<i>Water infrastructures buildings</i>	3	2	5
Infrastructures	2	6	8
<i>Bridge</i>	2	2	4
<i>Water (e.g., water tap, water reservoir, water pump)</i>	-	4	4
Graveyards	-	2	2
Shelters	1	2	3
Total	15	89	104

Source: NEMUS fieldwork survey

* Table shows the total number of edifications – 91, corresponding to 20 owners/institutions/properties



5.12. Cultural Heritage

5.12.1. Introduction

This section documents the cultural heritage baseline assessment as conducted in November 2014 – within the study area of 100 m around the full supply level at 1,105 masl – describing the performed research, field work and the heritage elements identified and their significance.

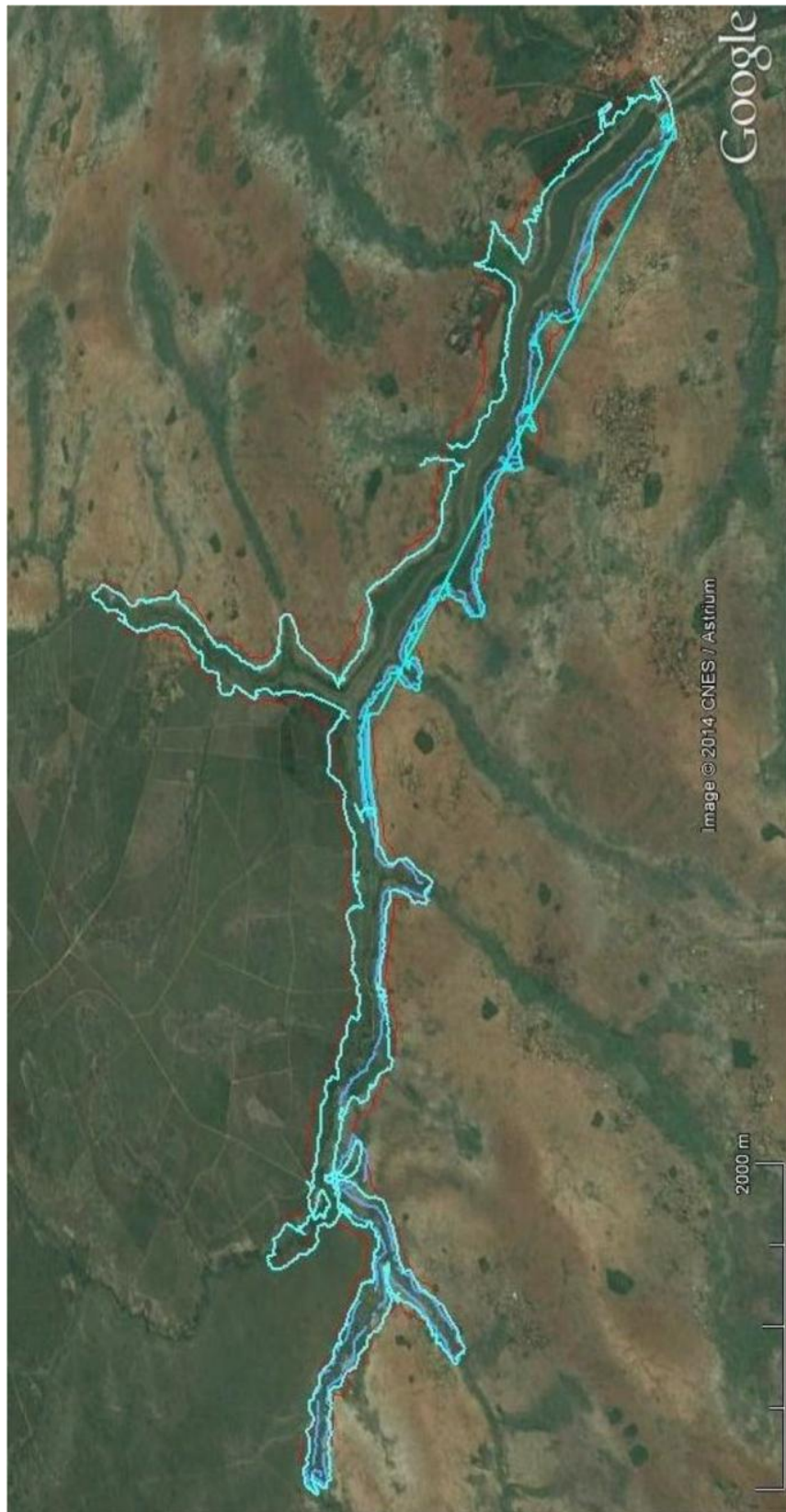
5.12.2. Research and field work

In order to assess the cultural heritage reference situation for the study area of the project the following methodology was adopted. For the identification of archaeological sites in a first instance the national site register was consulted at the Department of Antiquities, as well as published works. No sites and monuments were listed in the area.

The desk review was followed by a comprehensive field survey and *ad hoc* interviews with local residents. The latter was geared towards establishing the presence of relevant intangible cultural heritage.

The survey was conducted between 17 and 21 November 2014 and consisted of a transect walk of five (5) experienced archaeological surveyors (Table 2). They were spaced 20-40 m apart, depending on the area to be covered. It hereby intended to fully cover the projected inundation area and the 100 m study area. Two Garmin GPS's were used; in principle held on positions 2 and 4 of the survey line (see Figure 169). Sadly, the first tracks on one GPS were not recorded.

In general, visibility during the survey was good as the assessment area is mostly composed of agricultural land and people had tilled the soil in preparation for the imminent rainy season. Occasionally, the survey efficacy was hampered by dense vegetation cover, particularly in the forested areas. Inaccessibility of certain stretches was also an issue at times. This was caused by swampy conditions and/or fences around maize and vegetable gardens. At two occasions, land owners refused access to their gardens, citing opposition to the proposed project.



Source: aerial image from Google Earth (December, 2013)

Figure 169 – Survey GPS tracks (light and dark blue) and research area (red)



In agricultural fields along rivers, one is likely to find the odd pot sherd every 50 m or so. Isolated finds of one or two sherds were not considered a site. Nor did multiple sherds of presumably a single pot qualify for a site recording.

Given time constraints, no subsurface testing was done at this stage. Exposed materials on the surface recorded here thus only represent minimal areas of the possible total site extent. Particular care was however taken to inspect exposed sections such as at erosion gullies and excavation areas (e.g. for brick making).

No archaeological materials were collected. Selected findings were photographed in the field. Sites with a diameter of 20 metres or less are reported as single point. Larger sites are indicated by multiple points and polygons.

For the identification of possible intangible cultural heritage within the buffer zone local residents were interviewed whenever encountered during the survey at an *ad hoc* basis.

5.12.3.Results

During the field survey, 42 heritage sites were identified as listed in

Table 58. These include 40 archaeological sites of variable age.

The presence of archaeological sites in the area is not surprising as riverbanks have always been the preferred place of settlement given the need for drinking water. Moreover, rivers would provide a source of food, way of transport and line of defence. Given poor ground visibility at times and inaccessibility of certain sections, some sites are likely to have remained undiscovered. Moreover, no subsurface testing was performed at this stage.

Sedimentation rates can be high in alluvial areas. More sites may thus lie below the 20 cm plough zone and remain unexposed.

The original and predominant population of the area is Chewa. Despite mission influence (Linden, 1974), *nyau* societies are still quite common. This tradition is



included on the UNESCO Representative List under the 2003 ICH Convention, and thus of global significance. These secretive societies have two *dambwes*, or activity areas, at the edge of the research area, and form the final two identified heritage sites; these forest patches also serve as grave yards (Figure 170 and Figure 171).



Source: NEMUS (2014)

Figure 170 – Grave yard 1 (Kapininga)



Source: NEMUS (2014)

Figure 171 – Grave yard 2 (Chaponda)



Table 58 – Identified heritage sites and their significance

Site No.	Description	Significance
KD-01	Milky and crystal quartz flakes were found in the section the red loam embankment and erosion gullies, 0.5-1.8 m below surface. Probably Later Stone Age. A few undecorated sherds were also found on or close to the surface (<25 cm). These are probably of recent date. The site covers at least 0.5ha.	High
KD-02	In a tilled field in an area of ca. 2.6 ha, scattered clusters of thick undecorated pottery some 30m apart. Late 19 th century?	Moderate
KD-03	In a tilled field in an area of 20x20 m, a scatter of undecorated thin pottery; 1-5 sherds/m ² . Possibly Mawudzu tradition. Located at a confluence.	Potentially high
KD-04	In a tilled field in an area of 20x20 m, a scatter of undecorated thin pottery. Possibly contemporaneous with KD-03.	Potentially high
KD-05	In a tilled field, some 10 sherds in 2 m ² ; probably recent.	Low
KD-06	In a tilled field, a thin scatter (<1/m ²) of undecorated pottery with a few clustes of 10/m ² . Located at a confluence. Some slag at KD-06d. Total area is at least 0.28ha.	Potentially high
KD-07	Small scatter of undecorated pottery of variable thickness. Ca. 10 sherds in 2 m ² in an agricultural field at a confluence to southeast. Probably early 20 th century.	Low.
KD-08	Small scatter of thin undecorated pottery. Ca. 10 sherds in 2 m ² . Probably late 19 th to early 20 th century.	Low.
KD-09	A single bifacial core was found at a vein quartz outcrop. 4 flake scars on one side; 2 on the other. Weathered but not rolled. Potentially early Middle Stone Age.	Low
KD-10	Around an anthill, 20x20 m, a few comb impressed sherds of late Mawudzu tradition and an incised sherd.	Low
KD-11	In a gravel & cobble exposure a small chunky quartz core with two flake scars.	Low
KD-12	Crude milky quartz levallois flake in a gravel exposure.	Low
KD-13	Cluster of thick pottery; Ca. 10x10 m with 10 sherds per m ² . Pottery is mostly undecorated and eroded. A few sherds with comb dragging, incissions and comb-stamping. Potentially Nkope or Kapeni tradition.	Potentially high



Site No.	Description	Significance
KD-14	Some 25 sherds in a 2x3 m forest clearing. All sherds undecorated, but one with red-ochre burnishing. The area could be larger, given poor visibility in the forest.	Potentially high
KD-15	Pottery scatter continues in three clusters. One sherd with oblique lines is suggestive of Kapeni ware. Total area= ca 0.5 ha.	Potentially high
KD-16	In a quartz gravel exposure (4x1 m) some broken flakes and debitage was found and one rolled platform core with 7 flake scars. Later Stone Age. Not <i>in situ</i> .	Low
KD-17	Some 10 undiagnostic sherds in a 20x5 m area, possibly in association with recent charcoal burning. Located on high ground.	Low
KD-18	Contemporary pottery and plastic rubbish in a tilled field	Low
KD-19	In an agricultural field, pottery scatter (ca. 5/m ²) in an 8x8 m area. One comb impressed.	Potentially high
KD-20	KD-20a: Scattered slag mount (2x2 m), no pottery; KD-20b slag pieces with comb-impressed sherd. Total Area: ca. 0.07 ha.	Potentially high
KD-21	A scatter of slag in a tilled field (2x3 m). Also a piece of reed impressed dagga.	Moderate
KD-22	In a 5x5 m area in a tilled field, slag and undecorated pottery and a piece of furnace dagga with a pole imprint. Located at a confluence.	Moderate
KD-23	Some 12 sherds in a 2x3 m area. Three sherds with cross-hatching.	Low
KD-24	Single crystal quartz Levallois flake with broken tip in a tilled field. Edge damage caused denticulation.	Low
KD-25	15 sherds in a 5x5 m area at the foot of an anthill. All undecorated except for one comb impressed neck fragment. Late Mawudzu ware?. At a confluence.	Potentially high
KD-26	Some 10 undecorated sherds in a 4x2 m area at the foot of an anthill. Could be old or from contemporary termite collection. At a confluence.	Low
KD-27	KD-27a some 10 undecorated sherds in a 3x2 m area; K27b: slag, dagga and tuyere fragments at an anthill. Tuyere has an internal diameter of ca. 60 mm; thickness between 15 and 20 mm; KD-27c incised and impressed Mawudzu pottery. At a confluence. Total area: ca. 0.3 ha.	High



Site No.	Description	Significance
KD-28	KD-28a: Chunks of consolidated laterite with red-ochre bowl fragment (Nkhudzi ware probably). KD-28b: dense slag scatter in tilled field, 3x3 m; 5 m from an anthill. Total area: ca. 0.03 ha.	Moderate
KD-29	KD-29a 10 pieces of slag in a 2x2 m area; KD-29b chunk of laterite and some slag; KD-29c cluster of reed impressed dagga with slag nor pottery; house of furnace dagga? Total area: ca. 0.07 ha.	Moderate
KD-30	Very large Maravi settlement at a confluence: clusters of Mawudzu pottery: 5-10 sherds per m ² . Total area: ca. 3.5 ha.	Very high
KD-31	KD-31a some 10 Mawudzu sherds; KD-31b slag with some Mawudzu sherds. Total area: ca. 0.04 ha.	High
KD-32	Three quartz (LSA?) flakes in a gravel exposure (2x2 m).	Low
KD-33	Slag and tuyere fragment and 5 sherds. Some coarse incised decoration (late 19 th /early 20 th century?).	Moderate
KD-34	Clusters of potsherds (>10/m ²); each ca. 5x4 m. Mostly undecorated. Some incised pottery and graphite burnishing. Possible late 19 th to early 20 th century settlement, located at a confluence. Total area: ca. 0.3 ha.	Moderate
KD-35	Slag mound with tuyere fragments (4x1 m). Tuyeres were paired; internal diameter 40 mm. At an anthill at a confluence.	Potentially high
KD-36	Slag in a tilled field (10x10 m) with small tuyere and dagga fragments at an anthill.	Potentially high
KD-37	Some 10 pieces of slag in a field (2x3 m).	Low
KD-38	KD-38a: in a 5x5 m area in a field, slag, undecorated pottery and a tuyere fragment; more slag clusters KD-38b, KD-38c. Total area: ca. 0.2 ha.	Potentially high
KD-39	In a 5x5 m area lots of reed impressed dagga and pot sherds; two incised pieces. Possibly 19 th century.	Low
KD-40	Large Maravi settlement with clusters of Mawudzu pottery (<5/m ²). KD-40f has Mawudzu pottery with a tuyere fragment. The area is protected by two rivers and a ridge. Houses seem more spaced out than at KD-30; or more buried. Total area is at least 3.6 ha.	High
Nyau	Two <i>dambwes</i> – meeting places of nyau groups – at grave yards at the edge of the buffer zone	High



The earliest archaeological evidence dates to the Middle Stone Age (250,000 – 50,000 BP). This evidence is however scanty. KD-01 seems to be a potentially significant Later Stone Age site though. Site KD-13, KD-14 and KD-15 are possible all part of one ancient settlement which extended along the river bank. Also KD-19 and KD-20 are probably part of the same site; just as KD-25 and KD-26. Sites KD-30 and KD-40 are extensive Maravi settlement and of high significance as Malawi is named after this 12th to 18th century confederation of kingdoms (Phiri *et al*, 1992; Welling, 2004, 2005). There is further much evidence of iron smelting from Maravi times onwards. This is not surprising given the consolidated laterite bed rock in the area. For the nineteenth century iron smelting has been documented but not much is known from before (Killick, 1990).

The sites location is shown in the following figures.

The coordinates and photographic record of the heritage findings are compiled in Appendix 2.



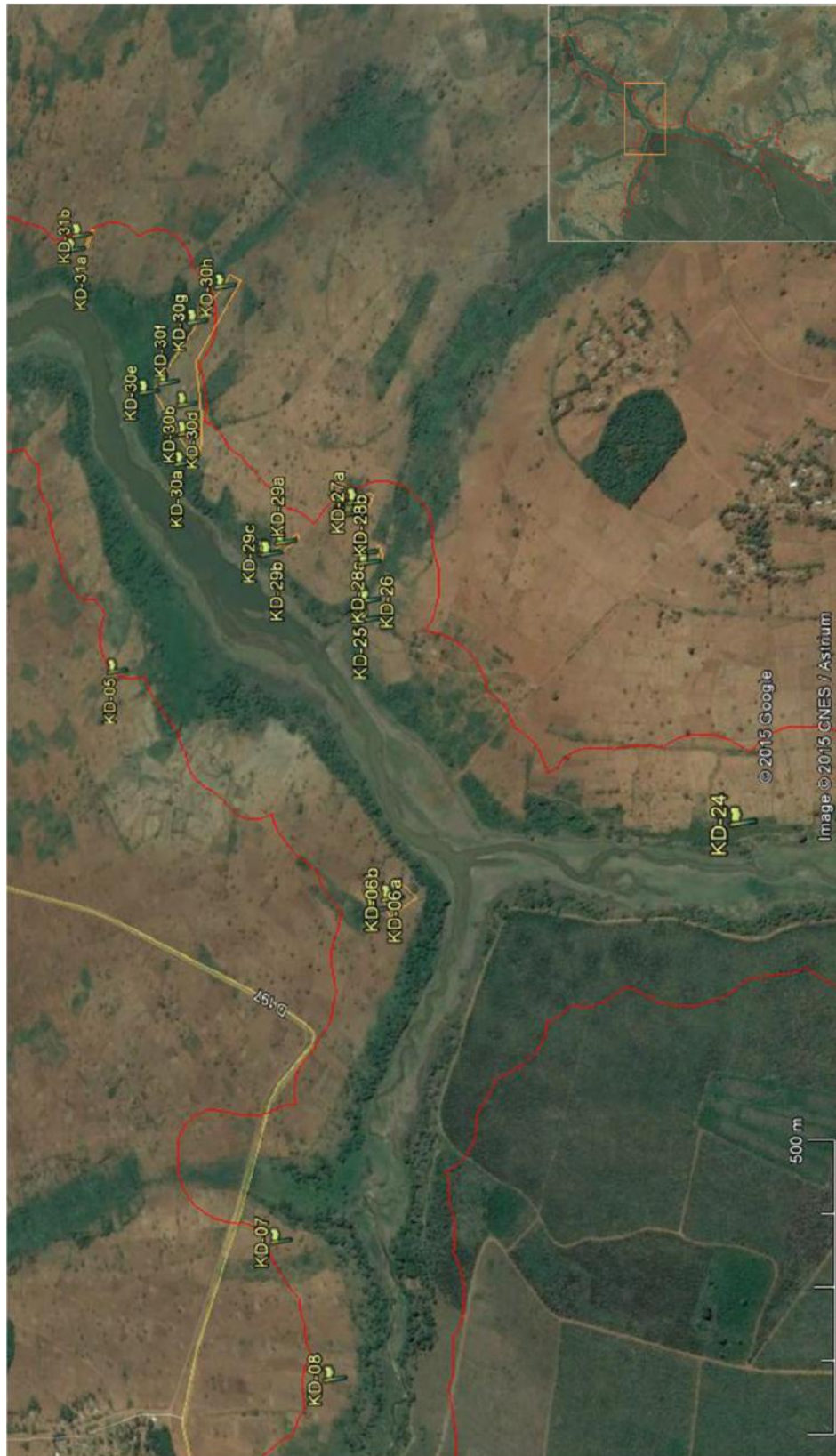
Source: aerial image from Google Earth (December, 2013)

Figure 172 – Heritage site map 1



Source: aerial image from Google Earth (December, 2013)

Figure 173 – Heritage site map 2



Source: aerial image from Google Earth (December, 2013)

Figure 174 – Heritage site map 3



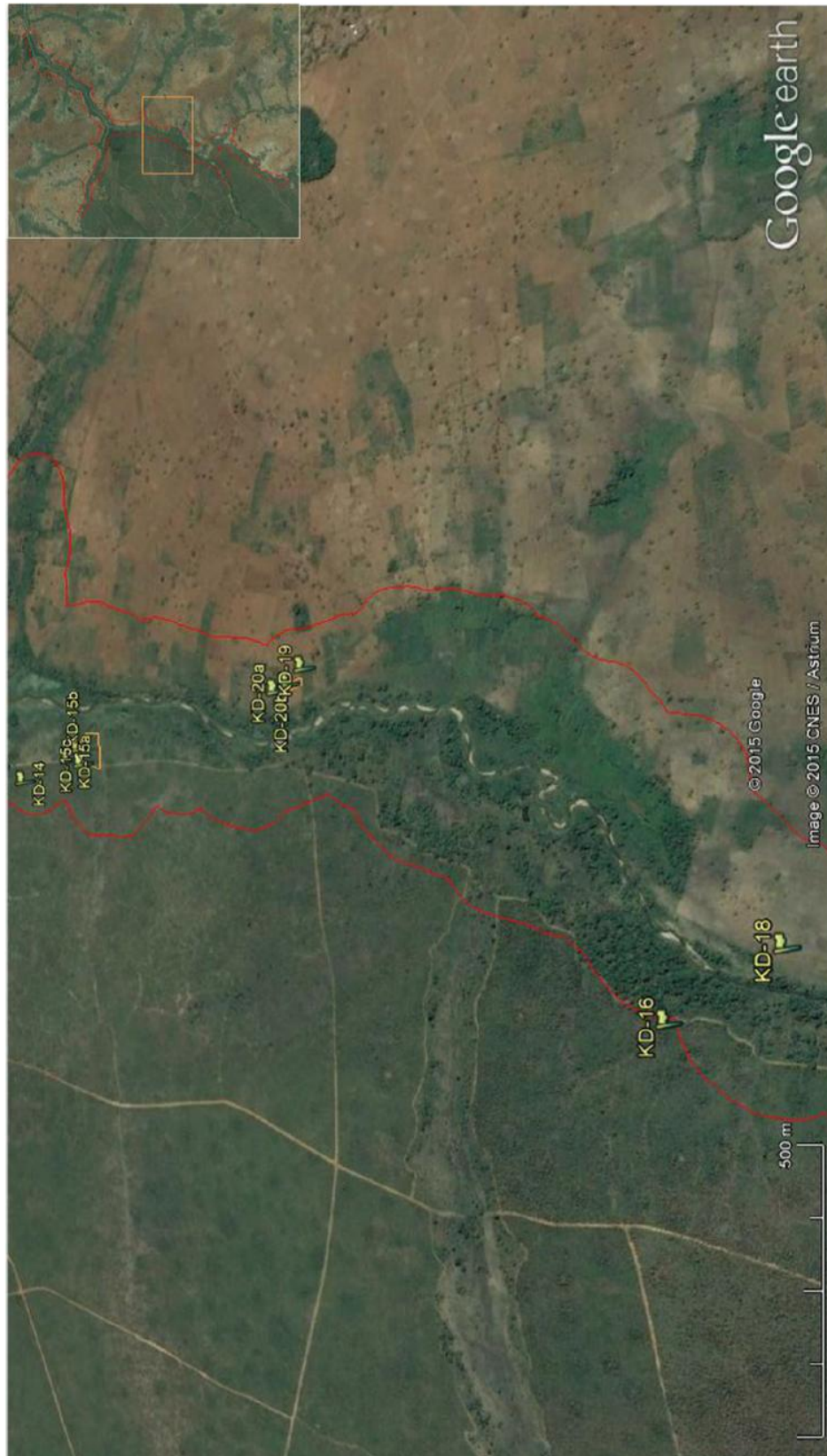
Source: aerial image from Google Earth (December, 2013)

Figure 175 – Heritage site map 4



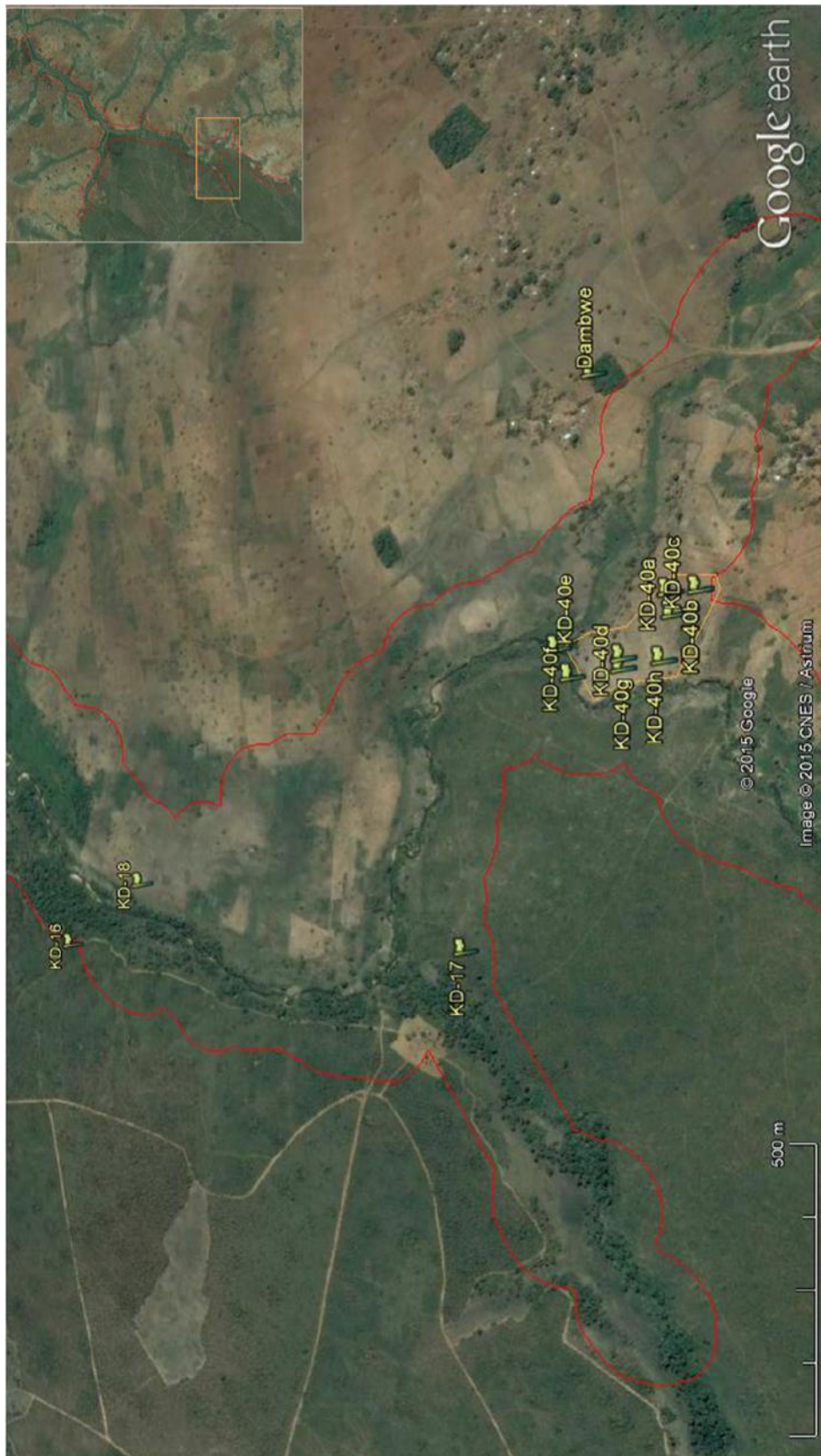
Source: aerial image from Google Earth (December, 2013)

Figure 176 – Heritage site map 5



Source: aerial image from Google Earth (December, 2013)

Figure 177 – Heritage site map 6



Source: aerial image from Google Earth (December, 2013)

Figure 178 – Heritage site map 7



Source: aerial image from Google Earth (December, 2013)

Figure 179 – Heritage site map 8



6. Assessment of Environmental and Social Impacts

6.1. Introduction

Impact assessment is a key stage of the ESIA through which the main effects on the environment are identified and evaluated, according to the main Project activities – listed in section 2.2.

The main goal is to identify the environmental and social impacts associated with the project at and around the site focussing on both positive and negative impacts as well as bio-physical, chemical, social, economic and cultural components of the environment. The method to assess the significance of environmental and social impacts includes the following steps:

- Defining the nature of the potential impact;
- Rating of the potential impact;
- Determination of the overall significance of the impact.

A. Defining the nature of the potential impact

Each potential impact is identified by its root cause (the project activity or action) that will result in an impact (change of the current conditions, be it positive or negative) on a receptor (environmental aspect that will be affected).

Based on the above, the potential impact is defined as either a positive impact (benefit) or a negative one. In addition the impact is defined as Direct or Indirect, and, if pertinent, cumulative. Terms for defining the nature of an impact are presented in the following table.

Table 59 – Defining the nature of the potential impact

Term	Definition
Positive Impact (Benefit)	An impact that is considered to represent an improvement on the baseline or introduces a positive change.
Negative Impact	An impact that is considered to represent an adverse change from the baseline, or introduces a new undesirable factor.



Term	Definition
Direct Impact	Impacts that result from a direct interaction between a planned project activity and the receiving environment/receptors (e.g. between occupation of a site and the pre-existing habitats or between an effluent discharge and receiving water quality).
Indirect Impact	Impacts that result from other activities that are encouraged to happen as a consequence of the Project (e.g. in-migration for employment placing a demand on resources).
Cumulative Impact	Impacts that act together with other impacts (including those from concurrent or planned future third party activities) to affect the same resources and/or receptors as the Project.

B. Rating of the potential impact

Each potential impact is rated based on a set of criteria (see tables below). For each criteria, a scale is used ranging from no or negligible impact to major impacts. Significance of the impact is a function of these criteria.

Table 60 – Impact rating table

Criteria	Definition
Extent	- On-site – Limited to within the site boundaries (for reservoir) plus a 50 m buffer area around the dam structures; - Local – Impacts that affect an area in a radius of 100 m around the reservoir and 500 m around the dam structures; - Regional – impacts that affect regionally important resources or are experienced at traditional authority or district scale; - National – impacts that affect nationally important resources or affect an area that is nationally important/ or have macro-economic consequences; - Transboundary/International – impacts that extend beyond country borders or affect internationally important resources.



Criteria	Definition
Duration	• Temporary – impacts are predicted to be of short duration and intermittent/occasional; • Short-term – impacts that are predicted to last only for the duration of the construction period; • Long-term – impacts that will continue for the life of the Project, but ceases when the Project stops operating; • Permanent – impacts that cause a permanent change in the affected receptor or resource (e.g. removal or destruction of ecological habitat) that endures substantially beyond the Project lifetime.
Likelihood	• Unlikely – The impact is unlikely to occur. • Likely – The impact is likely to occur under most conditions. • Definite – The impact will occur.
Intensity	• Biophysical environment – intensity can be considered in terms of the sensitivity of the receptor: – Negligible – the impact is not detectable; – Low – the impact affects the environment in such a way that natural functions and processes are not affected; – Moderate – where the affected environment is altered but natural functions and processes continue, albeit in a modified way; – High – where natural functions or processes are altered to the extent that it will temporarily or permanently cease. • Socio-economic environment – intensity can be considered in terms of the ability of project affected people/communities to adapt to changes brought about by the project – – Negligible – there is no perceptible change to people's livelihood or health; – Low – People/communities are able to adapt with relative ease and maintain pre-impact livelihoods and health; – Moderate – Able to adapt with some difficulty and maintain pre-impact livelihoods and health but only with a degree of support; – High – Those affected will not be able to adapt to changes and continue to maintain-pre impact livelihoods and health.



C. Determination of the overall significance of the impact

Significance can be seen as a judgement of the biophysical and socio-economic expression of all the preceding criteria over likely affected receptors.

Table 61 – Impact significance criteria

Significance criteria	
Negligible significance	An impact of negligible significance is where a resource or receptor will not be affected in any way by a particular activity, or the predicted effect is deemed to be imperceptible or is indistinguishable from natural background levels.
Low significance	An impact of low significance is one where an effect will be experienced, but the impact magnitude is sufficiently small and well within accepted standards, and/or the receptor is of low sensitivity/value.
Moderate significance	An impact of moderate significance is one within accepted limits and standards. The emphasis for moderate impacts is on demonstrating that the impact has been reduced to a level that is as low as reasonably practicable (ALARP). This does not necessarily mean that “moderate” impacts have to be reduced to “minor” impacts, but that moderate impacts are being managed effectively and efficiently.
High significance	An impact of high significance is one where an accepted limit or standard may be exceeded, or large magnitude impacts occur to highly valued/sensitive resource/receptors. A goal of the EIA process is to get to a position where the Project does not have any major residual impacts, certainly not ones that would endure into the long term or extend over a large area. However, for some aspects there may be major residual impacts after all practicable mitigation options have been exhausted (i.e. ALARP has been applied). An example might be the visual impact of a development. It is then the function of regulators and stakeholders to weigh such negative factors against the positive factors, such as employment, in coming to a decision on the Project.

Detailed impact description, justification and assessment for the considered environmental and social factors are presented in the following sections.



6.2. Geology and Topography

The project is located in an area with homogeneous geomorphological and geological features, typical from the South Lilongwe Plain. The area is dominated by superficial sandy clay deposits with only localised rock outcrops and, because of its long history of erosion, the area is also characterised by its monotonous flatness.

During construction phase, negative impacts over the Geology and Topography were detected. They relate essentially to the degradation and loss of soil both because of activities such as clearance of vegetation, excavations, compaction of soil and pilling of soil surplus. These environmental impacts will be especially felt around the Kamuzu Dam I and in areas where potentially borrow pits will be created. Impacts in the operation phase are null, if measures for construction phase are implemented.

6.2.1. Construction phase

Potential impacts on the Geology and Topography of the area refer essentially to changes in the soil structure and degradation of the soil quality as a result of erosion and compaction on areas directly affected by works of raising the Kamuzu Dam I by 5 m. This impact on soil resources will start during the construction and their endurance will depend on the success of reinstatement.

Several activities during the construction phase of raising the dam lead to the increase of soil erosion and contribution for siltation of water reservoirs of KD1 e KD2. This is especially important because most of the area of intervention is surrounded by cultivated fields and pastures and also because soil erosion contributes to siltation and degradation of Lilongwe river's water quality.

Activities which will promote soil erosion include:

- Clearance of vegetation
- Excavations
- Compaction of soil
- Pilling of soil surplus



The potential soil erosion due to operations during the construction phase is a negative impact with a local extent (Table 62). In terms of duration, in an extreme scenario, it may be permanent if no mitigation measures are taken. The fertile layer of material on the land surface which is capable of supporting plant growth is referred to as topsoil. The rate of topsoil formation can vary from <0.25 mm/year in dry/cold environments to >1.5 mm/year in humid/warm environments (Hammer, 1981; Hudson, 1981). However, if the mitigation measures (section 7.1) are taken into consideration, this impact may only be temporary.

Processes of erosion and siltation are mostly dependent on the occurrence of precipitation and surface run-off (allowing the transport of eroded soil particles to water reservoirs of both dams, promoting an increase of siltation); since the construction is expected to last for 10 months, this impact is likely to occur, even if mitigation measures are implemented. Without any mitigation the impact is considered to have medium intensity since the affected environment will be altered but natural functions and processes continue, albeit in a modified way.

Soil erosion and contribution to siltation in this project is considered of low significance (siltation on both dam reservoirs is mainly originated by soil erosion occurring in extensive farmland that characterises KD1 and KD2 basins); however with the application of mitigation measures it may be reduced to a negligible level of significance.

Table 62 – Impact assessment on Geology and Topography (construction phase): soil erosion and siltation

Criteria	Assessment
Status	Negative
Extent	On-site/Local (especially in construction yards and sites)
Duration	Temporary to Permanent
Likelihood	Likely
Intensity	Moderate
Significance (without mitigation)	Low
Significance (expected post-mitigation/enhancement)	Negligible



In any of the project alternatives (Fusegates, Fixed raising and Fixed raising with side channel) soil and rock (and by-products) will be needed for the construction of the infrastructures. No information was provided regarding construction material sources, especially of soil/rock/gravel needs and requirements and possibility of reuse of excavated material (when applicable). Assuming that excavations are only foreseen in the “Fixed raising with side channel” option, in the other two options materials will have to be mined from a close-by area.

The creation of borrow pits will be a negative impact on Geology and Topography because it:

- Is a change of the natural landscape;
- Promotes the degradation of soil characteristics into a deeper depth;
- Promotes erosion and transport of soil into watercourses.

Assuming there are active and authorised borrow pits outside the study area, the likelihood of creating borrow pits within the study area, and therefore the occurrence of their impacts, depends on the project option, as they need increasing amounts of materials for embankment construction. Impact intensity of the borrow pits created will also depend on the amount of material needed and therefore on the project option (Table 4).

Table 63 – Impact assessment on Geology and Topography (construction phase): creation of borrow pits

Criteria	Assessment
Status	Negative
Extent	On-site/Local
Duration	Temporary to Permanent
Likelihood	Definite (Fusegates); Definite (Fixed raising); Likely (Fixed raising with channel)
Intensity	Low to Moderate (Fusegates); High (Fixed raising); Low (Fixed raising with channel)
Significance (without mitigation)	Low to Moderate (Fusegates); High (Fixed raising); Low (Fixed raising with channel)
Significance (expected post-mitigation/enhancement)	Low (Fusegates); Moderate (Fixed raising); Negligible (Fixed raising with channel)



6.2.2. Mitigation Measures

The following table shows the mitigation measures applied to the geology and topography impacts. General mitigation measures should be applied to some impacts, as identified in the table. Those measures can be consulted in section 7.1.4.

Table 64 - Mitigation measures applied to the geology and topography impacts

Environmental Impacts	Mitigation/ Enhancement Measure
Construction	
Soil erosion and siltation (for construction areas)	- General mitigation measures: Yes - Erosion/runoff control barriers should be installed along the excavation/ embankment areas. Silt fences or check dams should be constructed on the slopes (check dams) or on the riverside (silt fences); appropriate maintenance of these barriers is required during construction. Collected soil should be redistributed to those areas most affected by erosion.
Creation of borrow pits	

6.3. Soils

6.3.1. Construction phase

The project has an incidence over soils since the raising of the dam requires the elevation of the non-overspill crest level – representing heightened and extended embankments and, therefore, loss of the newly embanked soil area. Also, the construction activities and facilities can also have negative effects over soils where they are directly developed – namely compaction. The main impacts and aspects to be focused in the following topics are:

- Soil loss;
- Soil erosion and changes in surface morphology;
- Soil contamination.



Soil loss

The definition of soil loss in this context is assumed as more than the removal of soil volumes/horizons from the affected areas. Particularly, it is understood that impacts are of such nature that hamper and/or disrupt the soil capability to perform its functions and the development of potential uses.

A soil can be extracted from the project area – soil loss in that strict context – and reused at a different location, without a significant modification of its characteristics. But a compacted soil, although it is not removed from one location, it is exposed to a physical process that induces a different structure and characteristics, preventing that soil portion to assure, for example, a good drainage, affecting the aeration in soil horizons and causing a depletion of fertility and use for agriculture or other vegetative cover.

In view of the above, the following construction activities in terms of soil loss are relevant:

- Raised and extended embankments to establish increased overspill crest levels (all three project alternatives, although with different backfill volumes);
- Cleaning and compaction of soil for setting of construction yard and support areas (all three project alternatives);
- Excavation for construction of side channel (fixed raising with side channel option);

The impact is considered permanent for the area occupied by the increased embankments (all project options), as well as for the side channel to be built if Option 3 is chosen. In such areas, the compaction of soil will hamper the embanked soil for its regulation and productivity functions/uses. Although soils present good quality with moderate suitability for agriculture, current soil use doesn't meet its potential use, as it supports human settlements and infrastructures (right embankment at Kapininga) and natural ground (left embankment at Malingunde). Hence, the potential significant negative impact is attenuated.



All remaining soil areas temporarily affected (construction yard, temporary accesses, borrow and other support areas) should be restored to its natural conditions and other soil recovery actions when the construction works are completed.

Taking into account the enforcement of the recommended soil-related measures (especially reuse of topsoil and scarification and aeration of compacted areas; for Option 3, the possible re-use of excavated material as borrow material for embankments), most of construction activities to be carried out will result in a temporary impact in terms of soil loss areas, with low to negligible residual impacts. Permanent impacts will be limited to the location of structural surrounding compacted soil (embankments and channel).

Table 65 – Impact assessment on Soils (construction phase): soil loss

Criteria	Assessment
Status	Negative
Extent	On-site
Duration	Temporary/Short-term (for recovered areas) Permanent (for embankments)
Likelihood	Definite
Intensity	Low
Significance (without mitigation)	Low to Moderate (if not maximised the reuse of excavated material in Option 3, and soil functions/ uses in temporary construction areas aren't recovered)
Significance (expected post-mitigation/enhancement)	Low

The raising of the dam will have a secondary impact related with loss of soil areas – increased reservoir area (flooded soils), to be addressed in the operation phase impacts.

Soil erosion and morphology

Impacts related with these aspects, which result from the exposure of soil in earthworks, definition and operation of construction sites and yards, as well as soil compaction associated to heavy machinery circulation, reducing the soil percolation and increasing surface runoff, were already discussed in section 6.2.1.



Soil contamination

Soil contamination risks are a major concern in construction activities, given the use of pollutant substances in construction sites along with potential occurrence of accidental spills.

Soil contamination can occur either at a physical level, with the introduction of materials of different nature and particle size, and/or at a chemical level, due to the spill of substances such as oils, lubricants, fuel, paint strippers, among other. Circulation and operation of heavy machinery and construction equipment may increase the probability for hydrocarbon accidental spillages with potential for significant local soil impacts. Although the pollution risk is extendable to road accesses, the probability of occurrence is superior in construction yards and active construction sites.

Table 66 – Impact assessment on Soils (construction phase): soil contamination

Criteria	Assessment
Status	Negative
Extent	On-site/Local (especially in construction yards and sites)
Duration	Temporary/Short-term
Likelihood	Unlikely
Intensity	Low to Moderate
Significance (without mitigation)	Low to Moderate (in the case of accidental spills and considering the good drainage conditions and proximity to water reservoirs)
Significance (expected post-mitigation/enhancement)	Low

Usually contamination events are reversible, either considering the soil regenerating capability and resilience, either recurring to appropriate decontamination methods – as listed in Mitigation Measures sub-chapter. The enforcement of good practices in construction sites and yards significantly reduces the probability of accidental events and pollutant substances mishandling.



6.3.2. Operation phase

No changes are expected regarding downstream effects.

Maintenance activities of Kamuzu Dam I infrastructures have the potential to induce negative impacts over soils, similar to those identified in the construction phase, but typically with much lower intensity and significance.

The main impacts in the operation phase are identified next.

Soil loss

Kamuzu Dam I raising will induce changes upstream the Lilongwe River, as well as in Katete River and other small tributaries.

The key impact is the loss of soil (under the criteria defined above) correspondent to the extended flooded ground. Considering the FSL at 1,105 masl (for evaluation purposes flood and events and drought periods are excluded as it represents sporadic situations; FSL represents the most frequent situation), the upstream area defined by the new regular water level will have an extra ~270 ha of permanently immersed soil. No aeration of soil horizons will be possible and organic matter will be consumed with the production of sub-products that will be adsorbed by soil and sediment particles – sediments and upstream erosion products and pollutants that will also cumulate.

Loss of good quality and suitable for agriculture soils is referred to current uses such as natural and protective vegetation cover and agricultural land, maximising the significance of the impact, considering the type of use meets the soil's potential and quality.

On the other hand, taking into account that the rigorous reservoir area is not yet defined, the potential significant impact should also consider the extensive presence of good quality soils in the surrounding area, attenuating the impact's intensity (reduced quantitative loss considering the available surrounding soil).



Table 67 – Impact assessment on Soils (operation phase): soil loss

Criteria	Assessment
Status	Negative
Extent	On-site
Duration	Long-term/Permanent
Likelihood	Definite
Intensity	Moderate
Significance (without mitigation)	High
Significance (expected post-mitigation/enhancement)	High

Soil loss (by flooding) is an inevitable impact that cannot be directly mitigated. However, compensation measures are to be fostered, as proposed in Chapter 7 regarding socioeconomics and public health – especially the proposal and development of a Resettlement Action Plan, which will include measures for compensation of populations for agricultural soil loss (resulting from the directly flooded area).

Also, construction and operation measures to prevent soil pollution and, especially, soil erosion, through the adoption of soil conservation techniques and some guidelines regarding soil occupation, are recommended in the ESMP.

It is pointed that in floodplain soils – that is, the area defined by the regular water line and the maximum flooded area (in extreme events) – the soil loss impact could be minimised in such areas if flood recession cropping is fostered outside the protection buffer to be enforced, for example, taking advantage of the residual soil moisture after floods recede, if limited to soil conservation measures proposed and if sanctioned by the Lilongwe Water Board.

Soil erosion

Soil erosion is a reality in the study area, as agricultural activity promotes the exposure of soil particles to wind and superficial water flow. Also, the inter-level bare soils, in situations of low flow/low water reservoir's levels, along with the grazing activities, are also erosion-exposed soils.



Such phenomena are also expected after the raising of the dam, so there is no additional impact when comparing with the baseline situation (unlike soil loss).

Still, the raising of the dam will flood the current riparian vegetation. If measures such as creation of a vegetated protection buffer area around the dam and other soil erosion prevention actions won't be implemented, that protection area won't be acting as a barrier to superficial runoff and will remain a susceptible area to erosion (aggravated by the close proximity to the water), being an added siltation factor to the water reservoir, although with a low significance.

Table 68 – Impact assessment on Soils (operation phase): soil erosion

Criteria	Assessment
Status	Negative
Extent	On-site/Local
Duration	Long-term/Permanent
Likelihood	Likely
Intensity	Low
Significance (without mitigation)	Low
Significance (expected post-mitigation/enhancement)	Negligible

Regarding the proposed protection buffer along the river, in order to prevent river bank erosion, it is emphasised that using vegetation to stabilise and control or minimize erosion problems near river banks and their immediate upslope area is less expensive than repairing erosion-caused damage.

Techniques to stabilise river banks work by either reducing the force of flowing water; increasing the resistance of bank to erosion forces; or by a combination of the previous two.

The following techniques (also known as soil bioengineering) will primarily increase the resistance of the riverbank through binding the soil with root systems and growing a vegetative cover. Once established, this living material will effectively control water runoff; filter soils from runoff; intercept raindrops, reducing soil erosion, improve rainwater percolation into the ground and moderate ground and water temperatures.



Among several soil bioengineering techniques which can be used for establishing this protection buffer, the following are addressed and recommended:

- Live stacking;
- Conventional plantings.

Live stacking method uses dormant, living woody cuttings of species able to root quickly in a streamside environment; it is appropriate on riverbanks of moderate slope (4:1 or less) and in original soil (not fill); It is most effective on small earth slips and slumps that are frequently wet; if cuttings can be obtained from nearby vegetation at little or no cost, the expense for this simple type of bank stabilization is minimal.

In conventional plantings transplants of all types are available, such as bare-root, container grown, balled, etc. Seedlings of grasses and/or forbs are also an option, as well as hydro-seeding, being spacing and layout determined by the plants selected. Although this method entails a greater cost and more installation work than live stacking, it offers a greater selection of plant materials.

These methods can be combined or intermixed to achieve the desired results. Others can also be used, such as live fascines, branch-packing, brush-layering or brush-mattresses. In all cases, local native species should be used, not only for ecological reasons, but also because of their adaptation to local conditions. When first installed, these buffer protections will offer little immediate stabilization to the river bank, but their value will quickly grow.

Finally, the buffer width should vary, as a result of the river bank conditions, due to the level of protection required but also respecting existing compatible land uses.

6.3.3. Mitigation Measures

The following table shows the mitigation measures applied to the soils impacts. General mitigation measures should be applied to some impacts, as identified in the table. Those measures can be consulted in section 7.1.4.



Table 69 - Mitigation measures applied to the soils impacts

Environmental Impacts	Mitigation/ Enhancement Measure
Construction	
Soil loss	- General mitigation measures: Yes - Before excavation and general earthworks start, a fertile topsoil layer must be removed and stored in haystacks for later reuse in the recovery of affected areas. Appropriate maintenance and handling of topsoil is essential to achieving this objective. - In regard to piles of earthfilling material or soil surplus, measures to reduce mobilisation of soil such as covering stockpiles and constructing silt fences around them should be undertaken where necessary. Soil stockpiles should be restricted to a maximum of 2 m in height to prevent compaction under its weight.
Operation	
Soil erosion	- General mitigation measures: Yes - Soil conservation measures and techniques should be promoted around the reservoir area, to be adopted accordingly with the local context, characteristics and potential, such as: – Ensure a permanent soil cover, either with adequate crop rotation, or with the use of crop residues over bare soil (like maize stalk, also enhancing the soil's organic matter, promoting infiltration); – Minimize the use of mechanical equipment, under the principle of minimum soil disturbance; – Minimize or prevent the use of herbicides and pesticides, thus preventing soil pollution; – Contour ridging – although this technique is disseminated in the area, it is not always used efficiently (in slope areas, the improper ridges accumulate water until their destruction and the formation of rills and gullies); – Box/tied ridging – creates micro-catchments for capturing rain water and enhances the infiltration into the root zone; – Raising of foot paths – in order to prevent the formation of deep gullies in those areas (due to superficial water erosion); – Gully reclamation – creation of barriers inside the gullies to promote the sedimentation of materials, raising the gully level over time; – Hedge row planting – to be used especially near the riverbank where slopes are steeper and the soil is more exposed to erosion; – Creation of storm drains – to direct the excessive rainwater without affecting the cultivated land and enhancing its water erosion.
Soil contamination	
Soil pollution	



6.4. Hydrogeology

The project is located in the vast aquifer in altered formations of the crystalline basement rock of the plateau. The degree of alteration increases from the parent rock upwards to the soil. Generally, the alteration zone is 15 m to 30 m thick on the plateau and sometimes more. Normally, the alteration zone is thinner in the vicinity of rock outcrops and thicker in the faulted zones.

During construction and operation phases, negative and positive impacts affecting the Hydrogeology system are foreseen. Negative impacts relate essentially to the potential of groundwater contamination caused by engineering activities and deactivation of boreholes and wells caused by inundation. While the first will potentially be felt around the Kamuzu Dam I and downstream from it, the second impact will be felt along all the area submerged by the new water reservoir.

As a positive impact there will be an increase of water table levels in areas adjacent to the new water reservoir and in areas upstream and downstream of the new water reservoir. The increase will be felt particularly in the new water reservoir margins close to the dam and immediately downstream from it.

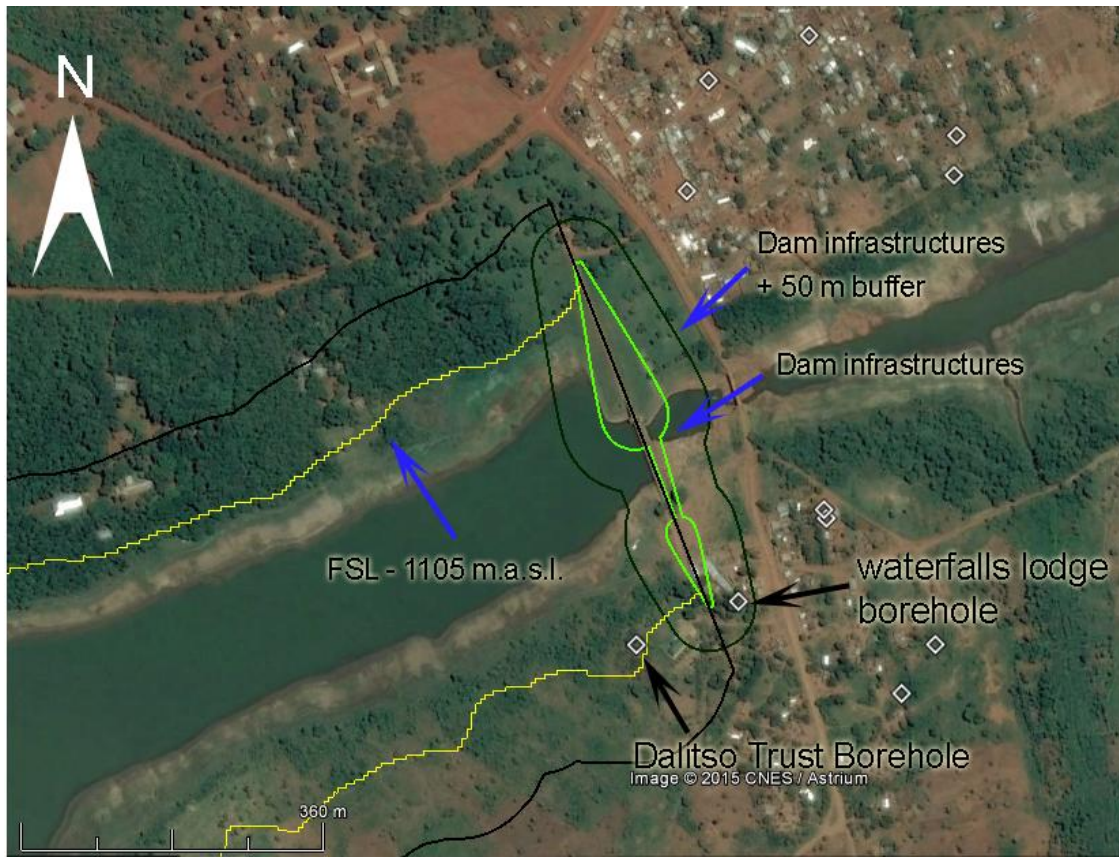
6.4.1. Construction phase

Potential impacts on groundwater of the area during the construction phase of the Kamuzu Dam I raising refer to groundwater contamination. This is especially important due to the possible accidental spillage of products (e.g. oils, fuels) from construction yards and machines operating in the area. This aquifer is especially vulnerable to infiltrations due to its superficial and detritic character and also because it underlies a relatively plain area.

Impacts related to possible groundwater contamination during construction will be especially felt in areas directly affected by actions supporting Kamuzu Dam I raising due to the operation of the construction yard and support sites (e.g. borrow pits, waste disposal locations, equipment temporary storage). According to the regional groundwater flow pattern in this area this impact may also extend to the margins downstream from the dam.



Figure 180 shows those boreholes and dug wells identified during fieldwork close to Kamuzu Dam I which seem to be more exposed to contamination, in case of an accident during construction phase.



Source: aerial image from Google Earth (December, 2013)

Figure 180 – Boreholes and dug wells (diamonds) identified nearby KD1

A contamination event on groundwater is assessed as a negative impact (Table 70), which can vary from on-site to local extent according to the amount of contaminant involved and also according to actions immediately after the event. The duration of such impact may be from short to long-term according to the type of contaminant. It is assumed that all necessary precautions will be taken to prevent contamination of groundwater during the construction phase and therefore these negative impacts will only result as accident events. In this view, presumably these will be of low intensity and minor significance.



Table 70 – Impact assessment on Hydrogeology (construction phase): groundwater contamination

Criteria	Assessment
Status	Negative
Extent	On-site/Local
Duration	Short-term/Long-term
Likelihood	Unlikely
Intensity	Low
Significance (without mitigation)	Low
Significance (expected post-mitigation/enhancement)	Negligible

6.4.2. Operation phase

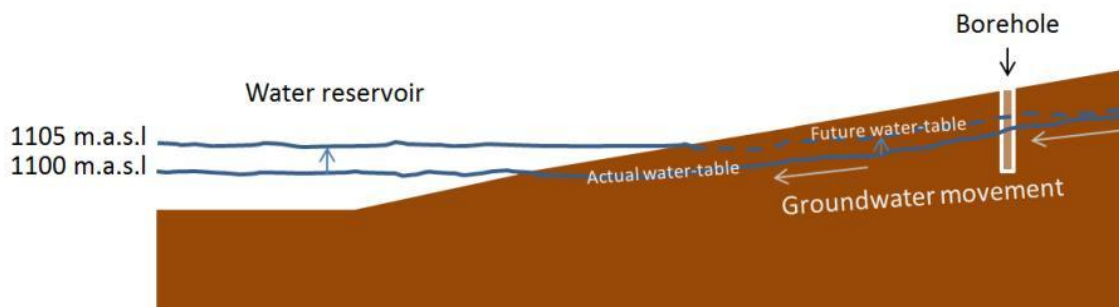
6.4.2.1. Positive impacts

Dam construction actions modify adjacent groundwater system boundary conditions and often result in a rise in the underlying and adjacent water table, yet, rarely are documented. Principally, the degree of groundwater level change will be a direct result of: 1) the magnitude of reservoir stage rise; 2) the rate of exchange between the reservoir, river sections, and the groundwater (losing or gaining conditions); 3) the regional groundwater conditions (constrained or unconstrained valley sediments), and 4) boundary conditions. Generally, as dams and reservoirs are constructed, the surrounding adjacent groundwater systems are likely to expand the zone of saturation raising local water tables (Berthelote, 2013).

The groundwater system around project area occurs beneath a general plain topography and is characterised by a porous and permeable geological formation, although aquifer properties are highly anisotropic. The closest monitored boreholes to the actual water reservoir (250 m – 450 m) show static water levels higher than the actual FSL (1,100 m.a.s.l.) (Figure 40) which indicates that for these conditions the aquifer supplies the water reservoir of the dam.



According to the above, the raising of the Kamuzu Dam I by 5 m will expectedly increase the water table level on the surrounding area of the dam, both down- and upstream from it (Figure 181).



Source: NEMUS

Figure 181 – Schematic interference of water table level by raising KD1

Considering all the monitored boreholes around the study area (Figure 40) water table is deeper than 2 m, even in those boreholes located closer to the water reservoir. Nevertheless, this information refers to just one survey and there is no reference to date of data collection.

The increase of water table level caused by raising Kamuzu Dam I by 5 m is assessed as a positive impact (Table 71), potentially with regional extent. The duration of such impact will be permanent as long as the dam and its FSL are maintained. Considering the increase of water tables verified in other areas after construction of dams (e.g. Berthelote, 2013) it is expected that this increase will reach a metre scale at its maximum, which implies low to medium intensities but medium to high significances.

Table 71 – Impact assessment on Hydrogeology (operation phase): increase of water table level

Criteria	Assessment
Status	Positive
Extent	Local to Regional
Duration	Permanent
Likelihood	Definite
Intensity	Low to Moderate
Significance (without mitigation)	Moderate to High
Significance (expected post-mitigation/enhancement)	Moderate to High



6.4.2.2. Negative impacts

The raising of Kamuzu Dam I by 5 m will deactivate boreholes operating close to the actual water reservoir. In Figure 180, the example of the Dalitso Trust borehole is illustrated, considering a FSL of 1,105 m.a.s.l., however, a thorough inventory of wells and boreholes that will be deactivated is still lacking.

The deactivation of boreholes is assessed as a negative impact (Table 72), with on-site extent. The duration of such impact will be permanent as long as the dam and the FSL are maintained. Considering that only a few boreholes were detected as in risk of deactivation in the exploration fieldwork, one may predict that the impact will be of low intensity and low significance.

Table 72 – Impact assessment on Hydrogeology (operation phase): deactivation of boreholes

Criteria	Assessment
Status	Negative
Extent	On-site
Duration	Permanent
Likelihood	High
Intensity	Low
Significance (without mitigation)	Low
Significance (expected post-mitigation/enhancement)	Negligible

The opening and construction of new boreholes to replace those deactivated, if feasible, will lower the impact's significance from low to negligible.

6.4.3. Mitigation Measures

The following table shows the mitigation measures applied to the hydrogeology impacts. General mitigation measures should be applied to some impacts, as identified in the table. Those measures can be consulted in section 7.1.4.



Table 73 - Mitigation measures applied to the hydrogeology impacts

Environmental Impacts	Mitigation/ Enhancement Measure
Construction	
Groundwater contamination Deactivation of boreholes	• General mitigation measures: Yes • Clearance of vegetation, excavations and compaction of soils and earthworks should be kept to strictly necessary areas, in particular when nearby boreholes or wells. • If there is exposure of the water table during excavations (e.g. “Fixed raising with side channel” option), actions that imply risk of contamination should not be performed or at least be restricted. • Situations where excavations imply the drawdown of the water table level should be fully studied and understood in order to mitigate effects in productivity of nearby wells or boreholes. • Construction water supply should be preferably from surface water instead of groundwater. Groundwater should only be used for domestic and potable water at the construction yards, if no other supply source is available, following abstraction and sustainability testing and appropriate permits from the relevant authorities. • In case a well or a borehole is deactivated due to the project, construction of a new one in a proper and close location is mandatory; it should follow the requirements of the Malawi Standard 733:2005: Borehole and shallow well water quality – Specification. • Groundwater quality and levels are to be monitored in the surrounding wells and boreholes (cf. Hydrogeology Monitoring Plan).
Operation	
Groundwater contamination Increase of water table level	• General mitigation measures: Yes • Groundwater quality and levels are to be monitored in the surrounding wells and boreholes (cf. Hydrogeology Monitoring Plan).



6.5. Hydrology

6.5.1. Construction phase

With the rehabilitation and raising measures, timing and works forecasted to Kamuzu Dam I's rehabilitation and raising, no significant impacts to hydrological regime during construction should occur.

6.5.2. Operation phase

6.5.2.1. Positive impacts

Kamuzu Dam I's raising is intended to manage and tackle water supply limitations and deficits and cater to the current water supply deficit and growing water demand in Lilongwe city. The increase in storage capacity of Kamuzu Dam I through its raising will increase raw water availability.

Thus, in their full operation phase, the raising project will have a direct, definite, permanent, regional and moderately significant positive impact in the amount of water available to the city's water supply, which will increase, according to Aurecon (2013b) study, from the current yield of 166,000 m³/day to 214,000 m³/day after the raising, about 29% more water available.

Table 74 – Impact assessment on Hydrology (operation phase): increase in water availability

Criteria	Assessment
Status	Positive
Extent	Regional
Duration	Permanent
Likelihood	Definite
Intensity	Moderate
Significance (without mitigation)	Moderate
Significance (expected post-mitigation/enhancement)	Moderate



As previously mentioned, a drought occurs in Lilongwe District once every 4-10 years and the 50-year return drought represents an extreme drought. Also according to Atkins (2011) based on the water demand and surface water availability assumptions, there is a water deficit in the study area in average dry season which will tend to increase in the future, due to population and economic growth, if no measures are taken.

In its full operation phase the raising of Kamuzu Dam I will increase the gross storage capacity in 257% (plus 13.1 million m³) and the water availability in 29% (plus 48,000 m³/day), which will be sufficient to meet the expected growing demand up to 2022 (Aurecon, 2013a). Thus, the raising project will have a direct, definite, long-term, regional, low intensity and low significance positive impact in mitigating the severity of droughts.

Table 75 – Impact assessment on Hydrology (operation phase): mitigation of droughts' severity

Criteria	Assessment
Status	Positive
Extent	Regional
Duration	Long-term
Likelihood	Definite
Intensity	Low
Significance (without mitigation)	Low
Significance (expected post-mitigation/enhancement)	Low

All these impacts would be of equal intensity and significance regardless of the chosen project option.

6.5.2.2. Negative impacts

As seen in section 5.5, the construction of Kamuzu Dam I led to the increase of flow and runoff especially in the dry season in stations 4D4 and 4D6 from Lilongwe River at Malingunde up to Lilongwe River at Lilongwe Old Town Bridge. For station 4D6 and after the opening of Kamuzu Dam I, the increase in flow and runoff was about 30%, on average, varying from 24.5% in February to



290% in October (the month with the biggest increase). December had the only non-significant change with a slight decrease in flow of -0.5%. In station 4D4 at Lilongwe Old Town Bridge the increase in flow and runoff was about 42%, on average, with the increases varying from 8% in February to 177% in October the month with the biggest increase.

The water from Kamuzu Dam I reservoir is discharged into Kamuzu Dam II and then to Lilongwe River and flows in its natural course up to the intake points of the treatment plants at Lilongwe city. The increase in flow and runoff occurs since operation control valves in both Kamuzu dams are opened as needed to assure a minimum flow in Lilongwe River and an adequate water level at Lilongwe City water treatment plants intake.

With Kamuzu Dam I raising project, this increase in flow and runoff is expected to continue and even increase. Therefore, in its full operation phase the project will have an indirect, likely, permanent, regional, negative impact since it will likely alter even more the hydrological regime of Lilongwe River. The impact's significance will depend on the water demand and the operating rules of Lilongwe City water treatment plants intake.

It should also be emphasised that Kamuzu Dam II reservoir tailwater extends to the lower part of Kamuzu Dam I wall, so the flow releases of Kamuzu Dam I should be defined and controlled by Kamuzu Dam II operating rules and equipment and also by Lilongwe water treatment plants. The project will increase water availability by 29% (plus 48,000 m³/day), which means that the maximum increase in flow and runoff likely to happen will be of 29%, on average. Since the hydrological regime was already altered by the constructions of both Kamuzu dams we can classify the significance of this incremental impact as negligible to low.

Table 76 – Impact assessment on Hydrology (operation phase): increase in flow and runoff up to Lilongwe water treatment plant

Criteria	Assessment
Status	Negative
Extent	Regional
Duration	Permanent
Likelihood	Likely



Criteria	Assessment
Intensity	Negligible to Low
Significance (without mitigation)	Negligible to Low
Significance (expected post-mitigation/enhancement)	Negligible

The raising of Kamuzu Dam I aim to increase water availability to Lilongwe water treatment plant. With the increase in water demand an increase in water abstraction at this plant will occur and the flow might decrease, thus affecting the hydrological regime downstream of the water treatment plant. However this impact is dependent on the operation rules of both Kamuzu Dam II and Lilongwe water treatment plant. If the environmental flow requirements are maintained this negative impact can be classified as indirect, regional, likely, long-term, but negligible.

Table 77 – Impact assessment on Hydrology (operation phase): decrease in flow downstream Lilongwe water treatment plant

Criteria	Assessment
Status	Negative
Extent	Regional
Duration	Long-term
Likelihood	Likely
Intensity	Negligible
Significance (without mitigation)	Negligible
Significance (expected post-mitigation/enhancement)	Negligible

In what concerns to sediments, the raising project will increase the capacity/inflow ratio which will lead to an increase in the trap efficiency of the reservoir. However as can be seen by the results of the model developed to study the evolution of sedimentation in the reservoir for the next 15 years, presented in Appendix 2, even though this increase in trap efficiency is a direct, definite, permanent, local negative impact, its significance regarding sedimentation rates and assuming that erosion within the catchment is not going to increase is negligible.



Table 78 – Impact assessment on Hydrology (operation phase): increase in trap efficiency/sediment deposition

Criteria	Assessment
Status	Negative
Extent	Local
Duration	Permanent
Likelihood	Definite
Intensity	Negligible
Significance (without mitigation)	Negligible
Significance (expected post-mitigation/enhancement)	Negligible

6.5.3. Mitigation Measures

The following table shows the mitigation measures applied to the hydrology impacts. General mitigation measures should be applied to some impacts, as identified in the table. Those measures can be consulted in section 7.1.4.

Table 79 - Mitigation measures applied to the hydrology impacts

Environmental Impacts	Mitigation/ Enhancement Measure
Operation	
Decrease of flow downstream Lilongwe water treatment plant	- General mitigation measures: No - Operating rules of the water treatment plant and of Kamuzu Dam II should be defined considering the environmental flow. The environmental flow should be assessed and evaluated through the application of different methodologies, namely hydrological (with emphasis on the one defined by the Ministry of Agriculture, Irrigation and Water Development) and habitat simulation methodologies, such as IFIM.
Decrease of flow downstream Lilongwe water treatment plant	- General mitigation measures: No - A stream flow gauge should be installed downstream of the Lilongwe water treatment plant to measure the available flow after abstraction and monitor the environmental flow releases.



Environmental Impacts	Mitigation/ Enhancement Measure
Increase in trap efficiency/ sediment deposition	- Awareness meetings focusing on the need for catchment conservation and forestation should be conducted. - Bi-annual surveys should be carried out to determine the trapped sediment volume; when the volume surpasses the Kamuzu Dam I's needed storage capacity dredging should be done.

6.6. Surface Water Quality

6.6.1. Construction phase

Given the Project's characteristics and the previous baseline assessment on surface water quality, the raising works are expected to cause the following negative impacts in local surface water quality, limited to the area around the construction site in Kamuzu Dam I reservoir and in close vicinity downstream, already in Kamuzu Dam II reservoir:

- Increase of suspended solids and turbidity due to erosion and earthworks near the reservoir;
- Increased risk of organic matter and faecal contamination, due to uncontrolled runoff from construction yards and workers settlements around the site;
- Increased risk of water pollution due to spillages of hydrocarbons and other hazardous substances to use in the construction activities.

The expected temporary water quality degradation will be mainly due to the increase in turbidity. Earthworks leave the soil exposed to erosion factors, resulting in increased turbidity after rainy periods.

This can affect suitability for the main existing uses (washing, bathing, fishing and abstraction for local consumption at Water Falls Lodge, LWB/ Land Conservation Department offices, Youth Camp and KIX nursery school) around the construction site, especially in closely populated areas of Kapininga and Malingunde.



Predicted overall impact tends to be of low intensity, and is likely to be limited to a small area around the site, nonetheless extending downstream to Kamuzu Dam II reservoir. Attributed significance is low to moderate since it may affect an area where villagers intensively use the reservoir's water not only for washing, bathing (and fishing), but also for local abstraction to human consumption. Displacement of that uses for cleaner areas is somewhat possible, upstream or downstream, but with prejudice regarding travel distance. Proposed mitigation will generally lower this impact significance.

Regarding the three project options, option 1 (fusegates) would be slightly more favourable as it involves fewer earthworks than the other two. Such difference however doesn't affect the overall impact assessment presented in Table 80.

Table 80 – Impact assessment on Surface Water Quality (construction phase): water quality degradation (suspended solids and turbidity)

Criteria	Assessment
Status	Negative
Extent	Local
Duration	Temporary/Short-term
Likelihood	Definite
Intensity	Low
Significance (without mitigation)	Low to Moderate
Significance (expected post-mitigation/enhancement)	Low

Organic and faecal contamination can be originated by uncontrolled runoff from construction yards and/or by new or existing settlements around the site, accommodating the workforce and services attracted by the project. While this can be a significant problem in larger constructions, like new dams, the project is not likely to involve a very large workforce, and most of it is likely to stay in the construction yard, where sanitation facilities can be installed, preventing this kind of pollution. Anyway, sensitive uses exist around the construction site, including water abstraction for drinking and bathing, so this impact, despite not definite, can be of moderate significance if proper mitigation is not implemented.



Table 81 – Impact assessment on Surface Water Quality (construction phase): risk of water quality degradation (organic and faecal contamination)

Criteria	Assessment
Status	Negative
Extent	Local
Duration	Temporary/Short-term
Likelihood	Likely
Intensity	Low
Significance (without mitigation)	Low to Moderate
Significance (expected post-mitigation/enhancement)	Low

Risk of accidental spillage of hydrocarbons and other hazardous substances to land and water during construction is nowadays generally low if appropriate safety measures and training are implemented. However, in case of significant accidental spillage of such pollutants, local and downstream water uses can be temporarily compromised, even posing health risks to nearby populations.

These kind of direct and indirect potential impacts are probabilistic, since they result from unpredictable situations and not from permanent construction sources.

Intensity and significance of these potential impacts ultimately depends on the type and quantity of the spilled substance. However, expected activities and machinery usually used for construction of this type of projects do not suggest that significant quantities of hazardous substances will be needed, so impacts can be considered generally low after mitigation.

Table 82 – Impact assessment on Surface Water Quality (construction phase): risk of water quality degradation (spillages of hydrocarbons and other hazardous substances)

Criteria	Assessment
Status	Negative
Extent	Local
Duration	Temporary/Short-term
Likelihood	Unlikely
Intensity	Variable (but expectably low)



Criteria	Assessment
Significance (without mitigation)	Low to Moderate
Significance (expected post-mitigation/enhancement)	Low

Both impacts would be similar in all three project options.

All this three forms of likely impacts on surface water quality can have adverse effects on the aquatic ecosystem, ranging from temporary habitat alteration and annoyances to aquatic species, forcing them to migrate to surrounding areas, to other kind of risks such as of eutrophication. This will be specifically assessed in the Ecology section (6.9.1).

6.6.2. Operation phase

The dam's raising will flood new areas upstream, extending the area of the current reservoir (considering the FSL at 1,105 masl). Progressive degradation of the existing vegetation on the margins that will be flooded can lead to water quality issues, such as oxygen depletion. This can be an issue especially when vast woodlands areas are to be flooded.

That would be the main impact on operation phase. As such, a specific assessment was performed considering two scenarios (with or without previous vegetation clearance. Appendix 2 presents a modelling study of such impacts on water quality along with impacts on increment in sedimentation.

The main causes for oxygen depletion are consumption by respiration on the water column and by organic matter decomposition near the bottom. Future conditions were modelled considering two different scenarios for dam raising: (i) organic matter is removed in new flooded areas and (ii) organic matter is not removed.

In both situations the new flooded areas will be very shallow and therefore under the influence of surface boundary conditions (reaeration). As it is not expected that the reservoir presents a very strong stratification in the upper layers (say 5 m), it is not likely that oxygen depletion occurs in these areas.



However, if the organic matter near the bottom is increased, more nutrients will be available in the water column and therefore an increase in primary production might be expected.

Main conclusions that arise from water quality modelling point out that maintaining a status similar to the present one – which is thought to be an oligotrophic status according to the few data available for nitrate – the concentrations of dissolved oxygen will remain in acceptable levels throughout the year. If the vegetation in the new areas to be flooded is not removed previously to the dam's raising, then it is possible that oxygen consumption in hypolimnion increases, leading to low concentrations in the deeper parts of the reservoir. In that case, if the amount of vegetation in the areas to be flooded is considerable and the overall loads of nutrients and organic matter produced in the catchment would increase, then it would be possible that the reservoir would experience low concentrations of dissolved oxygen throughout the water column during the summer peaks.

However, as it is not expected that an increase of nutrient and organic matter loads in the catchment will occur in the future, the impact would only be caused by the degradation of flooded vegetation, (if not removed previously); it does not seem to pose a very significant threat to future reservoir's water quality.

Nevertheless, due to the existence of some degree of uncertainty (either regarding future developments and changes in pollutant loads, or considering model uncertainties), while it does not seem essential to remove vegetation from the new areas to be flooded, that should indeed be done as a preventive measure to mitigate future issues. Obviously a complete prevention of deoxygenation problems would be obtained with the removal of vegetation. In this case, deforestation activities could actually be done with the assistance of and in the benefit of local communities, which reinforces its recommendation.

For water quality purposes, the above assessment considered only the flooding that occurs at the FSL 1,105 masl, therefore representative of all three project options. The different maximum water levels defined by the different project options have a negligible cumulative impact, once the immersion of soil in flood events considering a recurrence 1:200 year will be temporary and very sporadic.



Table 83 – Impact assessment on Surface Water Quality (operation phase): risk of water quality degradation (oxygen depletion)

Criteria	Assessment
Status	Negative
Extent	On-site
Duration	Short-term
Likelihood	Likely
Intensity	Low to Moderate (seasonably, in the first years after flooding)
Significance (without mitigation)	Low to Moderate (seasonably, in the first years after flooding)
Significance (expected post-mitigation/enhancement)	Negligible to Low

6.6.3. Mitigation Measures

The following table shows the mitigation measures applied to the surface water quality impacts. General mitigation measures should be applied to some impacts, as identified in the table. Those measures can be consulted in section 7.1.4.

Table 84 - Mitigation measures applied to the surface water quality impacts

Environmental Impacts	Mitigation/ Enhancement Measure
Construction	
Water quality degradation	- General mitigation measures: Yes - Special care must be taken when working near major river sites used by local population for washing/bathing/fishing. - Existing licensed raw water abstractions in Kamuzu Dam I at Malingunde, such as the Water Falls Lodge, the LWB/ Land Conservation Department offices, the Youth Camp and the KIX nursery school, shall be adequately protected during construction, accounting for possible accidental spillages of oils and hydrocarbons and increased turbidity or faecal contamination. For example, hydrocarbon floating booms can be installed around the intakes, if needed.



Environmental Impacts	Mitigation/ Enhancement Measure
	If water contamination around the site is confirmed from monitoring activities or in case of accidental spillages, the affected area and uses shall be immediately interdicted and authorities, local communities and water users shall be informed of the risks. Causes are to be investigated and adequate actions shall be taken to restore the situation as soon as possible. Until complete restoration, new water sources and/or safe areas with adequate water quality should be investigated and proposed as an alternative to local users.
Operation	
Water quality degradation	- General mitigation measures: Yes - Raise awareness and collaborate with relevant authorities for promoting sanitation improvements of settlements located around the Kamuzu Dam I reservoir. - Enforce the use of environmentally friendly agro-chemicals registered with the Pesticide Board of Malawi in the reservoir's protection area. - Promote sessions with farmers to raise awareness on the impacts of using fertilizers and pesticides on the reservoir water quality and inform about environmentally friendly available alternatives for increasing farming yield. Train farmers on proper storage, handling and use of agro-chemicals. - Improve the current water quality monitoring programme in the Kamuzu Dam I and II reservoirs (see monitoring plan for guidelines).



6.7. Noise

6.7.1. Construction phase

Negative impacts are expected during the construction phase, affecting local communities due to the increase of noise levels in the vicinity of construction site, construction yards, possible borrow pits/sites and road accesses.

The main impacts at this stage arise from two different noise sources:

- Construction activities (earthworks, rock works through blasting, concreting, among others) and operation of heavy machinery (excavators, bulldozers, pneumatic drill, roller compactor, generators, compressors, among other);
- Construction traffic, especially concerning heavy vehicles circulation.

The impact of the produced noise levels will be experienced temporarily, during the construction activities, and will also present a considerable variability along the predicted works timeline, considering the tasks to that will be undertaken, as well as the number, type and location of the machinery in operation at a given time. It is also pointed that the temporary nature of such construction activities induces a greater tolerance than noise-intensive activities of permanent nature.

Construction activities and heavy machinery

These noise sources are directly related with the operation of equipment and machinery, as well as the adopted construction methods. The noise levels generated by this type of sources can be, at certain periods, rather high (between 65 and around 100 dB(A)), although discontinuous.

The generated levels can present significant variations associated with the type of performed activity, its duration time, as well as the way the materials are used, the equipment and respective number – which are all factors dependable of the contractor construction strategy and options.

In light of the above, a qualitative approach/assessment of the generated sound levels in the construction phase is presented.



The following table refers, by usual point sources associated with construction works, to the correspondent distance at which the A-weighted equivalent sound pressure level (LAeq) of 65, 55 and 45 dB(A) are met (considering a homogeneous and quiescent propagation environment). Given the absence of specific legislation in Malawi regarding sound emissions threshold values of exterior equipments, the table uses as reference the emission values set by the Directive 2005/88/CE, of the European Parliament and the Council of the European Union (December 14th).

Table 85 – Distance to construction phase noise sources,
considering LAeq of 65, 55 and 45 dB(A)

Type of equipment	P: Net installed power (kW) Pel: Electric power (kW) m: Mass of appliance (kg)	Distance to source (m)		
		LAeq65	LAeq55	LAeq45
Compaction machines (vibrating rollers, vibratory plates, vibratory rammers)	P≤8	40	126	398
	8<P≤70	45	141	447
	P>70	>46	>146	>462
Tracked dozers, tracked loaders, tracked excavator-loaders	P≤55	32	100	316
	P>55	>32	>102	>322
Wheeled dozers, wheeled loaders, wheeled excavator-loaders, dumpers, graders, loader-type landfill compactors, combustion-engine driven counterbalanced lift trucks, mobile cranes, compaction machines (non-vibrating rollers), paver-finishers, hydraulic power packs	P≤55	25	79	251
	P>55	>26	>81	>255
Excavators, builders' hoists for the transport of goods, construction winches, motor hoes	P≤15	10	32	100
	P>15	>10	>31	>99
Hand-held concrete-breakers and picks	m≤15	35	112	355
	15<m≤30	≤52	≤163	≤516
	m>30	>65	>205	>649
Welding and power generators	Pel≤2	≤12	≤37	≤116
	2<Pel≤10	≤13	≤41	≤130
	Pel>10	>13	>40	>126



Type of equipment	P: Net installed power (kW) Pel: Electric power (kW) m: Mass of appliance (kg)	Distance to source (m)		
		LA _{eq} 65	LA _{eq} 55	LA _{eq} 45
Compressors	P≤15	14	45	141
	P>15	>15	>47	>147
Lawnmowers, lawn trimmers/lawn-edge trimmers	L≤50	10	32	100
	50<L≤70	16	50	158
	70<L≤120	16	50	158
	L>120	28	89	282

Depending on the number of equipments to use (and type) and on the sound propagation obstacles between the construction sites and the closest sensitive receptors/communities, the values indicated in the previous table can increase or decrease significantly. The table values indicate that, for a distance inferior to 10-20 m of the construction sites, the noise levels should be higher than 65 dB(A).

Despite that, for superior to 100 m distances from noise sources, noise levels are subject to attenuation factors which diminish the caused disturbance effect in close-by receptors.

These noise sources should be concentrated at the dam's construction site (if necessary, also in potential borrow areas), affecting temporarily and discontinuously in the daytime period a variable buffer in the immediate surroundings estimated of 10-20 m for the 65 dB(A) threshold and of 50-80 m for the 55 dB(A).

Besides the construction site, the construction yard and support areas represent areas of potential significant noise sources. Considering, as hypothesis, a context of an average continuous sound emission of around 7 dB(A) associated with the construction yard activity (threshold for industrial sites according with the IFC/WHO standards), and equating it to a point noise source, the noise attenuation in free range (that is, considering a pessimistic scenario) will be of 6 dB(A) by duplicating the distance to the source. In these conditions, the 55 dB(A) threshold is achieved between 6 to 12 m distance to the source.



In view of the sensitive receptors identified in section 5.7.2, as well as the previous considerations, the negative impacts will be of greater significance in the 20 m border of the construction site and yard (or other project areas such as borrow pits or backfill locations), in the Kapininga area (given its proximity to work areas) – especially the Dalitso Trust building, if considered an educational facility. At these locations, it is expected the elevation at given daytime periods of the maximum recommended levels by the WHO for residential and educational areas (considering the 3 dB(A) allowed increase to existent levels).

For other sensitive receptors located further than 50-100 m, the expected negative impact will be of reduced significance or residual.

Although construction yard(s) location is not yet defined, it is recommended its placement far (if and when possible) from human settlements.

Considering the three project alternatives, construction methods define different impact evaluations:

- Fusegates – the installation through sliding rails might origin high intensity noise emissions, although the method minimises the installation time;
- Fixed raising – this option represents a much more significant quantity of earthworks, increasing the use of earthworks machinery and materials transportation in comparison with other alternatives;
- Fixed raising with channel – the construction of the channel through excavation increases the possibility of use of rock blasting.

The following table synthesises the identified noise impacts.

Table 86 – Impact assessment on Noise (construction phase): construction activities and heavy machinery operation

Criteria	Assessment
Status	Negative
Extent	On-site/Local
Duration	Temporary
Likelihood	Definite (close vicinity in Kapininga); Likely (other sensitive receptors in Kapininga and Malingunde)



Criteria	Assessment
Intensity	Low (Fusegates); Moderate (Fixed raising); Moderate to High (Fixed raising with side channel)
Significance (without mitigation)	Moderate to high (50 m buffer) Low (other sensitive receptors further than 50 m)
Significance (expected post-mitigation/enhancement)	Moderate (50 m buffer) Negligible to Low (other sensitive receptors further than 50 m)

Traffic

Another source of potential impacts is the traffic generated by the project construction, especially considering the large proportion of heavy vehicles associated with the construction works traffic, with a greater potential in terms of noise emissions. The circulation of heavy transport vehicles generates immediately high noise levels (between 75 and 85 dB(A)). However, the characteristic of the produced noise, namely its intensity, depend of various factors, among them the traffic volume, circulation speed, vehicle maintenance and carried load and pavement conditions. The significance of negative indirect impacts depends also on the type of human occupation in the surroundings to road accesses.

The primary access is the local crossing from Malingunde to Kapininga and southern villages, linked to T364 (Likuni-Malingunde-Namitete) and D197 (Malingunde-Dzalanyama Mountains) and other dirt road accesses. These unpaved road accesses promote increased noise due to overtaking holes and bumps (along with higher engine revolutions of the low circulation speeds), especially in a 50 m border along the roads.

It should be pointed that the baseline situation is marked by residual traffic circulation. On the other hand, the circulation speed is low, as well as the population density (with some relevance at Malingunde and Kapininga).

The heavy traffic volume will also depend on the necessity of borrow materials and the option adopted for temporary landfill (for excavated materials for project



option “fixed raising with side channel”). These construction options are not yet defined.

Either way, the overall traffic will be variable and diluted in the total construction period, and also in a daily basis, limiting the incommmodity over the sensitive receptors located close-by the accesses. The fact that the construction activities are undertaken during daytime also helps to contain the discomfort due to generated noise.

The impact assessment considering traffic as a noise source is as follows.

Table 87 – Impact assessment on Noise (construction phase): construction traffic

Criteria	Assessment
Status	Negative
Extent	Local
Duration	Temporary
Likelihood	Likely
Intensity	Low
Significance (without mitigation)	Low
Significance (expected post-mitigation/enhancement)	Low to Negligible

6.7.2. Operation phase

The proposed rehabilitation and raising project alternatives does not include equipment with relevant noise emissions – especially elevation pumps. Therefore, no impacts in ambient noise should arise from the dam operation in comparison to the current situation.

Only temporary maintenance works could affect negatively the noise environment, with similar impacts to those identified for the construction phase, of lower intensity, significance and extent.



6.7.3. Mitigation Measures

The following table shows the mitigation measures applied to the noise impacts. General mitigation measures should be applied to some impacts, as identified in the table. Those measures can be consulted in section 7.1.4.

Table 88 - Mitigation measures applied to the noise impacts

Environmental Impacts	Mitigation/ Enhancement Measure
Construction	
Noise emission from construction activities and heavy machinery operation	- General mitigation measures: Yes - Restriction of the work schedule to daytime period (7-20h) when working near populated areas. This rule is also recommended for the circulation of heavy construction vehicles and machinery; if there is a specific imperative necessity to extent the construction works beyond the designated period, in those areas, local authorities and the exposed population must be previously informed. - If needed, the use of explosives to dismantle rocky patches shall be done only during daytime, from 8 to 17h, and accordingly to local regulations or internationally defined safety standards. - Promote acoustic isolation of stationary equipment that represent significant noise sources (diesel generators, pumps, etc.) near sensitive receptors, through the installation of soundproofed or enclosure devices, such as canopies or acoustic hoods.
Noise emission from construction traffic	



6.8. Air Quality

6.8.1. Construction phase

The construction project involves a set of actions susceptible of causing relevant impacts over the ambient air quality, including:

- Circulation of vehicles and machinery, at construction sites and road and construction accesses, borrow pits/sites and other support areas, with the subsequent emission of combustion gases such as nitrogen oxides, carbon monoxide and volatile organic compounds, although it should be highlighted the emission and re-suspension of particulate matter;
- Cleaning and ground clearance operations, earthworks in construction sites (excavations and backfills), possible borrow pits and construction yard(s) and the subsequent direct emission of particulate matter.

Particulate matter emissions

Associated with the above-mentioned actions is the emission of particular matter as the key factor in the degradation of local air quality. In the following table are presented some reference values, as a benchmark of particulate matter emissions associate with construction activities.

Table 89 – Particulate matter emission factors for construction operations

Operation	Emission factor
Truck earth loading	0.25 (kg/ton earth) <i>Soil with a 2% humidity</i>
Excavation	2.43 (kg/hour) <i>Soils with 2% of particles with a diameter inferior to 0.075 mm</i>
Compaction	0.19 (kg/km) by compactor in operation
Particles emission from earth deposits	2.58 (kg/acre.hour) – average value
Particles emission due to heavy vehicles circulation on unpaved surfaces	0.07 to 23 (kg/vehicle.km)
Particles emission in asphalted roads used by heavy vehicles	0.0006 to 8 (kg/vehicle.km)

Source: EPA AP-42



The air quality degradation depends not only of the introduction and emission of contaminant compounds into air, but also of meteorological factors that determine its local dispersion, wind being a key aspect.

The unfavourable periods (that is, where conditions promote more significant dust emissions and local dispersion) occur therefore with the coincidence of dry weather and the higher wind intensity in this season. As mentioned in section 5.8.4, the worst scenario in terms of dust emissions could be set for the months of September and October (high temperatures and wind intensity and low precipitation), for a wind direction of east/northeast. The months with higher average wind intensity concur with the dry season, for south-eastern winds.

After its suspension, the dust particles tend to maintain in the atmosphere and to be transported during a more or less prolonged period until its re-deposit. The time and distance of suspension particles transport varies with its grain-size distribution, humidity degree and wind speed. The largest particles rapidly deposit, covering short ranges. Typically, with average speed winds (as frequent in the Lilongwe region), particles with upper 100 μm diameters have a range inferior to 10 m in regard to the source, while for particles dimensions between 30 and 100 μm the range increases to a few dozens of metres.

Given that construction activities will be limited to interventions in dam structures, the impacts could potentially be felt at surrounding human settlements of Malingunde and Kapininga.

The main activities are earthworks, especially for the raising of embankments for all project alternatives, machinery operation emissions and setting and operation of construction yard and other support areas. Although no prediction on earthworks balance/quantities is given at this time for the three project alternatives, the NOC raising shouldn't represent a high intensity impact concerning dust emissions – low to medium intensity. Taking into account the preliminary estimates given by Aurecon (2013a), the use of fusegates represent 20,000 m^3 of embankment's raising (low intensity), fixed raising would require 130,000 m^3 (medium intensity) and fixed raising with side-channel a total of 53,000 m^3 between backfill and excavation (low intensity).



Also, the dominant east winds minimise the exposure of Malingunde and Kapininga's settlements (located east from the dam). Only border occupations such as Dalitso Trust and houses immediately located to the right embankment (within 50 metres) should be affected, with special regard to Dalitso Trust and Kapininga's houses given the proximity to the work area. KIX Nursery school and Youth Camp, although are located in the dominant's wind direction, are enclosed in a forested area (acting as a barrier to air pollutants) and located at more than 250 metres.

Hence, the impact significance will be medium to high in Kapininga and Dalitso Trust and low for other sensitive receptors at Malingunde and Kapininga (further than 50 metres).

The emission of particulate matter associated with heavy transport of borrow material, excavated soil for temporary deposition or landfill (if applicable) and other construction materials, as well as related to the construction yard activity, can be mitigated as indicated in proper chapter. Once there is no current definition of the construction yard location or other support areas (like borrow or deposition sites), it is not possible to determine the subsequent impacts.

It can be pointed that the settlements near T364, D197 and the local road access to Kapininga (unpaved surfaces), are potentially exposed to the re-suspension of dust due to the circulation of heavy vehicles, depending on the location of borrow sites and construction yard.

The type of construction activities indicates that it should always be considered the potential occurrence of higher intensity and significance of the identified impacts, although in a limited time frame and as a result of unfavourable dispersion conditions and its coincidence with other air pollution sources.

In summary, the overall impacts are those identified in Table 90.

Table 90 – Impact assessment on Air Quality (construction phase): particulate matter emissions

Criteria	Assessment
Status	Negative
Extent	On-site/Local
Duration	Temporary
Likelihood	Definite (close vicinity in Kapininga)



Criteria	Assessment
	Likely (other sensitive receptors in Kapininga and Malingunde)
Intensity	Low (Fusegates and Fixed raising with side channel); Moderate (Fixed raising)
Significance (without mitigation)	Moderate to High (close vicinity in Kapininga) Low (other sensitive receptors in Kapininga and Malingunde)
Significance (expected post-mitigation/enhancement)	Low to Moderate (close vicinity in Kapininga) Low (other sensitive receptors in Kapininga and Malingunde)

Gaseous emissions

Other factor responsible for altering locally the ambient air quality in the intervention area and vicinity is the emission of combustion gases, generated by vehicle and machinery in circulation to and from the construction sites. Among them are carbon monoxide, nitrogen oxides and particulate matter.

The emission of the pollutants will be not only dependent of the heavy vehicles circulation expected, but also of other relevant aspects, such as the type of carried load, type and maintenance condition of the vehicles and the circulation speed. The combination of the mentioned factors can induce in the immediate border of the used road accesses a temporary increase of atmospheric pollutants' concentration.

It stands out that the factors which influence air pollution and noise are very similar. In fact, the air impact assessment is analogue to the one performed for noise. In synthesis, it is not predictable that this component will generate very significant concentrations of gaseous pollutants, given the discontinuity of the heavy traffic during daytime and the atmospheric dispersion conditions (especially the average wind intensity between 4 and 6 km/h).

The unpaved and irregular surfaces of T364, D197 and local roads increases the potential for combustion gases emissions (more frequent accelerations and periods of higher engine revolutions), in an area of rural dispersed settlements.



Table 91 – Impact assessment on Air Quality (construction phase): gaseous emissions

Criteria	Assessment
Status	Negative
Extent	Local
Duration	Temporary
Likelihood	Likely
Intensity	Negligible to Low
Significance (without mitigation)	Low
Significance (expected post-mitigation/enhancement)	Negligible to Low

6.8.2. Operation phase

The operation of Kamuzu Dam I do not foresee the consumption of fuel associated with the infrastructures' equipment. Therefore, no impacts in ambient air should arise from the dam operation due to combustion gases production and emission.

Only temporary maintenance works could affect negatively the environmental air and the communities located nearby. Such negative and temporary impacts should be similar to those identified for the construction phase, of lower intensity, significance and extent.

6.8.3. Mitigation Measures

The following table shows the mitigation measures applied to the air quality impacts. General mitigation measures should be applied to some impacts, as identified in the table. Those measures can be consulted in section 7.1.4.



Table 92 - Mitigation measures applied to the air quality impacts

Environmental Impacts	Mitigation/ Enhancement Measure
Construction	
Particulate matter emissions Gaseous emissions	- General mitigation measures: Yes - Regularly sprinkle water where needed through the construction site, particularly during dry and windy periods, in order to mitigate dust dispersion. Workers shall wear adequate protective gear. - Unloading of the transported powdery materials should be performed recurring to drop-height regulation equipment, ensuring the lowest drop-height possible in these operations. - Onsite concrete production facilities (including raw materials storage areas), if needed, should be as far away from existing human settlements as possible. The concrete plant shall be equipped with dust emission control features, such as filters.

6.9. Terrestrial and Aquatic Ecology (Flora and Fauna)

6.9.1. Construction phase

In construction phase there are several actions susceptible to create impacts over the habitats and over the floristic and faunistic components:

- Installation of provisional structures of the work (construction yards, etc.);
- Vegetation clearing from the embankments;
- Excavations and soil removal (if applicable – option 3);
- Noise levels increase due to the circulation of machinery and construction activities;
- Construction works to achieve the intended raise of the dam.

These actions will have expected impacts, directly or indirectly, over the habitats and biological components. These impacts are included mainly in the following groups:

- Habitat alteration/destruction;
- Habitat contamination;
- Disturbance of faunistic communities.



Habitat alteration/destruction

The installation of provisional structures of the work, the vegetation clearing and the necessary earthworks will promote the alteration of some habitats, mischaracterising them of their ecological functions, and in some cases even leading to their elimination.

Clearance of native vegetation in the intervened areas will facilitate the proliferation of invasive plant species, characteristically more opportunist and of easy propagation. The expected disturbance over the habitats will originate a loss of food and space resources to the occurring biological communities.

Out of the intervened areas, the depletion of natural resources such as land, wood and grass may increase due to the influx of migrant workers during construction.

The significance of this impact varies according to the affected habitats, depending on their ecological relevance (their current conservation status and human intervention level):

- A low significance is attributed to habitats ecologically less interesting and with significant levels of human intervention, like croplands, human settlements and some other intervened habitats (e.g. planted gardens);
- A higher significance level is considered concerning habitats with ecological intrinsic value, like wetlands, woodlands, Lilongwe and Katete rivers and other forest plantations rather than gardens; these biotopes still preserve some original features and play an important role to biological communities.

Considering the habitat distribution in the study area and the intended location for project's components, a moderate significance could be attributed to some areas of wetlands, woodlands, river and forest plantation areas that will be intervened.

The interventions in the remaining areas acquire lower significance since the affected artificial habitats (human settlements and infrastructure areas) have no relevant ecological value.



Other new access roads or widening of existing ones that might be needed for construction have not been accounted since they are not defined in the present version of the project. Environmental measures were defined in order to guide site selection and mitigate possible impacts on natural habitats.

Considering the three project alternatives, the magnitude of associated earthworks potentially differentiates the intensity and significance of the impact. However, for all three project options the main affected habitat is human settlements and infrastructure areas, so a low significance is valid for all options.

Only the left embankment extension in Option 2 affects an additional area of mixed forest plantation/ infrastructure area habitat. Even considering the high significance associated to the forest plantation area, the increased impact area is not sufficient to change the overall low significance of habitat alteration/ destruction impact.

Table 93 – Impact assessment on Terrestrial and Aquatic Ecology (construction phase): Habitat alteration/ destruction

Criteria	Assessment
Status	Negative
Extent	Local
Duration	Permanent/Long-term
Likelihood	Likely/Definite
Intensity	Low
Significance (without mitigation)	Low (cultivated lands, human settlements and other heavily intervened habitats) to Moderate (wetlands and woodlands that still preserve original features, forest plantations)
Significance (expected post-mitigation/enhancement)	Low



Habitat contamination

During construction works, accidental spillage of fuel, oils and other pollutants may cause physical and/or chemical contamination of terrestrial and/or aquatic habitats. The adoption of preventive measures should be strictly promoted in order to nullify the likelihood of such incidents.

Table 94 – Impact assessment on Terrestrial and Aquatic Ecology (construction phase): Habitat contamination

Criteria	Assessment
Status	Negative
Extent	On-site/local (according to contaminant's type and spilled quantity)
Duration	Variable (according to contaminant's type and spilled quantity)
Likelihood	Unlikely
Intensity	Variable (according to contaminant's type and spilled quantity)
Significance (without mitigation)	Variable (according to contaminant's type and spilled quantity)
Significance (expected post-mitigation/enhancement)	Low

Disturbance of faunistic communities

During the construction phase several activities are expected to increase noise levels and general disturbance of the area, which will potentially affect the occurring faunistic communities:

- Circulation and operation of heavy machinery and vehicles;
- Soil and land removal;
- Vegetation clearing;
- Excavation operations;
- Operation of constructions yards;
- Rehabilitation and raising construction works.



The affected faunistic communities may disperse to non-affected neighbouring areas, thus altering their food and reproductive behaviours.

Road traffic increase due to circulation of heavy machinery and vehicles assigned to the project may lead to increased mortality by run over of species with characteristically less mobility, like reptiles and amphibians.

The significance of this impact is related to the conservation concern of the potentially affected faunistic values. Nevertheless, its temporary nature combined with the adoption of targeted mitigation measures may result in a final low significance.

Table 95 – Impact assessment on Terrestrial and Aquatic Ecology (construction phase):
disturbance of faunistic communities

Criteria	Assessment
Status	Negative
Extent	Local
Duration	Temporary/Short-term
Likelihood	Likely
Intensity	Moderate
Significance (without mitigation)	Low to Moderate
Significance (expected post- mitigation/enhancement)	Low

6.9.2. Operation phase

In operation phase the main activity likely to create impacts over the floristic and faunistic components is the flooding of upstream areas. This action will have expected impacts, directly or indirectly, over the habitats and biological communities. These impacts are included in the following groups:

- Creation of aquatic habitat;
- Loss of terrestrial habitats;
- Aquatic habitat alteration;



- Enhance proliferation of invasive species;
- Habitat fragmentation (terrestrial).

6.9.2.1. Positive impacts

Creation of new aquatic habitat

The provision of a larger inundation area will represent an enlargement of the aquatic habitat available, particularly lacustrine habitat. Aquatic vegetation and fauna, such as fishes, amphibians and birds will thus have an increase of available habitat, which may also represent an increase of food supply to many other animal species.

This promotion of ecological diversity is considered a positive impact of which its significance may be increased if some measures are taken into account.

Table 96 – Impact assessment on Terrestrial and Aquatic Ecology (operation phase): creation of a new aquatic habitat

Criteria	Assessment
Status	Positive
Extent	Local
Duration	Long-term
Likelihood	Definite
Intensity	Moderate
Significance (without mitigation)	Low
Significance (expected post-mitigation/enhancement)	Moderate



6.9.2.2. Negative impacts

Loss of terrestrial habitats

The raising of the dam will result in an increase of the current flooded area estimated in around 270 ha (considering exclusively the FSL at 1,105 masl). This permanent loss of terrestrial habitats by flooding will affect mainly woodlands (130.5 ha) and wetlands (111.5 ha), which have an intrinsic ecological value, but will also represent a loss of food resources and shelter to occurring wildlife.

This impact is classified as of high intensity concerning riverine and lacustrine floodplains (wetlands) and woodlands considering the extension of the loss of these habitats and their limited distribution in the surroundings. It's worth mentioning that the loss of riverine and lacustrine floodplains will be a temporary impact, since it is expected that with the establishment of the new flooded area, new floodplains will be created. Thus, woodlands may be the most relevant affected habitat since in some areas they occur as a narrow band and the expected flooding will promote its entire loss. The availability of this biotope in the surrounding areas is scarce which represents an enhancement of this impact's intensity.

To croplands, human settlements and infrastructure areas and forest plantation areas, a low intensity is attributed due to their availability in the non-affected study area and its vicinity.

In which concerns to this impact's significance, to habitats with lower ecological relevance, like croplands, forest plantation and human settlements and infrastructure areas, a low significance is attributed. Wetlands in general and woodlands excluding closed woodlands and graveyards achieve a medium significance due to their ecological relevance to biological communities. Closed woodlands and graveyards are the most relevant and preserved areas thus their loss represents a significantly high impact.

Considering the three project alternatives, different maximum water levels are defined by each option, resulting in the creation of temporary flooded areas, considering flood events, by the following decreasing size order (once no estimation on water levels boundaries is available): Option 2, Option 1 and Option 3.



Not only the main affected habitat within the study area is cropland, which as mentioned is very common in the vicinity of the study area and has a low ecological relevance, but also the probability of occurrence of such extreme flood events, along with its temporary nature, doesn't quite implicate a habitat loss. Hence, the general assessment described above remains valid for all three project alternatives.

Table 97 – Impact assessment on Terrestrial and Aquatic Ecology (operation phase): loss of terrestrial habitats

Criteria	Assessment
Status	Negative
Extent	Local
Duration	Temporary (Wetlands – Riverine and lacustrine floodplains); Long-term/Permanent (other habitats)
Likelihood	Definite
Intensity	Low (croplands, forest plantation, human settlements and infrastructure areas), Moderate (wetlands – dambos and permanent swamps and marshes) and High (wetlands – riverine and lacustrine floodplains and woodlands)
Significance (without mitigation)	Low (croplands, forest plantation and human settlements and infrastructure areas), Moderate (wetlands and woodlands) and High (closed woodlands and graveyards)
Significance (expected post-mitigation/enhancement)	Low (croplands, forest plantation and human settlements and infrastructure areas) to Moderate (wetlands and woodlands)

Aquatic habitat alteration

Currently the aquatic habitat of the study area is already a non-natural system due to the Kamuzu Dam I.

From the raising of the dam it is expected an alteration of the water column height (water level increase) which may interfere with the current physical and chemical conditions of the aquatic habitat, and consequently with the ecological conditions, according to aquatic flora and fauna preferences and habitat needs.

A low intensity and level of significance is assigned to this impact.



Table 98 – Impact assessment on Terrestrial and Aquatic Ecology (operation phase): aquatic habitat alteration

Criteria	Assessment
Status	Negative
Extent	Local
Duration	Long-term
Likelihood	Definite
Intensity	Low
Significance (without mitigation)	Low
Significance (expected post-mitigation/enhancement)	Low

Proliferation of invasive species

The increase of aquatic habitat may represent an opportunity to invasion and/or dissemination of invasive species. The lentic characteristics of the lacustrine system provided by the dam propitiates the proliferation of exotic species, which are typically more generalist and aggressive than the native species and of easy propagation.

Mitigation measures should be taken into account in order to minimise the significance level; these are conveniently presented in the Chapter 7.

Table 99 – Impact assessment on Terrestrial and Aquatic Ecology (operation phase): proliferation of invasive species

Criteria	Assessment
Status	Negative
Extent	On-site
Duration	Permanent
Likelihood	Likely
Intensity	Moderate
Significance (without mitigation)	Low
Significance (expected post-mitigation/enhancement)	Negligible



Habitat fragmentation (terrestrial)

The increased inundated area may represent the creation of new or wider physical barriers to terrestrial faunistic species by the interference with terrestrial habitat's continuity.

In the study area woodlands occur frequently in continuous narrow bands closed to the water; the enlargement of the aquatic habitat (reservoir) may thus fragment the existent continuum, affecting the faunistic values that choose this biotope as preferential habitat of occurrence.

Table 100 – Impact assessment on Terrestrial and Aquatic Ecology (operation phase): Habitat fragmentation (terrestrial)

Criteria	Assessment
Status	Negative
Extent	Local/Regional
Duration	Long-term
Likelihood	Definite
Intensity	High
Significance (without mitigation)	Moderate
Significance (expected post-mitigation/enhancement)	Low

The definition of a protection buffer, along with the proposal of the plantation of new riparian vegetation within it, should decrease the impact's significance.

6.9.3. Mitigation Measures

The following table shows the mitigation measures applied to the terrestrial and aquatic ecology impacts. General mitigation measures should be applied to some impacts, as identified in the table. Those measures can be consulted in section 7.1.4.



Table 101 - Mitigation measures applied to the terrestrial and aquatic impacts

Environmental Impacts	Mitigation/ Enhancement Measure
Construction	
Habitat alteration/destruction	- General mitigation measures: Yes - The awareness of the ecological relevance of natural resources should be transmitted to the workforce, in order to prevent an off-take of natural resources, like woody biomass.
Disturbance of faunistic communities	
Operation	
Habitat alteration/destruction	- General mitigation measures: Yes - Promote and disseminate more efficient methods of cultivation and less demanding crop varieties in order to increase agricultural production through optimization of the employed techniques rather than through an expansion of cultivated areas. - Raise awareness among the local communities on sustainable resource utilization, in order to enhance forestry management. - Protection of sensitive areas from grazing, biomass extraction and cultivation. - Clear reservoir of aquatic vegetation and reduce nutrient inflow to the water body to prevent eutrophication. - Regulation of fishing activities on the reservoir in order to assure sustainable fisheries; raise public awareness on the role of exotic species in the depletion of native fishes and habitat degradation.
Habitat contamination	
Loss of terrestrial habitats	
Aquatic habitat alteration	
Proliferation of invasive species	



6.10. Socioeconomics and Public Health

6.10.1. Construction phase

6.10.1.1. Positive impacts

Creation of employment and new opportunities to local business

The development of Kamuzu Dam I project requires temporary workforce, recruited locally or externally. It is an important socioeconomic contribution to an area that is poor in capital, with few sources of income (in quantity and diversity) and facing employment scarcity.

In addition to that, in the construction phase an increase of influx of persons around area of intervention will be expected. As a consequence, the purchase of goods and services with local businesses will increase.

The creation of new jobs and the enhancement of local business will have a positive impact in local to regional level, at short-term. It is expected to be an impact of moderate intensity and significance. Impacts can also be indirect (e.g., improving inhabitant's quality of life).

Table 102 – Impact assessment on Socioeconomics and Public Health (construction phase):
creation of employment and new opportunities to local business

Criteria	Assessment
Status	Positive
Extent	Local/Regional
Duration	Short-term
Likelihood	Definite
Intensity	Moderate
Significance (without mitigation)	Moderate
Significance (expected post- mitigation/enhancement)	Moderate to High

Local recruitment and consumption and use of local goods, materials and resources should be prioritised for construction phase, enhancing the positive effects.



6.10.1.2. Negative impacts

Influence of external workforce in local communities

External workforce can originate some socioeconomics and health problems in local communities, such as the increased pressure over resources (e.g., land and natural resources), existing infrastructures and facilities, such as health facilities and waters and sanitation services, temporary disruption of the local social environment, cultural differences, among others. The pressure over resources can cause temporary conflicts between inhabitants and migrants, with local and negative impacts during the construction phase. However, impacts will have a low intensity and significance (Table 103).

Table 103 – Impact assessment on Socioeconomics and Public Health (construction phase):
influence of external workforce in local communities

Criteria	Assessment
Status	Negative
Extent	Local
Duration	Short-term
Likelihood	Likely
Intensity	Low
Significance (without mitigation)	Low
Significance (expected post- mitigation/enhancement)	Low

Public health

The presence of migrant workers during the construction phase, without their families, tends to promote occasional sexual relations with local women. As a consequence, sexually transmitted diseases can increase. Note that rural population of Malawi has low information about diseases such as HIV/AIDS, as well as lack of access to sexual protection (AVERT, 2012). This is a negative impact, with local and regional extent, and with long-term consequences. Intensity is classified as low while significance should be moderated. Mitigation measures can reduce significance to low (Table 104).



Table 104 – Impact assessment on Socioeconomics and Public Health (construction phase):
increase of sexually transmitted diseases

Criteria	Assessment
Status	Negative
Extent	Local (risk) Regional (spreading of sexually transmitted diseases)
Duration	Short-term (risk) Long-term (infections with sexually transmitted diseases)
Likelihood	Likely
Intensity	Low
Significance (without mitigation)	Moderate
Significance (expected post-mitigation/enhancement)	Low

Additionally, communicable diseases (e.g., diarrhoea, cholera, and bilharzias) can be spread more quickly, due to the lack of sanitary conditions in migrants' houses. Some physical characteristics of the territory can also promote mosquito proliferation and be associated with other diseases, like malaria. Negative impacts are local and short-term, with low to moderate intensity and significance (Table 105).

Table 105 – Impact assessment on Socioeconomics and Public Health (construction phase):
spread of communicable diseases

Criteria	Assessment
Status	Negative
Extent	Local
Duration	Short-term
Likelihood	Likely
Intensity	Low
Significance (without mitigation)	Low to Moderate
Significance (expected post-mitigation/enhancement)	Low



Traffic disruption

During the construction phase, the presence of heavy trucks and construction machinery can originate some temporary disturbances (e.g., increase of circulation, pavement degradation and more accidents between vehicles and walkers) in everyday life.

Accessibility and mobility problems can also affect some human and economic activities, such as commerce and agriculture. The expected accessibility and mobility impacts will be short-term negative, of low intensity and significance (Table 106).

Mitigation measures, if implemented (namely those concerning the adequate planning of construction traffic and traffic diversion measures) should reduce the impact's significance to negligible.

Table 106 – Impact assessment on Socioeconomics and Public Health (construction phase):
traffic disruption

Criteria	Assessment
Status	Negative
Extent	Local
Duration	Short-term
Likelihood	Likely
Intensity	Low
Significance (without mitigation)	Low
Significance (expected post- mitigation/enhancement)	Negligible

Increase of accidents risk

Typically, construction works involve accidents consequence of landslides, operation of machinery, heavy traffic or movement of heavy loads, amongst others. These accidents can affect workers and local population.



The risk of accidents will be on-site and short-term, with negative impact and low intensity and significance without mitigation (Table 107). Some measures can reduce the risk of accidents, such as site fencing or information campaigns to workers and local population. Mitigation measures should be adopted during all construction phase.

Table 107 – Impact assessment on Socioeconomics and Public Health (construction phase):
increased risks of accident

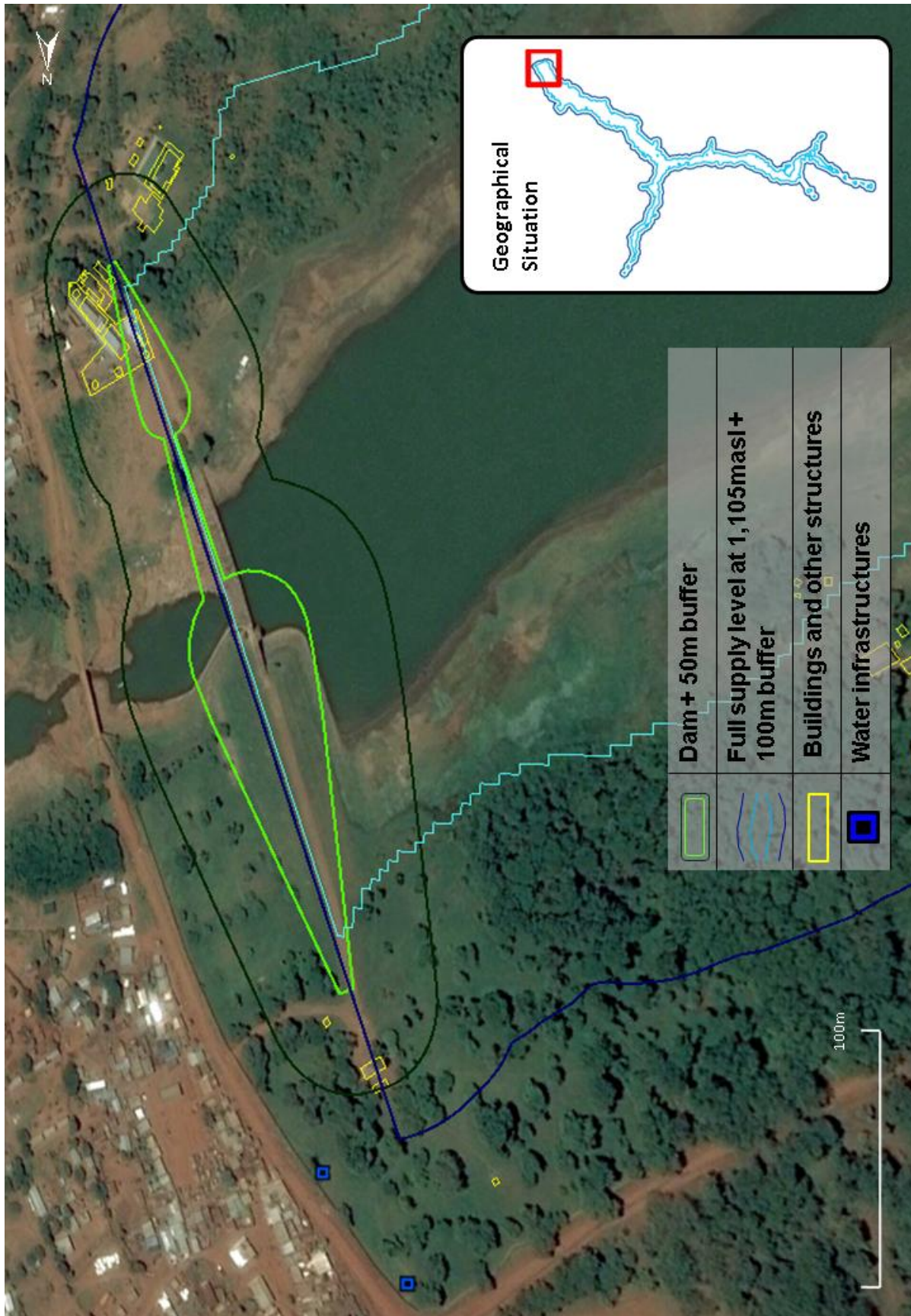
Criteria	Assessment
Status	Negative
Extent	Local
Duration	Short-term
Likelihood	Likely
Intensity	Low
Significance (without mitigation)	Low
Significance (expected post-mitigation/enhancement)	Negligible

Loss of buildings and other structures

The dam raising and rehabilitation works, especially the extended embankments, will result in the demolition (total or partial) of some buildings, in need of resettlement if that occurs:

- Right embankment (for fixed raising only) – LWB and Land Conservation Department Offices (definite);
- Left embankment (for all project options) – Water Falls Lodge (definite), 1 (definite) to 2 (likely) houses; Dalitso Trust (likely);

Definite affectations will require resettlement, according to the proposed Resettlement Action Plan (Chapter 0); likely affectations, if there is no need for demolishment, such edifications should be protected and strict safety measures should be undertaken at all times to avoid significant perturbation. Its inhabitants should be informed of the construction schedules and procedures, as well as the safety precautions to be implemented (see mitigation measures).



Source: aerial image from Google Earth (December, 2013)

Figure 182 – Definite and likely loss of buildings and other structures (construction phase)



Most of the affectations occur on the right embankment; buildings on the left embankment will only be demolished for the fixed raising option, resulting in a negligible significance impact, given that affected buildings are offices, without relevant use and directly related with the dam and LWB operation (close-by resettlement is available, within the LWB's dam protection area). Therefore, the impact assessment is similar to all three project options.

Table 108 – Impact assessment on Socioeconomics and Public Health (construction phase):
loss of buildings and other structures

Criteria	Assessment
Status	Negative
Extent	On-site/Local
Duration	Permanent
Likelihood	Definite/ Likely
Intensity	Low
Significance (without mitigation)	Low to Moderate
Significance (expected post- mitigation/enhancement)	Low

6.10.2.Operation phase

6.10.2.1. Positive impacts

Creation of employment

Kamuzu Dam I raising won't probably promote a significant increase of staff and other jobs (security and maintenance for example) comparing to the present situation, although some uncertainty should be mentioned that derives from the projection option to be chosen.

Nevertheless, some unplanned jobs might be created, directly (in LWB) or indirectly (e.g., suppliers, and contractors) If it happens, it will have a positive impact, with low intensity and significance (Table 8).



Table 109 – Impact assessment on Socioeconomics and Public Health (operation phase):
creation of employment

Criteria	Assessment
Status	Positive
Extent	Local
Duration	Long-term
Likelihood	Unlikely
Intensity	Low
Significance (without mitigation)	Low
Significance (expected post- mitigation/enhancement)	Low

Water management and supply

The raising of Kamuzu Dam I, independently of the chosen project option, for a Full Supply Level at 1,105 masl represents an increased water availability estimated in 48,000 m³/day (as evaluated in section 6.5) – from the current yield of 166,000 m³/day to 214,000 m³/day.

As mentioned for the baseline situation, the current yield can't satisfy the current water demand (population, institutional, commercial and industrial demand at Lilongwe City and surrounding areas). Analysing Table 22, the future water availability provided by the dam's raising will cater the water demand deficit problem only until 2025-2030, allowing a relevant timeframe for the Lilongwe Water Board to improve the water supply infrastructure – namely allowing the development and construction of a new raw water source to address the demand issue for the long-term, along with other necessary water infrastructure-investments.

Hence, the project guarantees a water management capability in the medium-term, ensuring that KD1 and KD2 water reservoirs can meet the water demand for Lilongwe City for the next 10-15 years.



The impact is, therefore, of high magnitude, positive and regional extension, which will definitely occur during the operation phase. It is an impact of high significance to public health and socio-economics at Lilongwe City.

Table 110 – Impact assessment on Socioeconomics and Public Health (operation phase):
increased water management and supply capability

Criteria	Assessment
Status	Positive
Extent	Regional
Duration	Medium-term
Likelihood	Definite
Intensity	Moderate
Significance (without mitigation)	High
Significance (expected post-mitigation/enhancement)	High

Enhancement measures are proposed in Chapter 0 to a more balanced territorial distribution of benefits, that is, Lilongwe Water Board should consider some local water supply improvements to ensure the accessibility to water for human consumption, without prejudice the needed incremental flow to ensure downstream water demand.

Territorial Planning

The rehabilitation and raising of Kamuzu Dam I follows and materialises some guidelines, goals and principles that frame and are proposed by main territorial, socioeconomic and sector policies and strategies, namely:

- Lilongwe District Development Plan (LDDP): to develop projects in various traditional authorities, in topics related with natural resources and environmental management;
- Malawi Vision 2020 (MV): to improve the water supply systems;
- Malawi Growth and Development Strategy (MGDS II): to manage natural resources;



- Water Resources Investment Strategy (WRIS): to meet a range of water needs for productive purposes, such as economic development (in agriculture, industrial/commercial, energy etc.); to deliver water supply requirements; to identify key water-related challenges for the country's economic development in the medium and long-term; to set-up priorities for water sector interventions in time and geographically; and to identify priority water resources sector investments.

The pursuance of such goals is viewed as a positive impact, although of low intensity and significance: note that project will respond to increasing supply water needs in Lilongwe urban areas (with little effect in the local rural area), with an intervention in an existing dam (it is therefore not an investment in a new water source and water infrastructure, but the extension of its life-cycle and capacity to cater short/medium-term needs). For this reason, the territorial extension will be local and regional and the duration will be long-term (Table 111).

Table 111 – Impact assessment on Land use and Spatial Planning (operation phase):
pursuance of territorial, socioeconomic and sector policies and strategies goals

Criteria	Assessment
Status	Positive
Extent	Local/Regional
Duration	Long-term
Likelihood	Definite
Intensity	Low
Significance (without mitigation)	Low
Significance (expected post- mitigation/enhancement)	Low



6.10.2.2. Negative impacts

Loss of agricultural land

The permanent loss of agricultural land represents a permanent direct impact from the establishment of a new Full Supply Level at 1,105 masl, which will imply the occupation and flooding of a significant area of the riverbanks whose present uses will not be possible to maintain. According to the habitat survey performed during fieldwork, and quantification presented in Table 32, agricultural land permanently affected by the future FSL totalises around 86 ha for all project alternatives.

The loss of agricultural land as of areas for grazing livestock may bring indirect impacts such as the loss of employment and income of farmers. For the agriculture land used for subsistence agriculture, that is, for consumption purposes, the loss of small scale farming (lands close-by the water reservoir, which are planted during all year, of which families rely on) implies the reduction of the livelihood of the ones that depend on it and – in face of an area of very low income households – can result on severe indirect impacts, including possible food privation.

The permanent loss of agricultural land is a definite negative impact, which will occur on-site and in a long-term to permanent way. It is a primary impact that generates indirect impacts as the reduction of income and livelihood changing of local populations or the arising of disputes during the relocation of land for grazing and cultivation. It is, therefore, an impact of moderate intensity (given its proportion in relation with the extensive agricultural area around KD1 reservoir) and high significance but of low to moderate significance after expected mitigation (considering compensation measures via RAP).

It should be pointed out that the scarcity of available soil to develop new agricultural activities can limit possible RAP proposals for compensation with agricultural land nearby the ones lost. RAP design must ponder such limitations and ensure alternative solutions for such cases.



Table 112 – Impact assessment on Socioeconomics and Public Health (operation phase): loss of agricultural land (at FSL)

Criteria	Assessment
Status	Negative
Extent	On-site
Duration	Long-term/Permanent
Likelihood	Definite
Intensity	Moderate
Significance (without mitigation)	High
Significance (expected post-mitigation/enhancement)	Low to Moderate

The above assessment, as mentioned, considers only the flooding that occurs at the FSL 1,105 masl, therefore representative of all three project options.

The different maximum water levels defined by the different project options have a cumulative impact, depending of the formal establishment of a protection buffer to the dam reservoir where no human constructions or activities are allowed, with the exception of conservation actions. Of recent consideration is the establishment of a protection buffer around water reservoirs 15 m beyond the Maximum Water Level (considering a 1:100 year flood).

Although present project development phase doesn't allow estimating the boundaries for the different MWL, the preliminary information available dictates the following decreasing size order of additional area where agricultural activities aren't allowed: Option 2, Option 1 and Option 3.

Considering that the three MWL should be enclosed within the ESIA study buffer (100 m to FSL), the additional agricultural land loss for local populations should vary between around 86 ha to 321 ha (a possible estimate for Option 2 agricultural land loss) – Table 32.



Table 113 – Impact assessment on Socioeconomics and Public Health (operation phase): loss of agricultural land (between FSL and MWL)

Criteria	Assessment
Status	Negative
Extent	Local
Duration	Long-term/Permanent
Likelihood	Likely
Intensity	Moderate (Fusegates); High (Fixed raising); Moderate to High (Fixed raising with side channel)
Significance (without mitigation)	Moderate to High (Fusegates); High (Fixed raising); High (Fixed raising with side channel)
Significance (expected post-mitigation/enhancement)	Low

Such flood events are improbable and/or very sporadic, resulting in the temporary immersion of the soil; given the decisive importance that agricultural land has for local population, and considering that temporary flood events can in some cases be favourable in terms of agricultural activity (increased soil humidity), Chapter 0 includes the proposal of a three-level protection buffer, allowing the use of areas between a 50 m buffer to the FSL and the recommended 15 m buffer to the MWL for agriculture (with restrictions). The implementation of such measures can reduce the significance of the cumulative impact, especially for Option 2. Nevertheless, if a protection buffer is enforced, the affected agricultural land will also be eligible for RAP purposes.

Loss of crops

Loss of seasonal crops can also occur if affected agricultural land is planted by the time the water reservoir raising occurs.

Considering the compensation with land in order for each farm owner to proceed with its activity and crop plantation, the potential moderate negative and on-site impact should be decreased to low significance. Other mitigation measures are the availability of land previously to the water level raising (allowing the plantation of the new land as soon as possible) or the temporary provision of vegetables and other food supplements to the affected families



during the time of reestablishment of their small-scale farming (see mitigation measures).

Table 114 – Impact assessment on Socioeconomics and Public Health (operation phase): loss of crops

Criteria	Assessment
Status	Negative
Extent	On-site
Duration	Permanent
Likelihood	Definite
Intensity	Moderate
Significance (without mitigation)	Moderate
Significance (expected post-mitigation/enhancement)	Low

Changes in land use mosaic

As shown in Table 34 and Figure 154 (Section 5.10.1), the most affected land uses by Kamuzu Dam I raising and the new FSL level are agricultural land, woodlands and indigenous vegetation coverage, promoting the change of a set of local important uses (agriculture, natural regulation and support land uses) to a water resource. No artificial areas are affected (check section 6.10 for detailed impacts on human settlements and infrastructures).

The increased water reservoir will induce the loss of agricultural land. Such impact is classified as negative, permanent and significant considering that local rural population around Kamuzu Dam I is very dependent of agriculture, both for subsistence and as income source.

Even considering the low intensity of the impact (the loss of such land is not representative, if taken into consideration the proportion of extensive agricultural land present on both reservoir margins), its importance to local populations and the scarcity of available land in the immediate surrounding area to the water reservoir for agricultural use maximises the impact significance (Table 116).



Table 115 – Impact assessment on Land use and Spatial Planning (operation phase): changes in land use mosaic

Criteria	Assessment
Status	Negative
Extent	Local
Duration	Permanent
Likelihood	Definite
Intensity	Low
Significance (without mitigation)	High
Significance (expected post-mitigation/enhancement)	Low to Moderate

A proper resettlement program, focused especially on compensation for loss of agricultural lands, should be designed to mitigate the impact, or at least compensate the local populations through providing other alternative income sources. As mentioned, the low availability of land at a short distance of Kamuzu Dam I water reservoir creates difficulties to the local resettlement of agricultural land, and such limitation must be considered during the Resettlement Action Plan development.

Loss of buildings and other structures

Unlike the previous impact, the loss of buildings and other human structures must consider and be planned according to the worst case scenario, regardless the probability of occurrence – therefore, the following impact assessment refers to the MWL defined by each project option. As previously mentioned, it is considered that the ESIA's study buffer (FSL+100 m) encloses the different MWL. In fact, it is not acceptable to expose human lives and important assets to the risk of flooding.

Considering that the most favourable project alternative is Option 1 (fusegates: MWL = 1,107,3 masl) and the least favourable is Option 2 (fixed raising: MWL = 1,111,2 masl), and according to the fieldwork survey (check Table 57 and



Figure 182 and Figure 183 to Figure 190) the loss of buildings (housing and other assets) will vary as follows:

- Potential maximum losses (at FSL+100 m buffer): 91 edifications (correspondent to 20 owners), 8 infrastructures and 2 shelters;
- Minimal potential losses (at FSL): 12 edifications, 2 infrastructures and 1 shelter.

The vast majority of affected edifications are for habitation, mostly scattered and isolated houses, since most settlements are located upland.

By its nature, the loss of housing and structures and consequent resettlement process is always a high magnitude and high significance negative impact for the ones directly affected, as it can induce important changes in people's livelihood, especially in rural areas. However, in the present case, the number of owners/families to be affected is not significantly high (a maximum of 20 owners considering the ESIA's study area; at FSL 1,105 masl, only annexe house structures such as water pumps are affected), comparatively with what is usual in other infrastructural projects of this kind. Thus, the overall raw impact is considered of moderate significance, decreasing to low after mitigation (considering resettlement and compensation measures, defined in the RAP).

Also, losses could be total or partial for each affected owner/institution/property. So if some affected parties are to be resettled (total or almost total loss occurs), others, regardless part of their land is potentially flooded, still have available area for reconstruction of affected edifications (minimising the negative impacts of social disintegration of resettlement). Resettlement should weigh each individual case, as they might require differentiated measures.

On the other hand, resettlement can be also viewed as an opportunity to improve living conditions and livelihood, through better housing, access to urban commodities like good quality drinking water, health services, etc, since local housing conditions at villages are generally very poor.



Table 116 – Impact assessment on Socioeconomics and Public Health (operation phase): loss of buildings and other structures

Criteria	Assessment
Status	Negative
Extent	Local
Duration	Permanent
Likelihood	Definite
Intensity	Low (Fusegates); Moderate (Fixed raising); Low to Moderate (Fixed raising with side channel)
Significance (without mitigation)	Low (Fusegates); Moderate (Fixed raising); Moderate (Fixed raising with side channel)
Significance (expected post-mitigation/enhancement)	Low

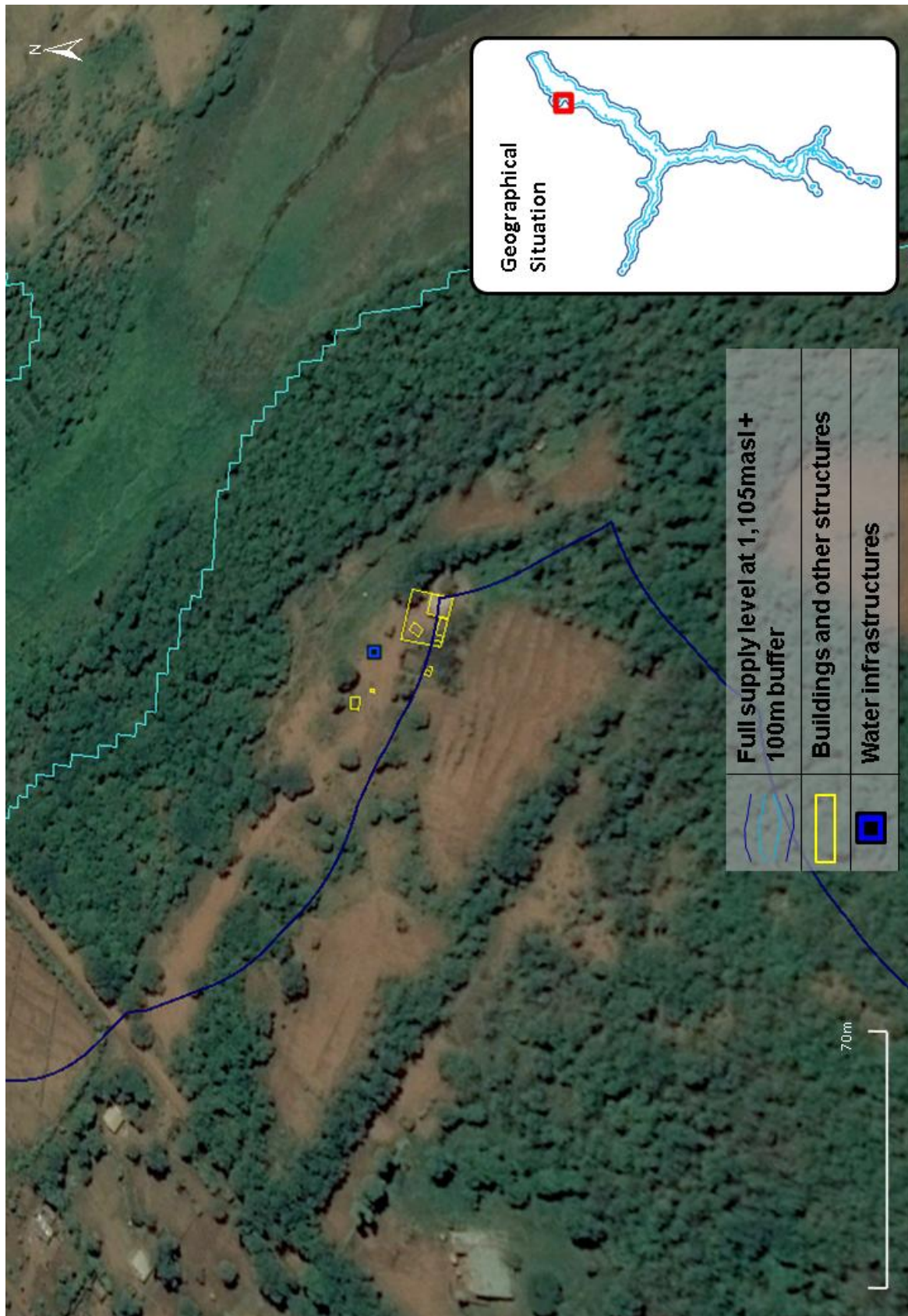
In ideal conditions, and previously to the water reservoir level raising, replacement houses should be built at a small distance from the place where originally settled. External latrines and other assets complementary to housing and allotments should be also replaced along with the houses.

While replacing affected houses, the potential improvement of housing conditions and hygiene, providing kitchen and toilets with water supply based on rainwater deposits, represents a possible indirect impact of the project implementation in the scope of the resettling action, meaning an opportunity to improve water access to population on-site, compensating the fact that this improvement occurs, through this project, only at Lilongwe City. This impact, concerning only to a very restricted number of households (those affected) can also be seen as a mitigation measure.



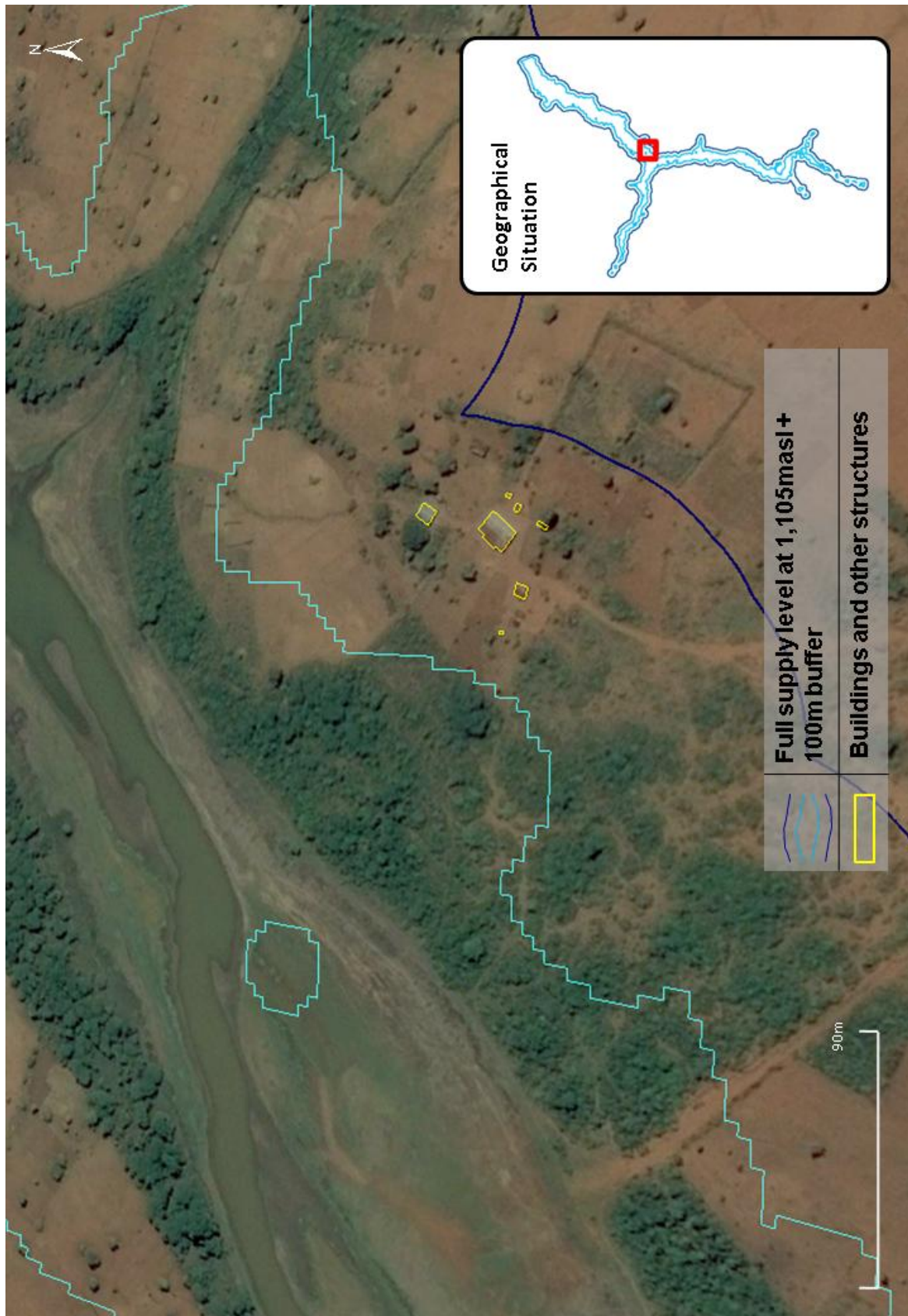
Source: aerial image from Google Earth (December, 2013)

Figure 183 – Loss of buildings and other structures (operation phase) (1)



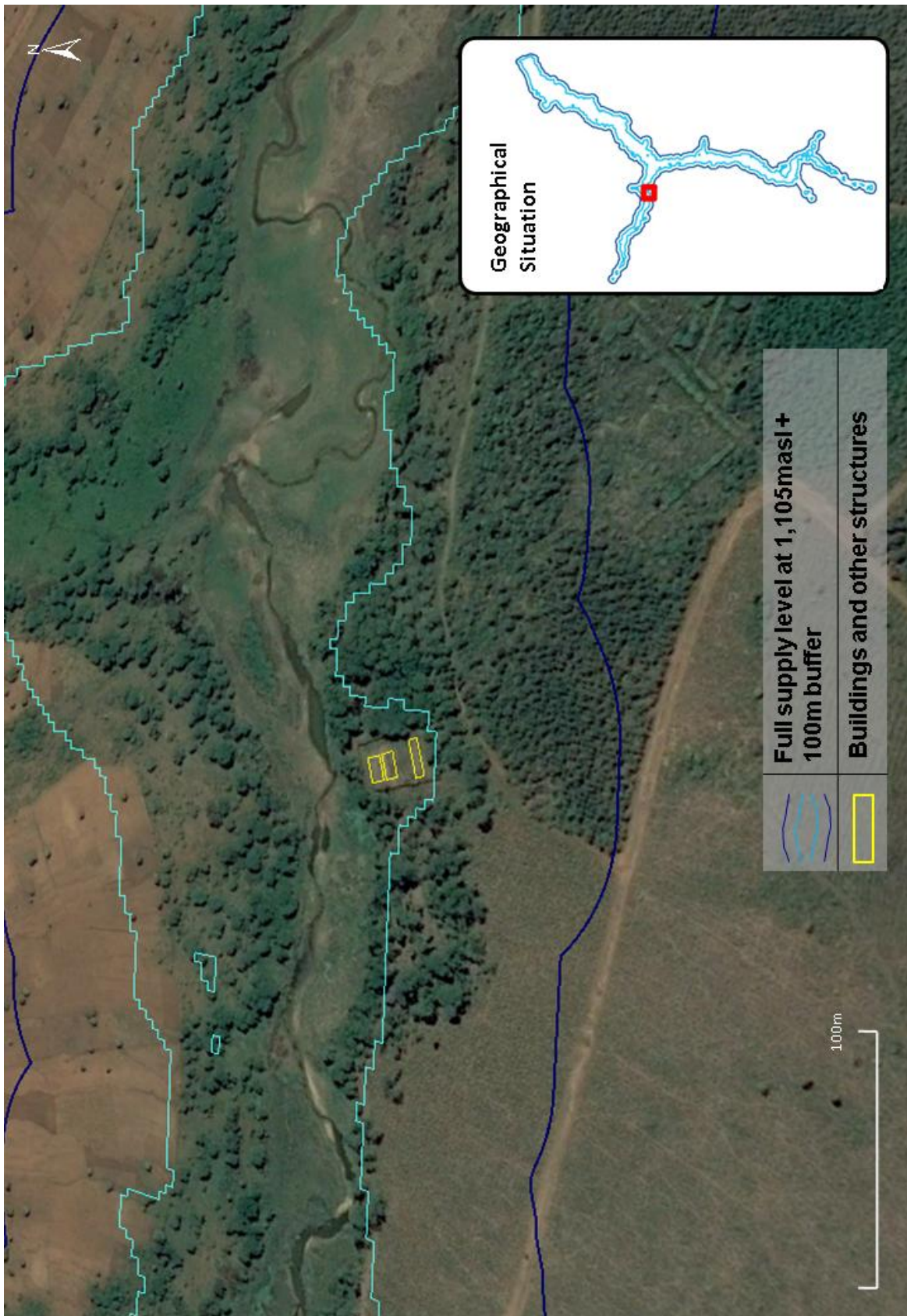
Source: aerial image from Google Earth (December, 2013)

Figure 184 – Loss of buildings and other structures (operation phase) (2)



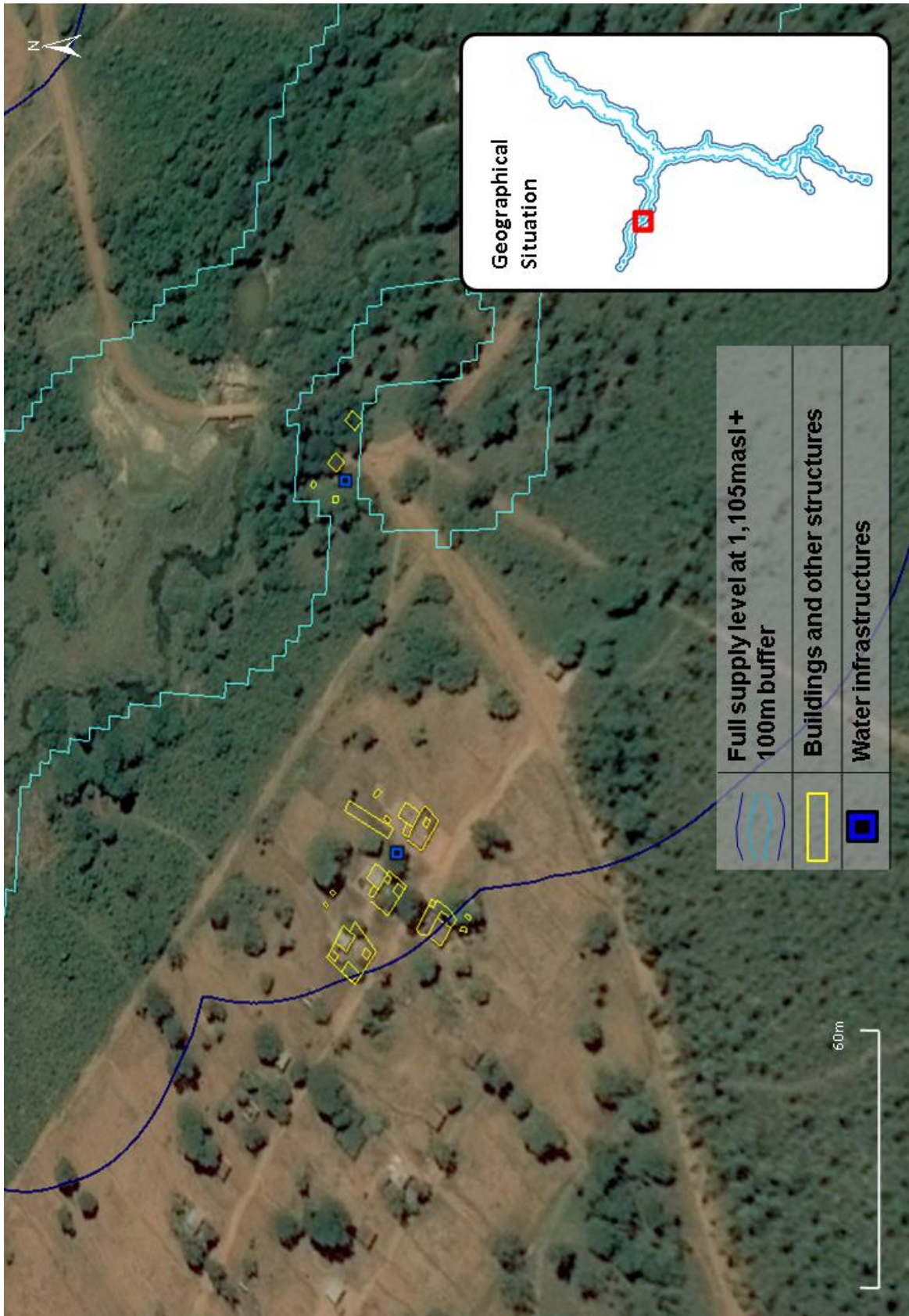
Source: aerial image from Google Earth (December, 2013)

Figure 185 – Loss of buildings and other structures (operation phase) (3)



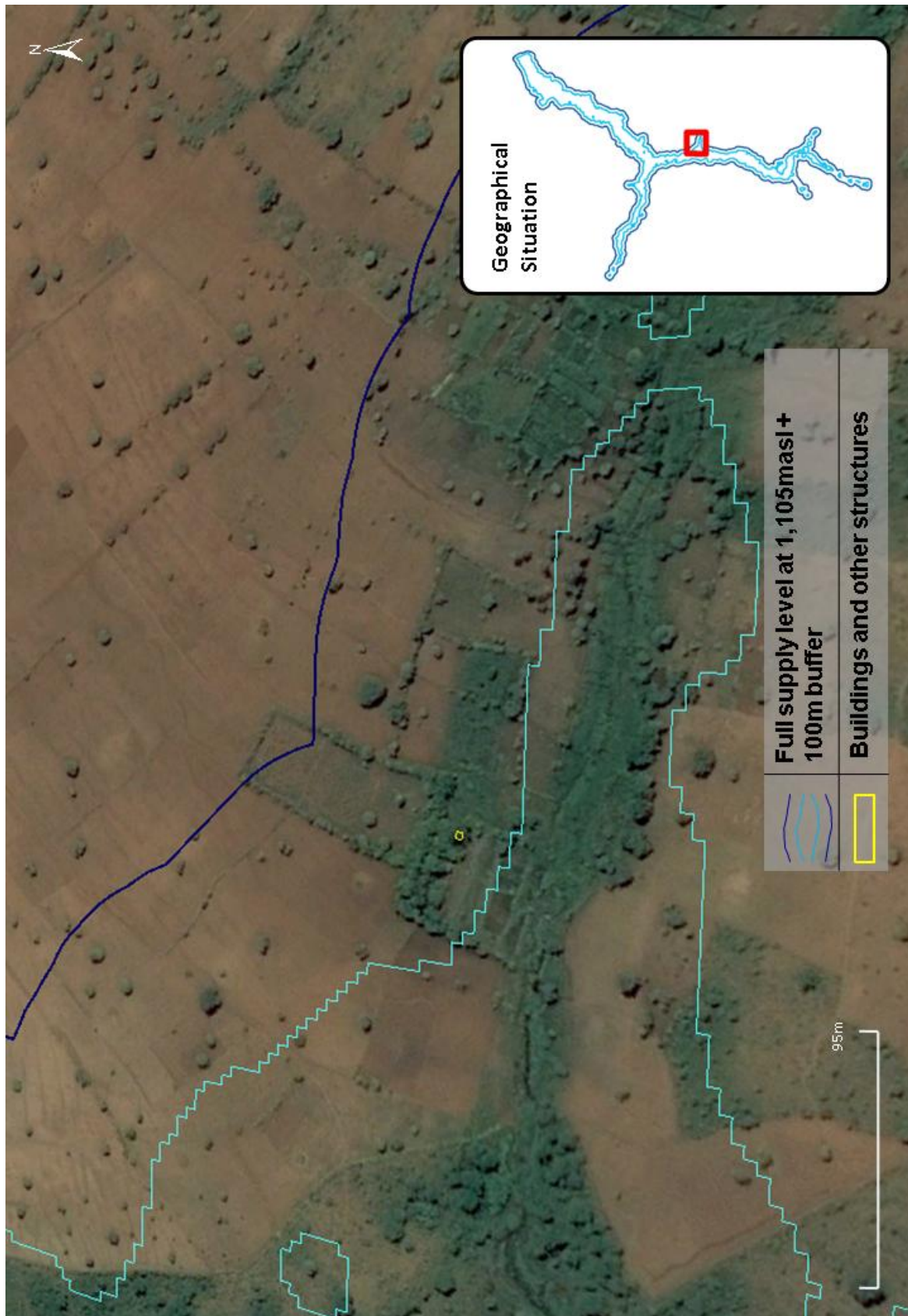
Source: aerial image from Google Earth (December, 2013)

Figure 186 – Loss of buildings and other structures (operation phase) (4)



Source: aerial image from Google Earth (December, 2013)

Figure 187 – Loss of buildings and other structures (operation phase) (5)

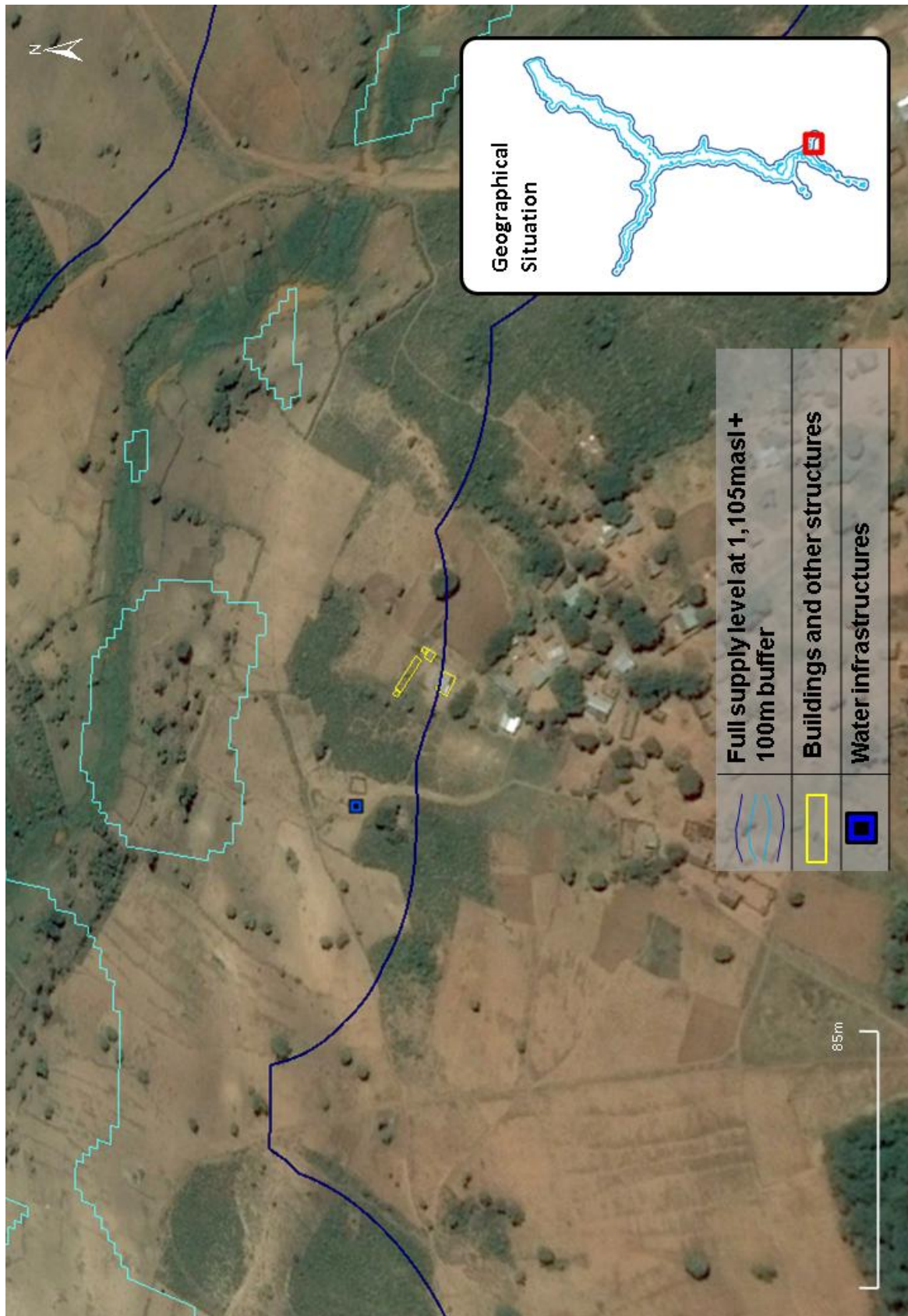


Source: aerial image from Google Earth (December, 2013)

Figure 188 – Loss of buildings and other structures (operation phase) (6)



Figure 189 – Loss of buildings and other structures (operation phase) (7)



Source: aerial image from Google Earth (December, 2013)

Figure 190 – Loss of buildings and other structures (operation phase) (8)



Disruption of accessibilities and mobility (loss of roads and bridges)

Disruption of accessibilities caused by the interruption of road and bridges due to permanent or temporary flooding will affect the mobility of local people, accessibility to/between villages and to assets, agricultural land and opposed river margin. For this purpose, the disruption of accessibilities' impact refers to the MWL defined by each project option (much like "loss of buildings and other structures" impact). As previously mentioned, it is considered that the ESIA's study buffer (FSL+100 m) encloses the different MWL.

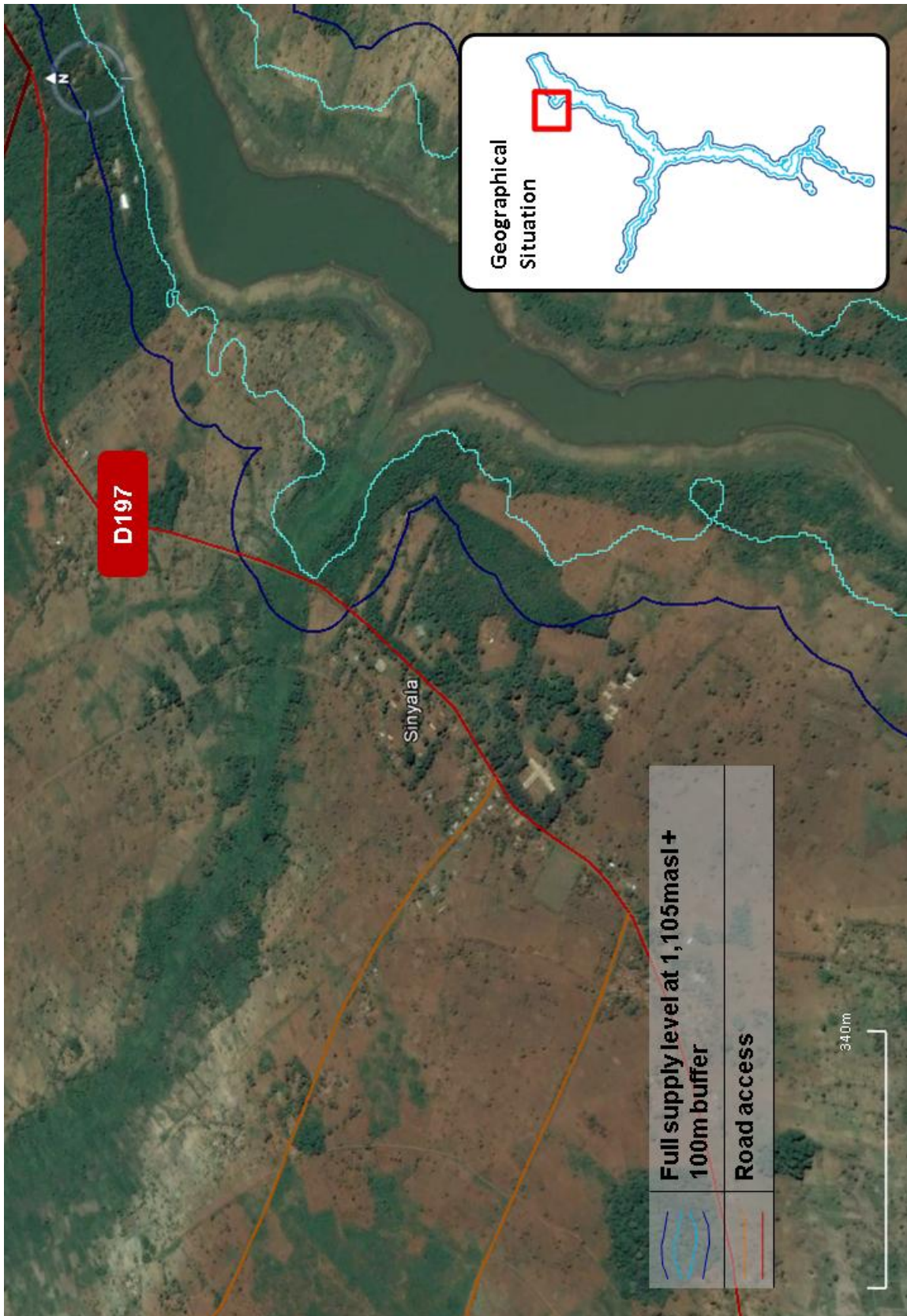
The directly affected roads and bridges identified within the FSL at 1,105 masl (and therefore affected regardless of chosen project option) are:

- D197 – south road section between Kaweche and Manuele (over Liombwe Dambo; Figure 192);
- D197 – road section and bridge (bridge 4 – Figure 158) in the crossing of Katete River to Katete (Figure 192);
- Local road access immediately to the south of Katete River and east of the Katete bridge, within the Dzalanyama Forest Reserve (Figure 192);
- Local road access and bridge (bridge 2) between Chisauka and Simalambo/ Mamina (Figure 193);
- Two pathways and wood-poles bridges (bridges 1 and 3 – Figure 159, Figure 196 and Figure 197) that allow the upstream crossing between Lilongwe River's margins.

Between the FSL and the 100 m study buffer, only the D197 road section immediately before Sinyala (over the Mbeza Dambo) is identified (Figure 191). Considering that the crossing is immediately after the FSL, it is considered that the mentioned road section is also impacted by all three project options.

Other pathways are affected around and near the water reservoir; however, considering that most pathways are accesses to the water or nearby agricultural, the increased flooded area makes such pathways' importance negligible.

Hence, considering that some villages will have their accessibility hampered (Katete, Chisauka and Sinyala) and bridges will be lost, the impact will be negative and permanent, with moderate intensity and high significance.



Source: aerial image from Google Earth (December, 2013)

Figure 191 – Road section potentially flooded – Sinyala

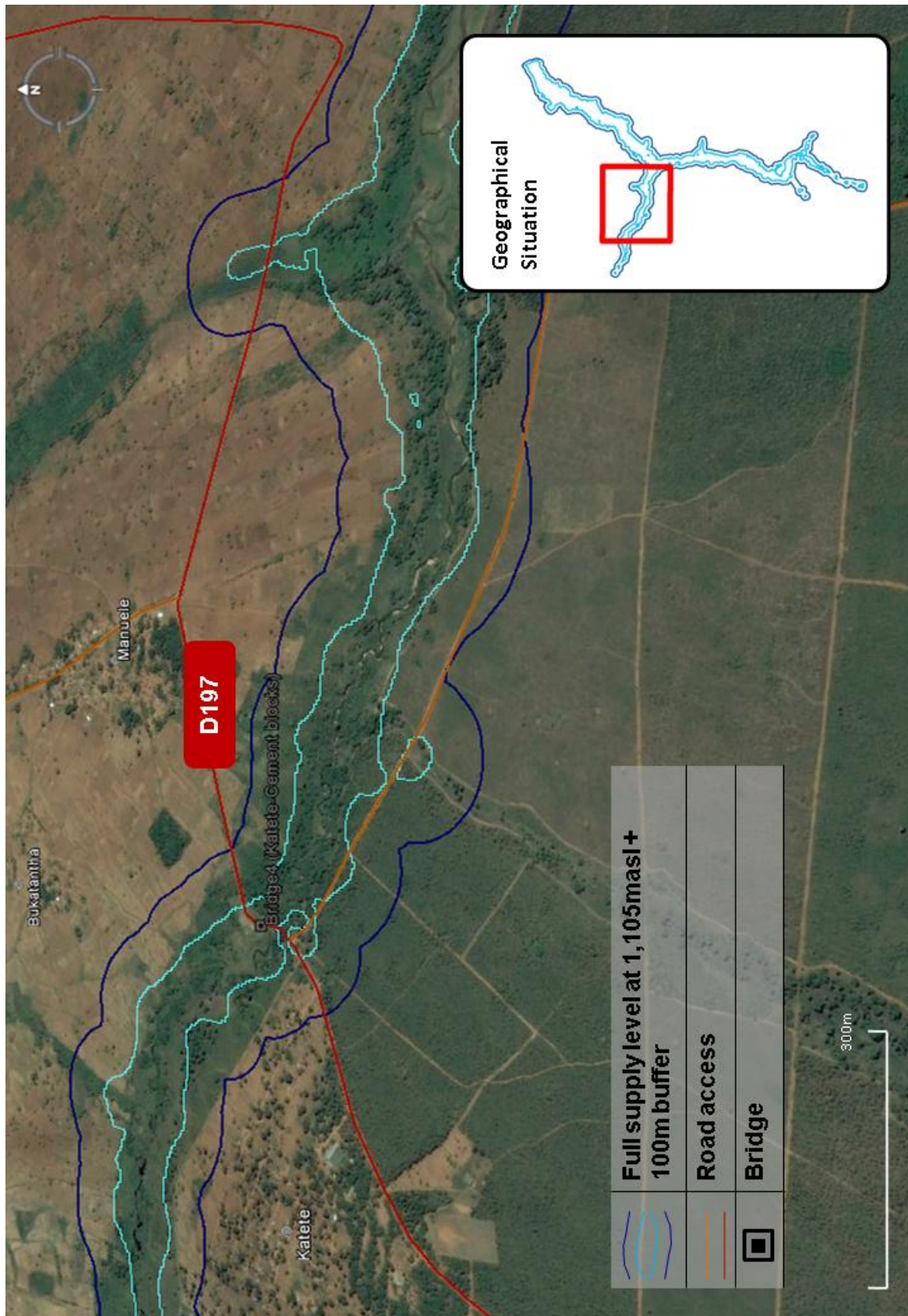
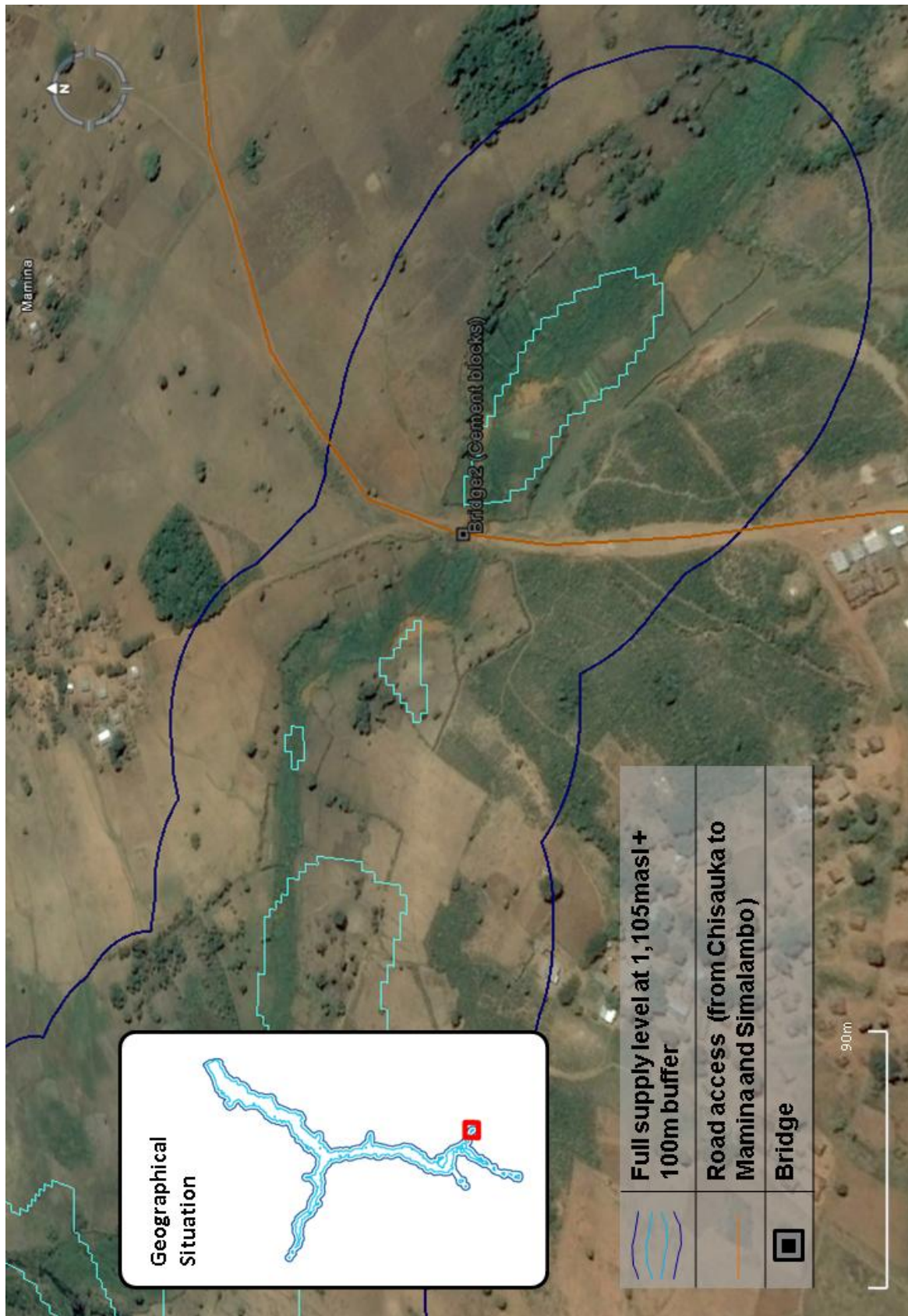
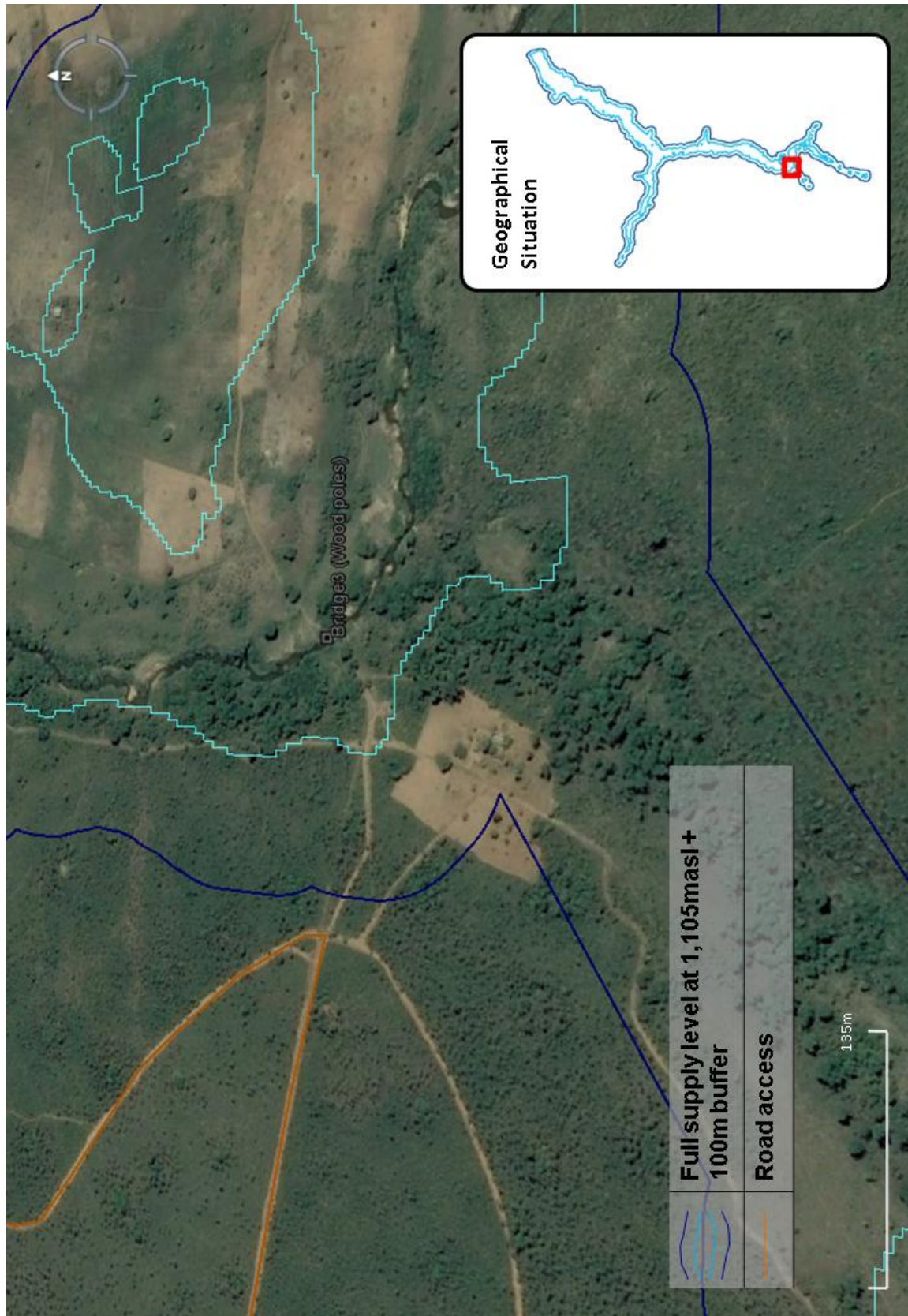


Figure 192 – Road sections and bridge potentially flooded – Katete, Manuele and Forest Reserve



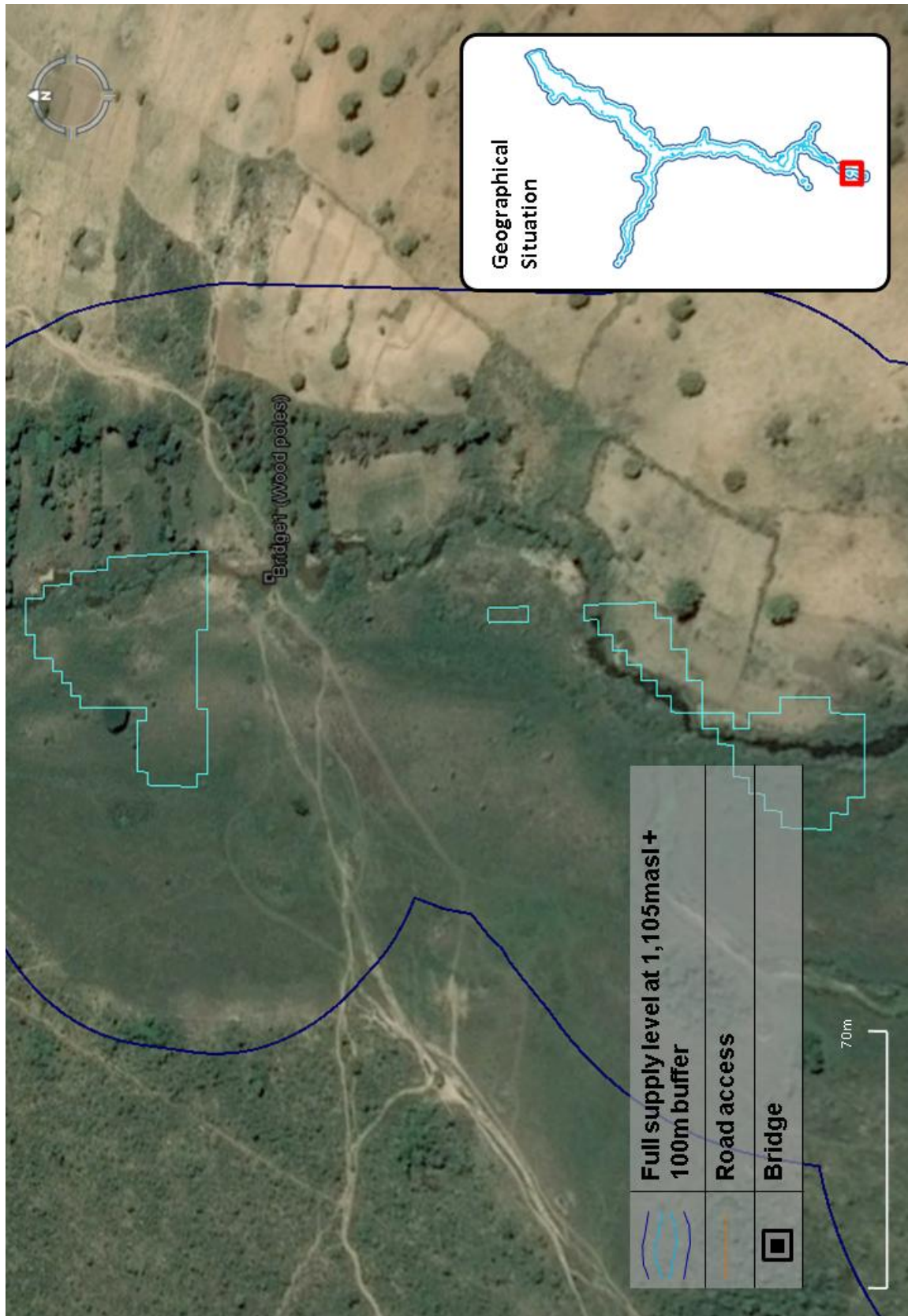
Source: aerial image from Google Earth (December, 2013)

Figure 193 – Road section and bridge potentially flooded – Chisauka



Source: aerial image from Google Earth (December, 2013)

Figure 194 – Wood-poles bridge potentially flooded – Confluence Lilongwe/Choulungwe Rivers



Source: aerial image from Google Earth (December, 2013)

Figure 195 – Wood-poles bridge potentially flooded – Jasoni



Mitigation measures like the replacement of affected bridges and affected road accesses, or ensuring viable alternative connections that won't reduce existent accessibility and mobility of populations will reduce the significance of the impact to low or negligible.

Table 117 – Impact assessment on Socioeconomics and Public Health (operation phase):
disruption of accessibilities and mobility (loss of roads and bridges)

Criteria	Assessment
Status	Negative
Extent	On-site/Local
Duration	Permanent
Likelihood	Definite
Intensity	Moderate
Significance (without mitigation)	Moderate to High
Significance (expected post- mitigation/enhancement)	Negligible to Low

Loss of graveyards

See section 6.11 for impact assessment and mitigation measures proposal regarding potentially affected graveyards (*nyau dambwes*).

6.10.3.Mitigation Measures

The following table shows the mitigation measures applied to the socioeconomics and public health impacts. General mitigation measures should be applied to some impacts, as identified in the table. Those measures can be consulted in section 7.1.4.



Table 118 - Mitigation measures applied to the socioeconomics and public health impacts

Environmental Impacts	Mitigation/ Enhancement Measure
Construction	
Traffic disruption Increased risk of accidents Loss of buildings and other structures Loss of agricultural land Loss of crops Disruption of accessibilities and mobility (loss of roads and bridges)	- General mitigation measures: Yes - Roads and bridges included within the designed maximum water level must be timely replaced to assure connection between territories and margins. If not feasible, alternative road accesses must be planned and provided, without worsening the accessibility and mobility of villages. - Local roads with maintenance needs should be repaired by the promoter, as a way to compensate the community.
Creation of employment and new opportunities to local business Influence of external workforce in local communities Increase of sexually transmitted diseases Spread of communicable diseases Traffic disruption	- General mitigation measures: No - Ensure proper compliance of safety and signalling standards on the public roads, taking the safety of population into consideration and to mitigate disruption of their everyday activities. - Construction yards, storage, disposal and borrow sites, machinery operation areas or any other area that can pose some sort of danger to local people (particularly children) and livestock should be properly fenced, in order to mitigate the risk of accidents. - Prioritise recruitment of local workers for construction jobs, mitigating the influx of migrants and increasing income for local families. - Construction job opportunities should be given to local workers affected by the project, directly and indirectly. Try to fit as many as possible in job vacancies for operation phase. - Equal job opportunities should be given to men and women. No child-labour shall be allowed.



Environmental Impacts	Mitigation/ Enhancement Measure
Increased risk of accidents Loss of buildings and other structures Loss of agricultural land Loss of crops	• Give preference to legally established local services/enterprises, to maximize local income and indirect job creation. • To minimize social conflicts originated by the expected influx of outside workers, a campsite for displaced workers should be created in the construction yard, offering adequate conditions for group accommodation in terms of housing conditions, water supply, sanitation and hygiene. • Settlements around the construction yards and site should not be allowed (or at least it should be controlled/ restricted). • Houses that do not require resettlement but are located nearby the construction site should be signaled and protected in order to avoid accidental affectations. • To minimize the risk of spreading of STIs, HIV/AIDS and communicable diseases, as a result of the influx of the working population, it is recommended to carry out regular awareness actions, informing and advising on ways of transmission and prevention of these diseases, both to workers and the local population; guidelines from Malawi's national HIV prevention program, promoting behaviour change should be followed and regular condom distribution should be made available. • To minimize any increased pressure on the local health system due to the influx of migrant workers, project sponsor or contractor should contribute, in coordination with local health authorities, to strengthen the response capacity of the local health system.
Creation of employment and new opportunities to local business Influence of external workforce in local communities Increase of sexually transmitted diseases	• General mitigation measures: No • A temporary health and first aid post should be available in the construction yard. The post should also perform regular HIV tests to workers (as usually performed by the Voluntary Counselling and Testing (VCT) centres from Malawi), or other kind of health tests (malaria, etc.). • Pools of stagnant water created by construction activities should be promptly disabled to control mosquito proliferation and insect-borne diseases (e.g., malaria). • In collaboration with the local authorities, measures of immediate relief have to be taken to protect people who will



Environmental Impacts	Mitigation/ Enhancement Measure
Spread of communicable diseases Loss of buildings and other structures Loss of agricultural land Loss of crops	have their low incomes or livelihood suddenly affected by the project's construction. These measures should include the provision of food supplements for people that will lose their crops or jobs at agricultural activities and that rely on them for getting most of their nourishment.
Operation	
Loss of buildings and other structures Loss of agricultural land Loss of crops Creation of employment Increased water management and supply capability	• General mitigation measures: Yes • Resettlement and compensation should be closely monitored during their implementation and for at least the first year after its completion, in order to accommodate eventual adjustments. • Provision of social protection and assistance to resettled families and vulnerable people's groups. • Preference should be given to recruit local people for job positions necessary in the operation phase (management, maintenance, surveillance, etc.), especially the ones whose jobs may have been affected during construction. Equal job opportunities should be given to men and women. • For operation and maintenance outsourcing needs, preference should be given to legally established local suppliers and contractors (legal permits for conducting the proposed activities should always be checked before acceptance).



6.11. Cultural Heritage

Inundation (either permanent for the water reservoir or temporary in flood events) is for archaeological sites potentially destructive for botanical remains, faunal remains and pottery. But even if site preservation is adversely affected, inundation affects the accessibility of archaeological sites for future research. The significance of the impact further depends on the size and nature of the site. Without full understanding of these aspects any impact assessment remains tentative. As no subsurface testing was conducted and the exact inundation area is still unknown, the impacts indicated next are preliminary.

Table 119 – Heritage sites impact assessment

Site No.	Heritage site value	Nature of the impact	Significance of the impact
KD-01	High	Possible inundation	Potentially high
KD-02	Moderate	Inundation	High
KD-03	Potentially high	Inundation	High
KD-04	Potentially high	No impact; outside the study area	Null
KD-05	Low	Probably no impact.	Null
KD-06	Potentially high	Inundation	High
KD-07	Low	Possible inundation	Possibly high
KD-08	Low	Possible inundation	Possibly high
KD-09	Low	No impact as located at the edge of the study area	Null
KD-10	Low	No impact; outside the study area	Null
KD-11	Low	No impact; outside the study area	Null
KD-12	Low	No impact; located on high ground	Null
KD-13	Potentially high	Possible inundation	High
KD-14	Potentially high	Possible inundation	High
KD-15	Potentially high	Possible inundation	High
KD-16	Low	None, as located on high ground	Null



Site No.	Heritage site value	Nature of the impact	Significance of the impact
KD-17	Low	None, as located on high ground	Null
KD-18	Low	Inundation	High
KD-19	Potentially high	Inundation	High
KD-20	Potentially high	Inundation	High
KD-21	Moderate	Possible inundation	High if inundated, but probably outside the inundation zone
KD-22	Moderate	Inundation	High
KD-23	Low	Possible inundation	High if inundated
KD-24	Low	Inundation	High
KD-25	Potentially high	Inundation	High
KD-26	Low	Inundation	High
KD-27	High	Potential inundation	High if inundated
KD-28	Moderate	Inundation	High
KD-29	Moderate	Inundation	High
KD-30	Very high	Inundation	High
KD-31	High	Possible inundation	High if inundated
KD-32	Low	Possible inundation	High if inundated
KD-33	Moderate	Inundation	High
KD-34	Moderate	Inundation	High
KD-35	Potentially high	Inundation	High
KD-36	Potentially high	None, as located outside the study area	Null
KD-37	Low	Possible inundation	High if inundated
KD-38	Potentially high	Possible inundation	High if inundated
KD-39	Low	Possible inundation	High if inundated
KD-40	High	Inundation	High
Nyau	High	Possible inundation; Accessibility	High if inundated, but probably outside the inundation zone; Low if only accessibility is affected

Since impact significance is more dependant of the individual value of each site than the number of sites affected, the overall significance of cultural heritage impacts is considered similar between all project options.



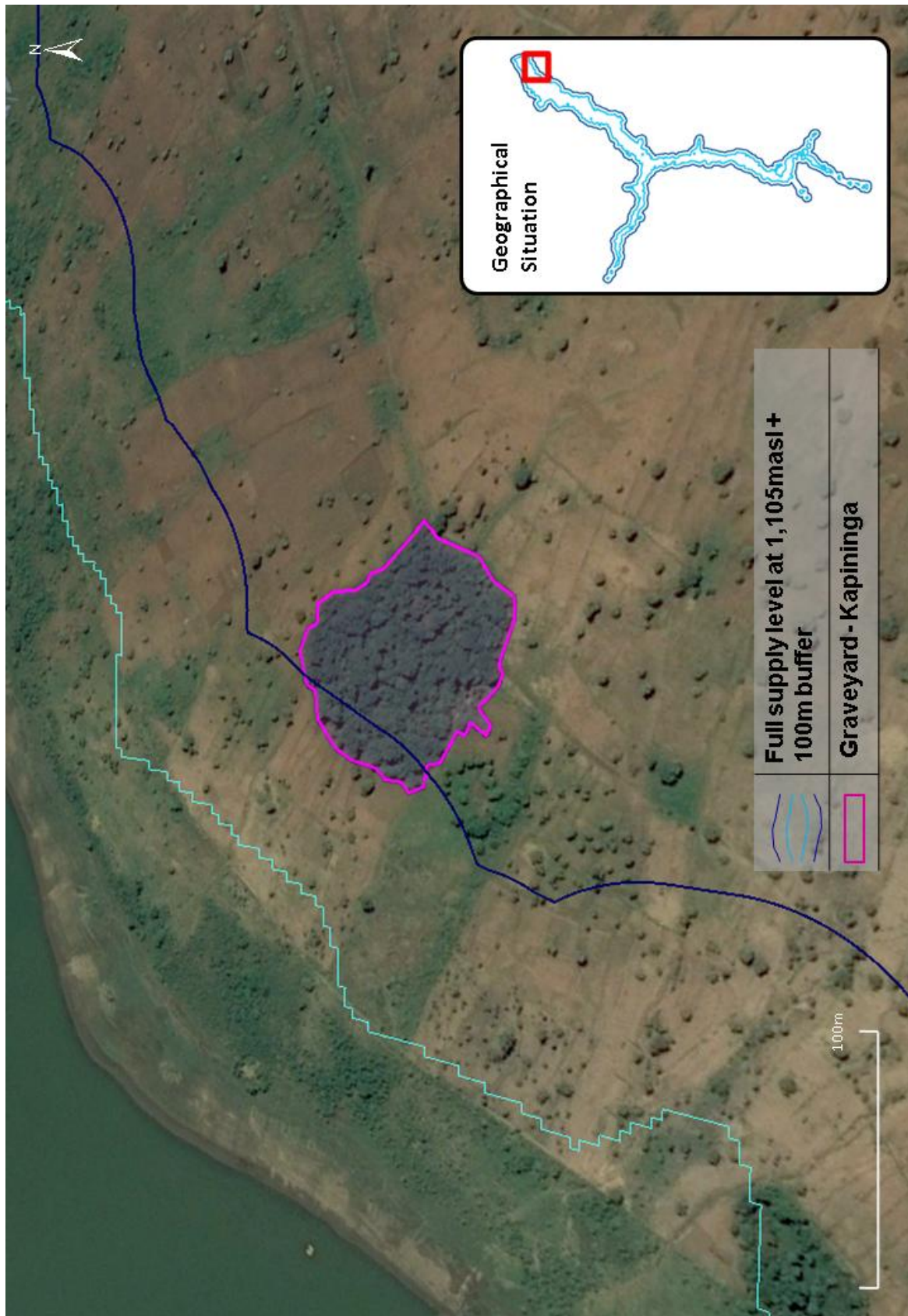
The proposed works will be (partially) destructive to some archaeological sites. These do, however, not have a touristic value, only a scientific value. It would thus be appropriate to allow for archaeological excavations prior to inundation to allow for the development project to go ahead without loss of scientific information.

As the significance of some archaeological sites could not be determined yet, there will be need for the digging of test pits to assess the nature and integrity of these sites. Depending on the outcome more extensive excavations may be required.

For some sites (KD-30 and KD-40) the significance is evident. For those, excavation for rescue archaeology is recommended.

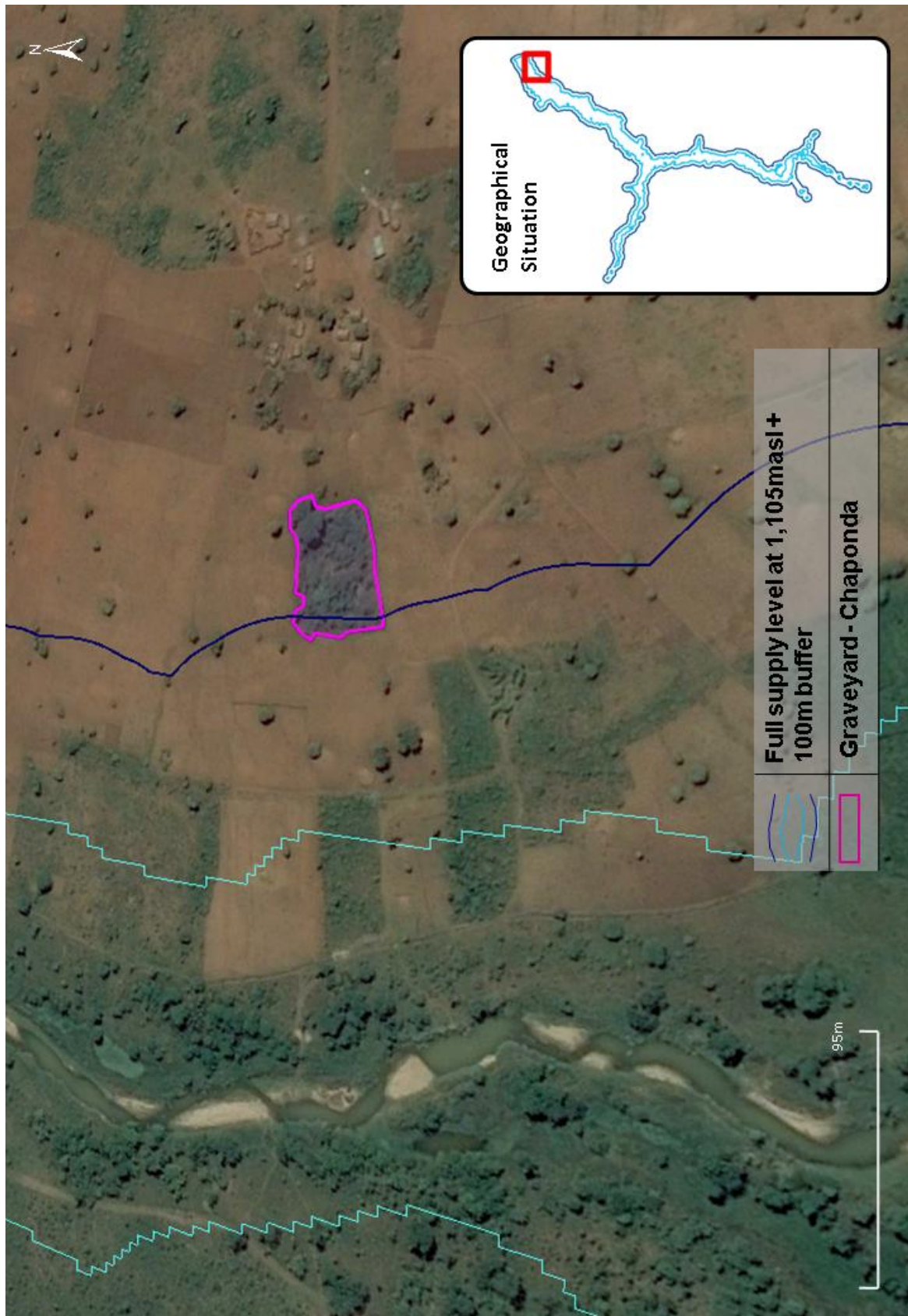
As the *nyau dambwes* are at the very fringe of the study area, the groves are not expected to be affected by the inundation itself. It should be ensured though that local communities retain access to the indicated *nyau* groves for burials and *nyau* activities – Figure 196 and Figure 197.

With more detailed design of project options in further stages, namely during the development of the Resettlement Action Plan, the rigorous assessment of the possible impact over graveyards and need to resettlement to new burial sites will be evaluated thoroughly and mitigated as adequate, with the involvement of responsible authorities (Department of Antiquities, Department of Lands and Department of Surveys) and articulation with local leaders. Proposed RAP guidelines are presented in Chapter 0 includes such evaluation and compensation and resettlements measures.



Source: aerial image from Google Earth (December, 2013)

Figure 196 – Possible interferences with *nyau dambwes* (Kapininga)



Source: aerial image from Google Earth (December, 2013)

Figure 197 – Possible interferences with nyau dambwes (Chaponda)



6.12. Overall Impact Assessment

6.12.1. Introduction

Following the impact identification and assessment presented in the previous topics, as well as the mitigation and enhancement measures' recommendation in chapter 1, the present section presents a summary and overall assessment of the projects' expected social and environmental impacts.

The detailed impact description, justification and assessment for the environmental and social factors considered is presented in sections 6.2 to 6.11. Therefore, the following tabular assessment should be read in conjunction with the support text in the referred topics.

The overall assessment is presented in the form of a synthesis matrix. The main interest of this format resides with the possibility of allowing a simultaneous presentation of information about all the variables involved, allowing for an easy reading and cross-referencing.

Even though the matrix allows for a quick view of the overall assessment of the project, its analysis and interpretation should take into account that it corresponds, by definition, to a simplified description of the identified impacts, so it does not dismisses the consultation of the detailed support content in sections 6.2 to 6.11.

The matrices presented display the studied descriptors on the horizontal axis and on the vertical axis the evaluation obtained according to pre-defined criteria.

It is noted that the results presented in the matrix in terms of net significance include a preview of the mitigation/enhancement possibilities, thus roughly corresponding to the significance of residual environmental impacts. However, one should point out that the evaluation process for residual impacts is never without some uncertainty, since it is difficult to determine the effectiveness of some measures, since they depend on multiple factors which can also be of great variability. Even the response of those environmental factors for which possible changes were predicted is not a linear process, consequently introducing an additional complexity factor. Given these limitations, synthesis



matrices should be primarily regarded as an overview of the approximate project balance in terms of the residual impacts' significance.

A colour scheme was added to allow for a more immediate perception of the general significance of the impact after mitigation, using green hues for positive impacts and red for negative, as well as increasing the colour's intensity according to the severity of its significance degree.

Negative	Significance	Positive
	Null or Negligible	
—	Low	+
—	Moderate	+
—	High	+

Considering the available information in the present stage, some of the impacts identified in Chapter 6 have correspondent effects which do not depend on the chosen project alternative. This results in the project's construction or operation activities/effects generating similar impacts for all three options.

Other impacts are differentiated by the dissimilarity that characterises each project alternative (such as the different maximum water levels or increased magnitude of earthworks required).

Hence, to facilitate the consultation of the impact synthesis matrices and to allow for an expedite assessment of the most environmental and socially preferential option, two matrices were produced, one for each case:

- Table 120 for impacts common to all three initial project options, 1/A, 2/B and 3/C;
- Table 121 for impacts identified and classified by initial project option (1/A FG – Fusegates; 2/B FR – Fixed Raising; 3/C FRc – Fixed Raising with side channel).

Finally, Table 122 summarises the identified impacts and its qualitative assessment considering the implementation of the preferred project Option E.



6.12.2. Impact matrix for common impacts to all three initial project options (1/A, 2/B and 3/C)

Synthesis impact matrix for common impacts to all three initial project options (1/A, 2/B and 3/C) is presented next.



Table 120 – Summary of environmental and social impact assessment: common impacts to all three initial project options (1/A, 2/B and 3/C)

Impact	Project Phase	Status	Extent	Duration	Likelihood	Intensity	Significance (without mitigation)	Significance (post-mitigation/enhancement)
GEOLOGY								
Soil erosion and siltation (for construction areas)	Construction	Negative	On-site/ Local	Temporary to Permanent	Likely	Moderate	Low	Negligible
SOILS								
Soil loss (construction site)	Construction	Negative	On-site	Temporary/ Short-term (recovered areas); Permanent (embankments)	Definite	Low	Low to Moderate	Low
Soil contamination	Construction	Negative	On-site/ Local	Temporary/ Short-term	Unlikely	Low to Moderate	Low to Moderate	Low
Soil loss (reservoir area)	Operation	Negative	On-site	Long-term/ Permanent	Definite	Moderate	High	High
Soil erosion (reservoir area)	Operation	Negative	On-site/ Local	Long-term/ Permanent	Likely	Low	Low	Negligible



Impact	Project Phase	Status	Extent	Duration	Likelihood	Intensity	Significance (without mitigation)	Significance (post-mitigation/enhancement)
HYDROGEOLOGY								
Groundwater contamination	Construction	Negative	On-site/ Local	Short-term/ Long-term	Unlikely	Low	Low	Negligible
Increase of water table level	Operation	Positive	Local/ Regional	Permanent	Definite	Low to Moderate	Moderate to High	Moderate to High
Deactivation of boreholes	Operation	Negative	On-site	Permanent	High	Low	Low	Negligible
HYDROLOGY								
Increase in flow and runoff up to Lilongwe's water treatment plant	Operation	Negative	Regional	Permanent	Likely	Negligible to Low	Negligible to Low	Negligible
Decrease in flow downstream of Lilongwe's water treatment plant	Operation	Negative	Regional	Long-term	Likely	Negligible	Negligible	Negligible
Increase in trap efficiency/sediment deposition	Operation	Negative	Local	Permanent	Definite	Negligible	Negligible	Negligible
Increase in water availability	Operation	Positive	Regional	Permanent	Definite	Moderate	Moderate	Moderate



Impact	Project Phase	Status	Extent	Duration	Likelihood	Intensity	Significance (without mitigation)	Significance (post-mitigation/enhancement)
Mitigation of droughts' severity	Operation	Positive	Regional	Long-term	Definite	Low	Low	Low
SURFACE WATER QUALITY								
Water quality degradation (suspended solids and turbidity)	Construction	Negative	Local	Temporary/ Short-term	Definite	Low	Low to Moderate	Low
Water quality degradation (organic and faecal contamination)	Construction	Negative	Local	Temporary/ Short-term	Likely	Low	Low to Moderate	Low
Risk of water quality degradation (spillages)	Construction	Negative	Local	Temporary/ Short-term	Unlikely	Variable (Low)	Low to Moderate	Low
Risk of water quality degradation (oxygen depletion)	Operation	Negative	On-site	Short-term	Likely	Low to Moderate	Low to Moderate	Negligible to Low
NOISE								
Construction traffic	Construction	Negative	Local	Temporary	Likely	Low	Low	Negligible to Low



Impact	Project Phase	Status	Extent	Duration	Likelihood	Intensity	Significance (without mitigation)	Significance (post-mitigation/enhancement)
AIR QUALITY								
Gaseous emissions	Construction	Negative	Local	Temporary	Likely	Negligible to Low	Low	Negligible to Low
TERRESTRIAL AND AQUATIC ECOLOGY (FLORA AND FAUNA)								
Habitat alteration/destruction	Construction	Negative	Local	Permanent/Long-term	Likely/Definite	Low	Low to Moderate	Low
Habitat contamination	Construction	Negative	On-site/Local	Variable	Unlikely	Variable	Variable	Low
Disturbance of faunistic communities	Construction	Negative	Local	Temporary/Short-term	Likely	Moderate	Low to Moderate	Low
Loss of terrestrial habitats	Operation	Negative	Local	Temporary; Long-term/Permanent	Definite	Low/Moderate/High	Low/Moderate/High	Low to Moderate
Creation of a new aquatic habitat	Operation	Positive	Local	Long-term	Definite	Moderate	Low	Moderate
Aquatic habitat alteration	Operation	Negative	Local	Long-term	Definite	Low	Low	Low
Proliferation of invasive species	Operation	Negative	On-site	Permanent	Likely	Moderate	Low	Negligible
Habitat fragmentation (terrestrial)	Operation	Negative	Local/Regional	Long-term	Definite	High	Moderate	Low



Impact	Project Phase	Status	Extent	Duration	Likelihood	Intensity	Significance (without mitigation)	Significance (post-mitigation/enhancement)
LAND USE AND SPATIAL PLANNING								
Changes in land use mosaic	Operation	Negative	Local	Permanent	Definite	Low	High	Low to Moderate
Pursuance of territorial, socioeconomic and sector policies and strategies goals	Operation	Positive	Local/ Regional	Long-term	Low	Low	Low	Low
SOCIOECONOMICS AND PUBLIC HEALTH								
Creation of employment and new opportunities to local business	Construction	Positive	Local/ Regional	Short-term	Definite	Moderate	Moderate	Moderate to High
Influence of external workforce in local communities	Construction	Negative	Local	Short-term	Likely	Low	Low	Low
Increase of sexually transmitted diseases	Construction	Negative	Local/ Regional	Short-term/ Long-term	Likely	Low	Moderate	Low
Spread of communicable diseases	Construction	Negative	Local	Short-term	Likely	Low	Low to Moderate	Low
Traffic disruption	Construction	Negative	Local	Short-term	Likely	Low	Low	Negligible
Increased risk of accidents	Construction	Negative	Local	Short-term	Likely	Low	Low	Negligible



Impact	Project Phase	Status	Extent	Duration	Likelihood	Intensity	Significance (without mitigation)	Significance (post-mitigation/enhancement)
SOCIOECONOMICS AND PUBLIC HEALTH (cont.)								
Loss of buildings and other structures	Construction	Negative	On-site/ Local	Permanent	Definite/ Likely	Low	Low to Moderate	Low
Loss of agricultural land (at FSL)	Operation	Negative	On-site	Long-term/ Permanent	Definite	Moderate	High	Low to Moderate
Loss of crops	Operation	Negative	On-site	Permanent	Definite	Moderate	Moderate	Low
Disruption of accessibilities and mobility (loss of roads and bridges)	Operation	Negative	On-site/ Local	Permanent	Definite	Moderate	Moderate to High	Negligible to Low
Creation of employment	Operation	Positive	Local	Long-term	Unlikely	Low	Low	Low
Increased water management and supply capability	Operation	Positive	Regional	Medium-term	Definite	Moderate	High	High
CULTURAL HERITAGE								
Affectation of heritage sites	Operation	Negative	On-site/ Local	Permanent	Likely/ Definite	Low to High	Low to High	Negligible to Moderate



6.12.3. Impact matrix by initial project options (1/A, 2/B and 3/C)

Synthesis impact matrix by initial project options (1/A, 2/B and 3/C) is presented next.

Table 121 – Summary of environmental and social impact assessment: impacts by initial project option (1/A FG – Fusegates; 2/B FR – Fixed Raising; 3/C FRc – Fixed Raising with side channel)

Project Option	Impact	Project Phase	Status	Extent	Duration	Likelihood	Intensity	Significance (without mitigation)	Significance (post-mitigation/enhancement)
GEOLOGY									
1– FG	Creation of borrow pits	Construction	Negative	On-site/ Local	Temporary to Permanent	Definite	Low to Moderate	Low to Moderate	Low
2– FR						Definite	High	High	Low to Moderate
3– FRc						Likely	Low	Low	Negligible



Project Option	Impact	Project Phase	Status	Extent	Duration	Likelihood	Intensity	Significance (without mitigation)	Significance (post-mitigation/enhancement)
NOISE									
1– FG	Construction activities and heavy machinery operation	Construction	Negative	On-site/ Local	Temporary	Definite (close vicinity in Kapininga; Likely (other sensitive receptors)	Low	Moderate to High (50 m buffer); Low (other sensitive receptors further than 50 m)	Moderate (50 m buffer); Negligible to Low (other sensitive receptors further than 50 m)
2– FR							Moderate		
3– FRc							Moderate to High (blasting actions)		
AIR QUALITY									
1– FG	Particulate matter emissions	Construction	Negative	On-site/ Local	Temporary	Definite (close vicinity in Kapininga; Likely (other sensitive receptors)	Low	Moderate to High (close vicinity in Kapininga); Low (other sensitive receptors)	Low to Moderate (close vicinity in Kapininga); Low
2– FR							Moderate		
3– FRc							Low		



Project Option	Impact	Project Phase	Status	Extent	Duration	Likelihood	Intensity	Significance (without mitigation)	Significance (post-mitigation/enhancement)
SOCIOECONOMICS AND PUBLIC HEALTH									
1– FG	Loss of agricultural land (between FSL and MWL)	Operation	Negative	Local	Long-term/ Permanent	Likely	Moderate	Moderate to High	Low
2– FR							High	High	Low
3– FRc							High	High	Low
1– FG	Loss of buildings and other structures	Operation	Negative	On-site/ Local	Permanent	Definite	Low	Low	Low
2– FR							Moderate	Moderate	Low
3– FRc							Low to Moderate	Moderate	Low



6.12.4. Discussion of overall environmental and social impacts for the initial project options (1/A, 2/B and 3/C)

As shown in the first table above (Table 120), most impacts arising in the construction phase, more or less independently from the chosen option, are due to the necessary construction activities, namely: land clearance, earthworks/excavations, operation of heavy machinery, traffic and others. These are likely to cause mainly temporary to short-term negative impacts such as soil erosion, several sorts of pollution (noise, dust, and possible spillages to soil and water) and general annoyance of local people's everyday life. The impacted area is expected to be rather contained, mainly around the construction site near Kamuzu Dam I's wall and embankments, thus affecting, even if only partially, the Malingunde and Kapaninga villages. Mitigation is normally possible for this kind of situation, resulting in mostly low significance impacts after adequate action and management.

Construction itself will also generate some long-term to permanent negative impacts on soil and land uses, habitats, buildings and other structures existing along the site needed for the dam's raising. These were evaluated overall as of low significance after mitigation, exception made to habitat alteration/loss that will be in the low to moderate range due to a more difficult mitigation and to the importance of some of the affected habitats.

Other negative impacts from the construction phase arise in the social and economic sphere, such as possible conflicts with migrant workers, risk of accidents and the spread of sexually transmitted and communicable diseases (like HIV/AIDS). These were considered of general low significance after the application of the recommended mitigation measures' extensive set.

On the other hand, construction will create employment and new local business opportunities, which will lead to positive impacts on local income, improvement of household's living, empowerment of local contractors and suppliers, among other indirect benefits. Construction will require a significant workforce, part of which should be recruited locally. It is considered an impact of moderate intensity, but facing the low rates of local employment it is rated as of moderate to high significance after enhancement, even though this will be a short-term effect.



The resulting reservoir's enlargement in the operation phase will present the major identified positive impacts, with the most important one being the improvement of raw water reserves available for supplying Lilongwe City's (and other minor uses) increasing demand. Availability of water supply is an important economic development factor, so the expected improvements can give a beneficial boost to various sectors of Lilongwe's economy. Taking into consideration the rapid population growth and increasing demand in Lilongwe City and the current water limitation and deficit, the raising of Kamuzu Dam I also increases the water management capability to support the growing demand in the medium-term, until new raw water sources and water infrastructures investments are put into operation.

A larger inundation area will represent an increment in the available aquatic habitat and thus a favourable opportunity for water-related vegetation and fauna, such as fishes, amphibians and birds. At the same time this will represent an increase in food supply to many other animal species. This promotion of ecological diversity is considered a positive impact, which significance may be increased to a moderate level if some recommended enhancement measures are taken.

The increase of the water table level due to the reservoir's raising would be another permanent positive impact worth mentioning, evaluated as of medium-high significance and with a potential regional extent.

Soil and agricultural land/crops loss (as well as terrestrial habitat loss) are inevitable interconnected negative permanent impacts of the reservoir's extension to FSL. Loss of housing and other man-made structures located within the new possible maximum water limits (MWL), which vary according to the project option, would be another negative effect in this case. What these impacts have in common is the possibility of being mitigated and compensated through a properly organized and thorough resettlement plan, which can include compensation measures directed to the community or to promote alternative income sources, when direct resettlement or compensation for agricultural and infrastructural losses is possible (water infrastructures, schools and road improvements, amongst others).



The permanent loss of agricultural land is a primary impact that generates other indirect impacts such as the reduction of livelihood and income for local populations or the arising of latter disputes during the relocation of land for cultivation and grazing. Particularly, loss of small scale subsistence farming (lands near the water reservoir, which are farmed all year long and from which families rely on) is one of the major concerns, as it can result in severe indirect impacts, including possible food privation. Considering the proportion of losses in relation with the extensive agricultural area existing around KD1's reservoir, this impact is rated of moderate intensity, but with likely higher significance if not mitigated/compensated. Compensation through the resettlement plan would lower this significance.

Affected houses and associated assets must be resettled. Depending on the survey's spatial criteria (which vary with the project option) between 12 and 91 edifications, mostly isolated, are at risk. By nature, the loss of housing and structures and the consequent resettlement process is always a high intensity and high significance negative impact for the ones directly affected, as it can induce important changes in people's livelihood, especially in rural areas. However, in the present case, even without a final definition of the different maximum water limits (MWL), the possible number of houses/families affected was surveyed and does not seem particularly high when compared with what is usual in other infrastructural projects of this kind. Thus, the overall raw impact was considered of moderate significance, decreasing to low after mitigation (considering resettlement and compensation measures, to be defined in the RAP).

The detailed design project to be developed must consider these issues and try to spare as much assets as possible (by dimensioning the dam's raising and rehabilitation in a way that limits the correspondent maximum water level as much as possible). Fair compensation and resettlement will be provided under the guidelines of a Resettlement Action Plan that will be prepared according to the World Bank's operational policies on this matter.

On the other hand, resettlement can also be viewed as an opportunity to improve living conditions and livelihood through better housing, access to urban commodities like good quality drinking water, health services, etc., since local housing conditions in the villages are generally very poor.



Regarding habitat loss, woodlands and wetlands should be the most affected. Both have an intrinsic ecological value, but will also represent a loss of food resources and shelter to occurring wildlife. However, while loss of riverine and lacustrine floodplains (wetlands) will be mostly a temporary impact, since it is expected that new floodplains will be created with the establishment of the new flooded area, woodlands loss will be of greater intensity as they are quite scarce in the surrounding area. Overall, a low to moderate significance impact is predicted, regardless of the project option.

The increase of the inundated area will also represent a wider physical barrier to terrestrial faunistic species by interfering with terrestrial habitat's continuity (fragmentation effect, for instance in existing woodlands). Local/regional negative impact of moderate significance is predicted.

Cultural heritage sites found along the new flooding area will be affected with different degrees of severity, from low to high, but none of them presents a red flag to the projected development as mitigation or rescue is possible, regardless of the project option.

Because the *nyau dambwes* are at the very fringe of the study area, the groves are not expected to be affected by the inundation itself. It should be ensured though that local communities retain access to the indicated *nyau* groves for burials and *nyau* activities. With a more detailed design of project options in further stages, namely during the development of the Resettlement Action Plan, the rigorous assessment of the possible impacts over graveyards and the need for the resettlement to new burial sites will be evaluated thoroughly and adequately mitigated, with the involvement of responsible authorities and articulation with local leaders.

As a final note for the operation phase, no significant water quality issues are expected in the augmented reservoir, particularly oxygen depletion-related ones, considering that current pollution sources will remain the same (and protection measures will continue to be enforced). Nonetheless, as a preventive measure towards this prediction, tree and vegetation clearance in the new flood area is recommended to be done previously.



In this context (with positive effects transversal to other environmental components), the establishment of a levelled protection buffer zone is also proposed (with different restrictions to human activities allowed at each level) as well as the reestablishment of a riparian and protective vegetation buffer next to the future FSL.

The raising project will increase the water capacity/inflow ratio which will then lead to an increase in the trap efficiency of the reservoir. However, its significance regarding sedimentation rates is negligible, assuming that erosion within the catchment is not going to increase.

As for differentiating impacts between the three project options (see Table 53), the main feature that distinguishes the magnitude and significance of each option's impacts is the type and dimension of embankments.

Regarding construction's (mostly temporary) impacts, Option 2 is the least favourable option as it demands a high quantity of borrow material to construct the necessary embankments. The necessary earthworks dictate larger needs of soil and the creation of borrow pits, while at the same time the increased noise and dust emissions are significant for close sensitive receptors, since this option implies more intense construction works than the remaining alternatives. As for Options 1 and 3, the latter would be slightly more favourable concerning soil demand – as excavation products could make up for part of the earthworks necessities thus decreasing the need for the creation of borrow pits. In case blasting rocky patches is required for the construction of the side-channel though, Option 3 will present itself as the least favourable.

Having no clear agreement on which option is the most favourable in the construction phase – even though Option 2 presents itself as more unfavourable, long-term/permanent operation phase impacts are the ones that shall dictate the verdict.

As previously mentioned, the different project options determine different maximum water levels; thus losses will be proportional to the MWL of each option, by the following decreasing order: Option 2 (MWL = 1111 masl), Option 3 (MWL = 1108 masl) and Option 1 (MWL = 1107 masl).



For the impacts “loss of agricultural land” and “loss of buildings and other structures”, Option 1 is the most favourable option. Between Options 2 and 3, Option 2 is again the most unfavourable one (as it will generate the highest water level). Nonetheless, after adequate compensation all options are equally placed, resulting in low significance negative impacts – it should be emphasized though that compensation costs will also be proportional to the MWL of each option.

Comprehensive Environmental and Social Management and Monitoring Plans (Chapter 0) have been developed with mitigation, enhancement, compensation and monitoring measures and actions to address all the main identified impacts and provide monitoring and an environmental performance assessment of the project.

6.13. Preferred Project Option E Impact Assessment

Preferred Project Option E considers similar actions than the previously assessed ones (Options 1/A, 2/B and 3/C), namely:

- Construction works for the establishment of the projected infrastructures, covering both banks of Lilongwe River, at the dam’s location (Kapininga and Malingunde);
- Extended water reservoir area upstream Kamuzu Dam I (TA Malili and TA Masumbankhunda).

Nevertheless, the differentiated design, earthworks quantities, estimated water levels and other aspects that are now known may induce some changed and / or new impacts.

In the following sections such comparative analysis is carried out, by project phase (construction and operation).

Lastly, a synthesis impact matrix that summarises the overall impact assessment is presented individually for preferred project Option E.

The Impact Assessment’s scope for Option E that supports the present Chapter is presented in Appendix 1 (Map 8).



6.13.1. Construction phase

The preferred Option E will require similar construction works to those identified in the ESIA Report, but also presents some differentiated actions:

- Temporary cofferdam;
- Larger work area to enclose the cofferdam;
- Intermediate soil and rock needs for filling and embankment;
- Phased works (due to hydrological regime and necessary dry-works);
- Intermediate permanently affected area (by project implementation – accounts the spillway extension and design and size of left and right embankments).

These actions will not imply expected impacts different from those initially assessed for options A/1, B/2 and C/3, but may represent a change on the intensity and significance of some impacts already identified.

In which concerns the new project layout, the projected structures will occupy a very similar area considering the three initial alternatives – only Option 1/A will have an inferior footprint (no spillway extension and smaller embankment crest; the other options either have more higher crests or a more extent spillway), but not significantly smaller.

Therefore, impacts that derive from the direct implantation area of project option E are analogue to those previously identified for the initial alternatives designs. The most relevant impact would be the loss of buildings, but its intensity and significance remains overall unaltered.

Impacts that derive from the overall work area (including construction yards and support areas, heavy machinery circulation, among other) are also similar, as the area needs can be considered equal. Although preferred Option E will require the construction of a cofferdam downstream the Malingunde bridge, the implantation site and work accesses don't represent a significant change in the overall area. Also, the close-by riverbank doesn't have any settlements that will require resettlement and the affected habitats will be recovered at the end of the constructions works, as proposed in the ESIA's ESMP.



The temporary cofferdam construction will potentially induce the temporary disruption of the hydrological regime. Considering that the cofferdam will be constructed in September and removed in January, in that period water doesn't usually free-flow from KD1 to KD2's reservoir – only when required the bottom outlet is open to reinforce the KD2's water level. Therefore, that disruption will not represent a significant change to the reference situation and is classified of short-term, likely with intensity and significance negligible to low.

Considering the temporary nature of the cofferdam and the increased phased works (less intense at each given moment than for other options), issues such as soil erosion and siltation, water quality degradation and disturbance of faunistic communities are not maximised for Option E and the impact assessment remains valid.

As mentioned in section 2.2.10.3 and quantified in Table 7, Option E will require a significant amount of borrow material (43,400 m³ for embankments, plus 15,000 m³ for cofferdam construction), only inferior to Option B (77,000 m³). But again, considering the phasing of the construction activities, the filling material necessary for the cofferdam might be reused in latter construction stages for the embankment definition, minimising the need for additional borrow material (the total borrow material need will be minimised to 43,400 m³).

Still, it positions Option E as the second most favourable regarding impacts such as creation of borrow pits and other regarding population's livelihood and safety (increased earthworks represent more intense heavy machinery circulation, a more intense or more prolonged in time noise and dust emissions, etc.). If the latter impacts can be considered the same as those already assessed in the previous sections (considering that a more phased construction period will reduce the intensity of emissions and circulation of machinery at a given time), the creation of borrow pits is classified as a moderate intensity and significance impact, that can be reduced to a low to moderate significance if mitigation measures are implemented.

In summary, construction methods, options and activities applicable to Option E do not significantly change the assessment presented in the previous sections of Chapter 6, regarding the three initial project options, as the identified impacts are overall analogue in terms of quantitative and qualitative assessment.



6.13.2.Operation phase

Impacts concerning the operation phase are mainly due to the full supply level rising and the definition of a no-activity (settlements, infrastructures, agriculture and livestock grazing) protection buffer around the enlarged water reservoir, resulting specially in the loss of habitats, agricultural land, buildings and other structures.

During the initial stages of the ESIA, no estimate was provided by the Design Team regarding FSL and water levels for the three alternative project options. Therefore, a broad impact assessment scope was considered, enclosing a 100 m buffer around the estimated Full Supply Level at 1,105 masl that expectedly included all maximum water levels for all three alternatives.

The definition of a preferred project option, supported by a topographic survey (SMEC, 2015) allowed the estimation of more rigorous project water levels.

Also, to account the definition of a protection buffer around the reservoir, the recommendation of the Ministry of Agriculture, Irrigation and Water Development is followed. That recommendation states that impacts should consider the definition of a buffer zone based on the estimated 100 year-flood level (equals 1,106.4 m.a.s.l. for preferred Option E – SMEC; 2015), with an added 15 m protection buffer on either side of the dam's reservoir for new developments.

Considering the above, the initial impact assessment regarding the three first project options was performed under a pessimistic scenario – that is, it considered a study area that enclosed all maximum water levels, which were defined according to the probable maximum flood. On the other hand, preferred project Option E impacts are limited to the estimated 100-year floodline (SMEC, 2015) plus a 15 m buffer.

The losses associated with the new water reservoir level and protection buffer for Option E are overall analogue to the classification present in the previous sections, regarding alternatives A, B and C. Considering all alternatives, Option E impact area is intermediate, considering the hierarchy defined by the estimation of 100-year recurrence flood levels (Option B: 1,107 masl, Option E: 1,106.4 masl, Options A and C: 1,106 masl; SMEC, 2015).



Regarding agricultural land, estimates for Option E total losses are of approximately 120 ha, considering the protection buffer (inferior to the estimated worst case scenario in the ESIA for Option B – estimated in a maximum of 321 ha). Still, considering that Options A and C will have lower land loss than Options E and B (in that order), the overall loss of agricultural land is classified of moderate to high intensity (considering loss area and importance for local population), that might be mitigated to low to moderate considering resettlement and compensation for losses.

In which concerns habitats loss, the impact assessment was based on each affected habitat value and their relative importance. Considering that in the protection buffer some habitats might be regenerated and fragmentation can be reduced, the overall assessment of the ESIA Report remains valid.

Loss of buildings and other structures was a potentially significant impact (like loss of agricultural land), since it affects directly people's property and assets, social and cultural structure and integration, among others negative impacts. With the more rigorous definition of FSL and protection buffer for Option E, the potential impact over 20 owners around the reservoir (estimated in the initial project options) was reduced to 7 owners. Hence, although the significance remains unaltered (moderate) given the influence it has on people's life (even if over few families) the intensity is reduced to low.

The identification and classification of the remaining impacts presented in the ESIA Report aren't significantly altered between project Option E and the three alternative options and, therefore, are applicable to it.

6.13.3. Impact matrix for preferred project option E

The global synthesis impact matrix is updated next, summarising the identified impacts and its qualitative assessment considering the implementation of the preferred project Option E.



Table 122 – Summary of environmental and social impact assessment: impacts of Option E

Impact	Project Phase	Status	Extent	Duration	Likelihood	Intensity	Significance (without mitigation)	Significance (post-mitigation/ enhancement)
GEOLOGY								
Soil erosion and siltation (for construction areas)	Construction	Negative	On-site/ Local	Temporary to Permanent	Likely	Moderate	Low	Negligible
Creation of borrow pits	Construction	Negative	On-site/ Local	Temporary to Permanent	Definite	Moderate	Moderate	Low to Moderate
SOILS								
Soil loss (construction site)	Construction	Negative	On-site	Temporary/ Short-term (recovered areas); Permanent (embankments)	Definite	Low	Low to Moderate	Low
Soil contamination	Construction	Negative	On-site/ Local	Temporary/ Short-term	Unlikely	Low to Moderate	Low to Moderate	Low
Soil loss (reservoir area)	Operation	Negative	On-site	Long-term/ Permanent	Definite	Moderate	High	High
Soil erosion (reservoir area)	Operation	Negative	On-site/ Local	Long-term/ Permanent	Likely	Low	Low	Negligible
HYDROGEOLOGY								
Groundwater contamination	Construction	Negative	On-site/ Local	Short-term/ Long-term	Unlikely	Low	Low	Negligible



Impact	Project Phase	Status	Extent	Duration	Likelihood	Intensity	Significance (without mitigation)	Significance (post-mitigation/enhancement)
HYDROGEOLOGY (cont.)								
Increase of water table level	Operation	Positive	Local/ Regional	Permanent	Definite	Low to Moderate	Moderate to High	Moderate to High
Deactivation of boreholes	Operation	Negative	On-site	Permanent	High	Low	Low	Negligible
HYDROLOGY								
Temporary disruption of the hydrological regime	Construction	Negative	On-site	Short-term	Likely	Negligible to Low	Negligible to Low	Negligible to Low
Increase in flow and runoff up to Lilongwe's water treatment plant	Operation	Negative	Regional	Permanent	Likely	Negligible to Low	Negligible to Low	Negligible
Decrease in flow downstream of Lilongwe's water treatment plant	Operation	Negative	Regional	Long-term	Likely	Negligible	Negligible	Negligible
Increase in trap efficiency/sediment deposition	Operation	Negative	Local	Permanent	Definite	Negligible	Negligible	Negligible
Increase in water availability	Operation	Positive	Regional	Permanent	Definite	Moderate	Moderate	Moderate
Mitigation of droughts' severity	Operation	Positive	Regional	Long-term	Definite	Low	Low	Low



Impact	Project Phase	Status	Extent	Duration	Likelihood	Intensity	Significance (without mitigation)	Significance (post-mitigation/enhancement)
SURFACE WATER QUALITY								
Water quality degradation (suspended solids and turbidity)	Construction	Negative	Local	Temporary/ Short-term	Definite	Low	Low to Moderate	Low
Water quality degradation (organic and faecal contamination)	Construction	Negative	Local	Temporary/ Short-term	Likely	Low	Low to Moderate	Low
Risk of water quality degradation (spillages)	Construction	Negative	Local	Temporary/ Short-term	Unlikely	Variable (Low)	Low to Moderate	Low
Risk of water quality degradation (oxygen depletion)	Operation	Negative	On-site	Short-term	Likely	Low to Moderate	Low to Moderate	Negligible to Low
NOISE								
Construction activities and heavy machinery	Construction	Negative	On-site/ Local	Temporary	Definite (close vicinity in Kapininga); Likely (other sensitive receptors)	Moderate to High (blasting actions)	Moderate to High (50 m buffer); Low (other sensitive receptors further than 50 m)	Moderate (50 m buffer); Negligible to Low (other sensitive receptors further than 50 m)



Impact	Project Phase	Status	Extent	Duration	Likelihood	Intensity	Significance (without mitigation)	Significance (post-mitigation/enhancement)
NOISE (cont.)								
Construction traffic	Construction	Negative	Local	Temporary	Likely	Low	Low	Negligible to Low
AIR QUALITY								
Particulate matter emissions	Construction	Negative	On-site/ Local	Temporary	Definite (close vicinity in Kapininga; Likely (other sensitive receptors)	Moderate	Moderate to High (close vicinity in Kapininga); Low (other sensitive receptors)	Low to Moderate (close vicinity in Kapininga); Low
Gaseous emissions	Construction	Negative	Local	Temporary	Likely	Negligible to Low	Low	Negligible to Low
TERRESTRIAL AND AQUATIC ECOLOGY (FLORA AND FAUNA)								
Habitat alteration/ destruction	Construction	Negative	Local	Permanent/ Long-term	Likely/ Definite	Low	Low to Moderate	Low
Habitat contamination	Construction	Negative	On-site/ Local	Variable	Unlikely	Variable	Variable	Low
Disturbance of faunistic communities	Construction	Negative	Local	Temporary/ Short-term	Likely	Moderate	Low to Moderate	Low



Impact	Project Phase	Status	Extent	Duration	Likelihood	Intensity	Significance (without mitigation)	Significance (post-mitigation/enhancement)
TERRESTRIAL AND AQUATIC ECOLOGY (FLORA AND FAUNA) (cont.)								
Loss of terrestrial habitats	Operation	Negative	Local	Temporary; Long-term/Permanent	Definite	Low/Moderate/High	Low/Moderate/High	Low to Moderate
Creation of a new aquatic habitat	Operation	Positive	Local	Long-term	Definite	Moderate	Low	Moderate
Aquatic habitat alteration	Operation	Negative	Local	Long-term	Definite	Low	Low	Low
Proliferation of invasive species	Operation	Negative	On-site	Permanent	Likely	Moderate	Low	Negligible
Habitat fragmentation (terrestrial)	Operation	Negative	Local/Regional	Long-term	Definite	High	Moderate	Low
LAND USE AND SPATIAL PLANNING								
Changes in land use mosaic	Operation	Negative	Local	Permanent	Definite	Low	High	Low to Moderate
Pursuance of territorial, socioeconomic and sector policies and strategies goals	Operation	Positive	Local/Regional	Long-term	Low	Low	Low	Low



Impact	Project Phase	Status	Extent	Duration	Likelihood	Intensity	Significance (without mitigation)	Significance (post-mitigation/enhancement)
SOCIOECONOMICS AND PUBLIC HEALTH								
Creation of employment and new opportunities to local business	Construction	Positive	Local/ Regional	Short-term	Definite	Moderate	Moderate to High	Moderate to High
Influence of external workforce in local communities	Construction	Negative	Local	Short-term	Likely	Low	Low	Low
Increase of sexually transmitted diseases	Construction	Negative	Local/ Regional	Short-term/ Long-term	Likely	Low	Moderate	Low
Spread of communicable diseases	Construction	Negative	Local	Short-term	Likely	Low	Low to Moderate	Low
Traffic disruption	Construction	Negative	Local	Short-term	Likely	Low	Low	Negligible
Increased risk of accidents	Construction	Negative	Local	Short-term	Likely	Low	Low	Negligible
Loss of buildings and other structures	Construction	Negative	On-site/ Local	Permanent	Definite/ Likely	Low	Low to Moderate	Low
Loss of agricultural land	Operation	Negative	On-site/ Local	Long-term/ Permanent	Definite	Moderate to High	Moderate to High	Low to Moderate
Loss of crops	Operation	Negative	On-site	Permanent	Definite	Moderate	Moderate	Low
Loss of buildings and other structures	Operation	Negative	On-site/ Local	Permanent	Definite	Low	Moderate	Low



Impact	Project Phase	Status	Extent	Duration	Likelihood	Intensity	Significance (without mitigation)	Significance (post-mitigation/enhancement)
SOCIOECONOMICS AND PUBLIC HEALTH (cont.)								
Disruption of accessibilities and mobility (loss of roads and bridges)	Operation	Negative	On-site/ Local	Permanent	Definite	Moderate	Moderate to High	Negligible to Low
Creation of employment	Operation	Positive	Local	Long-term	Likely	Moderate	Moderate to High	Moderate to High
Increased water management and supply capability	Operation	Positive	Regional	Medium-term	Definite	Moderate	High	High
CULTURAL HERITAGE								
Affectation of heritage sites	Operation	Negative	On-site/ Local	Permanent	Likely/ Definite	Low to High	Low to High	Negligible to Moderate



7. Environmental and Social Management

7.1. Environmental and Social Management Plan

7.1.1. General considerations

Following the assessment of environmental impacts, this chapter intends to identify the environmental measures that should be taken to minimize or compensate the negative environmental impacts and enhance the positive impacts of the project.

These measures' main goal is to implement the project in the most optimized way from an environmental point of view, safeguarding the interests of the social and the biophysical environment and reducing or nullifying potentially significant negative impacts that may affect the project or have severe consequences over any of the considered environmental descriptors in this study.

According to the EIA Guidelines (produced by the Environmental Affairs Department), an *“EIA should have an environmental management plan which provides details of the work programme or schedule. These may include technical control measures, an integrated management scheme, monitoring, contingency measures, operating practices, project scheduling, joint management with affected groups, mitigation costs and value judgements”*.

The minimum information to be presented in an Environmental Management Plan are the planning and design measures directed to reduce or eliminate potential impacts (or maximize the positive ones), through the outline of activities to be undertaken by the proponent, governmental entities or others.

Also, the World Bank's Operational Policy on Environmental Impact Assessment, in its annex C concerning Environmental Management Plans (OP 4.01 – Annex C), refer that the Environmental Management Plan must be integrated into the project's overall planning, design, budget and implementation.



Considering that the project is developed at a preliminary stage, the following ESMP does not specify thoroughly the technical details of each mitigation measure and recommendations (designs, equipment descriptions, operating procedures, among others). That must be pondered in the detail project design phase for the selected option, discussing, adjusting and including the feasibility and cost-effectiveness of the proposed measures, along with its integration in the work planning and schedule and overall project's budget.

In view of the above, and taking into consideration the EIA Guidelines and the Annex C of OP 4.01, regarding Environmental Management Plans, the following ESMP consists of a set of mitigation, monitoring and institutional measures to be taken during implementation and operation of the project, in order to eliminate adverse environmental and social impacts, offset them or reduce them to acceptable levels, and also to enhance environmental benefits.

In the following subchapters the following is detailed:

- Institutional framework to be responsible for the implementation of the mitigation measures and compliance monitoring;
- Management procedures and reporting;
- Tabular environmental management plan, listing the proposed measures.

The proposed environmental and social management plan identifies:

- all anticipated positive and negative impacts of the project;
- mitigation measures and recommendations, along with the respective project stage to be implemented (planning and design, construction works and operation of the project) and institutions or entities responsible for it.

7.1.2. Roles and Responsibilities

The Lilongwe Water Board, as a promoter of the project, but also as the governmental institution with jurisdiction in water projects and waterworks interventions, has the key responsibility in implementing the ESMP and to ensure that all the mitigation measures and monitoring actions are carried out.



That responsibility is shared with the Environmental Affairs Department, the central authority that coordinates and advises on all environmental issues, including EIA procedures and requirements.

The successful implementation of the ESMP depends directly of the capability of the Contractor of ensuring the implementation of all the general and specific measures to avoid or minimize environmental, social and health impacts during construction, as well as to apply national and international standard quality assurance procedures.

The efficiency and control of measures implementation is also dependable of the involvement and liaison with other relevant institutions and authorities, with special regard to:

- Lilongwe District Council;
- Ministry of Lands, Housing and Urban Development (especially the Department of Lands;
- Ministry of Agriculture, Irrigation and Water Development (especially the Department of Water Resources and Land Resources & Soil Conservation Department;
- Ministry of Tourism and Culture (Department of Antiquities and Department of Culture);
- Sectorial stakeholders (forestry, health, agriculture, public works, small businesses and others)
- Local authorities and communities (Traditional Authorities, local leaders and committees at village level particularly the Group Village Headmen, Village headmen and others).

During construction, an environmental and social management team can be foreseen, which can include in its composition representatives of the following parties:

- Project Manager – the LWB designated person/officer to manage the project implementation in all stages;
- Environmental Manager – an environmental technician to provide support to the contractor and project manager in the implementation of environmental and social measures, and manage possible adjustments necessary to some measures or procedures;



- Contractor/construction manager – the contractors designated to carry out the specific project components and construction works must appoint a responsible person to coordinate with the other environmental and social management parties; in alternative, a general construction manager can be appointed to manage the entire construction phase of the project;
- Safety Manager – with the responsibility for safety issues related to the operational workforce.

7.1.3. Management procedures and reporting

The environmental and social management team proposed in the previous section is responsible for enforcing the compliance with all the proposed measures and recommendations.

The monitoring of the execution and implementation of mitigation measures should be achieved by:

- Continuous monitoring of construction works by one of the parties designated under the proposed team;
- Periodical *in situ* supervision by the environmental manager and project manager;
- Periodical supervision by authorities, namely Environmental Affairs Department Officers.

All licences, permits and authorisations must be present at all times at the construction yard.

The periodical supervision of the ESMP's implementation by the environmental manager should result in supervision reports, summarising the project status, implementation and efficiency/ efficacy of proposed measures and monitoring plans (a synthetic checklist of measures can be used as support for *in situ* supervision actions) and need of adjustment of any measures, with proper justification. The periodical supervision reports can be presented to the Environmental Affairs Department, if request or as a register and evidence of the regular monitoring of the construction works to authorities.



7.1.4. List of environmental and social measures and recommendations

This section organizes the inventory of all the proposed mitigation measures, divided by the different project phases (planning/construction/operation), to enable quick reference and responsibilities for implementation. The purpose of this inventory is to produce an operational document that facilitates the implementation of measures in each phase of the project.

The measures were organized in a tabular format to simplify the overall consultation. The various columns represent the following aspects:

- Activity – represents the respective field where impacts and measures are applied.
- Environmental Impact – describes the various potential impacts which are the subject of the mitigation measures.
- Mitigation/ Enhancement Measure – brief description of the respective measures to be implemented.
- Time Target/ Period for implementation – corresponding to the appropriate phase to apply measures.
- Institution/ Persons responsible for implementation of the mitigation measures.
- Estimated cost – cost estimates for the appropriate mitigation measures (when applicable).

The general mitigation measures and recommendations proposed are the result of several specialist assessments considered in the ESIA, taking into account that the same mitigation measure can be applicable to a broad set of impacts over different environmental and social factors (for instance, soil erosion control measures will mitigate impacts on soil, water resources, aquatic ecology and river water use by the communities). These transversal measures are mainly related to construction activities, specifically with the installation and management of the construction site, work activities, machinery operation and circulation, among others, and are grouped according to the intended activity. The predicted measures for the construction phase are to be integrated in the environmental terms of reference for contractors, to ensure their effective application.



In order to estimate costs and given the current stage of development of the project, which means there is still no detailed information about the construction, we relied primarily on team experience and reference costs of similar interventions/works performed.

Most of the recommended measures are directed at the construction phase, and shall be implemented by the chosen contractor. Therefore, some implementation costs shall be estimated by the Contractor and included in the bidding budget.

As previously stated, many of the recommended measures are best practices or standard norms which the Contractor must comply with and should therefore be included in the bidding budget or simply do not apply (do not have an associated cost). Some measures rely on construction quantifications and circumstances and therefore also have to be included in the bidding budget and the cost will be estimated by the Contractor.



Table 123 – ESMP: Planning and pre-construction phase measures

Activity	Environmental Impacts	Mitigation/ Enhancement Measure	Time Target/ Period for implementation	Institution / Persons responsible for implementation of the mitigation measures	Estimated cost
General mitigation measures and recommendations	<i>(All measures and recommendations proposed refer to transversal issues that are applicable to several impacts and environmental and social components, as well as to general good practices, procedures and actions to be undertaken at construction works)</i>	Detail project design and decision on preferred project option should assume as a key dimensioning factor the minimization as feasible as possible of the non-overspill crest. That is, project design should limit as much as possible the maximum water level of the dam and the subsequent impacts over soil, habitats, agricultural land and houses and other infrastructures' losses.	Planning and Design	Detailed Design Consultant and Lilongwe Water Board	Not applicable
		Detail project design should prevent/minimise as technically feasible the impact over local population's houses, assets, as well as other private owners and public and communal infrastructures, especially regarding embankments design, topographic/terrain modelling, necessary work areas, construction methods, specific design measures for some affected structures (walls or small embankments)	Planning and Design	Detailed Design Consultant and Lilongwe Water Board	
		The Environmental and Social Management Plan (ESMP), defined in the present ESIA shall be integrated as part of the Terms of Reference (ToR) for the bidding process for construction. The developer and contractor shall be contractually obliged by the ESMP to implement all the identified mitigation and monitoring measures according to the planned schedule.	Planning / Construction Bidding	Lilongwe Water Board and Contractor	
		It is recommended that urgent preventive land use measures should be taken to avoid or stop encroachment within the study area, especially around the KD1 site. Land uses should be closely monitored by the Lilongwe Water Board and some kind of legal measures should be considered to prohibit or at least control new developments in this area.	Planning/ Pre-construction/ Preparation for construction works	Lilongwe Water Board, in cooperation with Lilongwe District Assembly and Department of Lands	850.000 MWK
		Publicize the construction work schedule to local populations. The information provided should include the construction purpose, location, main actions to undertake, their scheduling and potential disturbances on everyday activities, as well as safety measures to adopt in case of need. Awareness sessions and even training should be implemented in close collaboration with TAs authorities and local village leaders.	Pre-construction/ Preparation for construction works	Lilongwe Water Board and Contractor, assuring the proper coordination with local authorities (TAs, local leaders, village committees or others)	500.000 MWK
		Setup a public service for inquiries and complaints regarding construction works. Complaints about construction activities should be registered and timely solved by the contractor, under supervision of the LWB.	Pre-construction/ Preparation for construction works	Contractor and Lilongwe Water Board	500.000 MWK



Activity	Environmental Impacts	Mitigation/ Enhancement Measure	Time Target/ Period for implementation	Institution / Persons responsible for implementation of the mitigation measures	Estimated cost
		Provide training to construction workers and supervisors and raise awareness regarding the actions most likely to cause environmental impacts. This training should also cover the mitigation measures to be implemented and best practices during the construction phase.	Pre-construction/ Preparation for construction works	Contractor	300.000 MWK
		Ensure the application of international best-practices and rules of safety, health and hygiene at work (e.g., site fencing), describing all procedures associated, during construction phase.	Pre-construction/ Construction	Contractor	Not applicable
		Elaborate an emergency plan defining what actions to take in case of spillage of hazardous substances to soil, water, boreholes or wells, and fire scenarios. Adequate training shall be provided to workers.	Pre-construction/ Construction	Contractor	4.500.000 MWK
General mitigation measures and recommendations	<i>(All measures and recommendations proposed refer to transversal issues that are applicable to several impacts and environmental and social components, as well as to general good practices, procedures and actions to be undertaken at construction works)</i>	If the use of explosives to dismantle rocky patches is foreseeable (Option C – side channel – and E – potential temporary diversion channel), elaborate a Safety and Management Plan for Explosives Use, and provide proper training to workers. The plan should address issues like storage, intended use, general and specific safety procedures and measures, restrictions to use, scheduling and means of information and alert to local populations, actions to take in emergency scenarios, among others.	Pre-construction/ Preparation for construction works	Contractor	7.500.000 MWK
		- Construction yards and storage sites should be located either within the construction site limits or in previously existing degraded areas; flat or gentle slope locations within close range to construction site should be favoured to avoid or minimize the need for earthworks and roads. The following locations should not be occupied: – River catchment protection areas and floodplains; – Groundwater protection areas (high infiltration areas); – Wellhead protection area; – Areas with good quality soils for agriculture; – Areas with protected status, particularly nature conservation; – Other areas where protected flora and fauna species can exist; – Geotechnical sensitive sites; – Scenic sensitive sites; – Agricultural areas; – Proximity of urban and/or touristic areas; – Cultural heritage sites (archaeological, other). - The yards and supply parks should be fenced in accordance with the applicable legislation to avoid impacts resulting from its normal operation.	Pre-construction/ Preparation for construction works	Contractor and Lilongwe Water Board	Not applicable



Activity	Environmental Impacts	Mitigation/ Enhancement Measure	Time Target/ Period for implementation	Institution / Persons responsible for implementation of the mitigation measures	Estimated cost
		- In case specific disposal areas are needed, site selection shall exclude: - River catchment protection areas and floodplains; - Groundwater protection areas (high infiltration areas); - Wellhead protection area; - Areas with good quality soils for agriculture; - Areas with protected status, particularly nature conservation; - Other areas where protected flora and fauna species can exist; - Geotechnical sensitive sites; - Scenic sensitive sites; - Agricultural areas; - Proximity of urban and/or touristic areas; - Cultural heritage sites (archaeological, other).	Planning and design; Pre-construction/ Preparation for construction works	Detailed Design Consultant, Lilongwe Water Board and Contractor; Waste management authorities and Land Resources & Soil Conservation Department should be involved	Not applicable
General mitigation measures and recommendations	<i>(All measures and recommendations proposed refer to transversal issues that are applicable to several impacts and environmental and social components, as well as to general good practices, procedures and actions to be undertaken at construction works)</i>	- In case large quantities of borrow soil is needed, the following guidelines should be considered when selecting borrow pit sites: - The borrowed soil must be brought from close locations to minimize transportation impacts; - The borrowed soil must not be from: - Land located in river beds and its banks; - Areas at risk of flooding (except future permanent flooded areas of the new water reservoir), high-infiltration areas and wellhead protection areas; - Other areas where the earthworks may affect protected fauna and flora species; - Geotechnical sensitive sites; - Scenic sensitive sites; - Agricultural areas; - Proximity of urban and/or touristic areas; - Cultural heritage sites (archaeological, other).	Planning and design; Pre-construction/ Preparation for construction works	Detailed Design Consultant, Lilongwe Water Board and Contractor; Waste management authorities and Land Resources & Soil Conservation Department should be involved	Not applicable
		Favour the use of existing pathways to access work sites. Should it be necessary to build new roads or to improve existing ones, the works should be carried out so as to minimize changes in land use outside road areas.	Planning and design; Construction	Detailed Design Consultant, Lilongwe Water Board and Contractor	<i>To be estimated by the Contractor and/ or the Detailed Design Consultant and included in the bidding budget</i>
		Adequate circulation routes must be studied and chosen for the transport of equipment and materials from/and to the construction site, to borrow pits and/or surplus materials for transport to adequate disposal, minimizing, whenever possible, passage through densely populated areas and near sensitive receptors (such as health care services and schools).	Planning and design; Pre-construction/ Preparation for construction works	Detailed Design Consultant, Lilongwe Water Board and Contractor	



Activity	Environmental Impacts	Mitigation/ Enhancement Measure	Time Target/ Period for implementation	Institution / Persons responsible for implementation of the mitigation measures	Estimated cost
Geology	– Soil erosion and siltation (for construction areas) – Creation of borrow pits	• Definition of mining areas for the construction of the embankment: – Privilege mining areas already active in the region in order to avoid untouched areas; – If new mining areas have to be created, these should be defined within areas that will be submerged in the operation phase, if there are suitable resources in those areas.	Planning and design; Pre-construction/ Preparation for construction works; Construction	Detailed Design Consultant, Lilongwe Water Board and Contractor; Waste management authorities and Land Resources & Soil Conservation Department should be involved	Not applicable
Hydrogeology	– Groundwater contamination – Increase of water table level – Deactivation of boreholes	• Perform a thorough inventory of the wells and boreholes directly affected by the project, also surveying the purpose of the extracted water and the number of inhabitants who rely on it.	Pre-construction/ Preparation for construction works	Contractor and Lilongwe Water Board; Department of Water Resources should be involved	1.800.000 MWK
		• Groundwater quality and static water levels are to be monitored in the surrounding wells and boreholes before the beginning of the construction (cf. Hydrogeology Monitoring Plan).	Pre-construction/ Preparation for construction works	Contractor and Lilongwe Water Board	1.500.000 MWK
Hydrogeology	– Groundwater contamination	• No temporary facilities (construction yards, general storage areas, fuel storage areas) should be located within 50 m of wells and boreholes. Fuelling, washing or maintenance of machinery should not occur in or adjacently to a drain or watercourse or in areas where high level groundwater conditions prevail (e.g. where shallow hand-dug wells are found).	Pre-construction/ Preparation for construction works	Contractor and Lilongwe Water Board	Not applicable
Hydrology	– Flow disruption	• If a temporary diversion channel is to be used during the construction phase, it should be dimensioned considering a possible occurrence of at least one design flood during the construction period. Simulate the operation of the diversion system for different flow conditions to evaluate its safety	Pre-construction/ Preparation for construction works	Detailed Design Consultant, Contractor and Lilongwe Water Board	<i>To be estimated by the Contractor and/ or the Detailed Design Consultant afterwards, if needed</i>
		• Evaluation of the amount of material needed for the cofferdam, estimating the material loss released or washed-out through the water • Cofferdam can eventually be overtopped or even suffer disruptions if control measures are not adopted. Thus, in order to avoid this type of accidents, various measures of prevention and mitigation can be taken, such as: – Use of fuse plug spillway, that in a presence of an exceptionally large flood, controls the overtopping of cofferdams and prevent from breakup; – Use of overtopping cofferdams, which efficiently controls the overtopping barriers and minimize the rupture risks.	Pre-construction/ Preparation for construction works	Detailed Design Consultant, Contractor and Lilongwe Water Board	<i>To be estimated by the Contractor and/ or the Detailed Design Consultant and included in the bidding budget</i>



Activity	Environmental Impacts	Mitigation/ Enhancement Measure	Time Target/ Period for implementation	Institution / Persons responsible for implementation of the mitigation measures	Estimated cost
Surface Water Quality	– Water quality degradation	- As a preventive measure to avoid possible water quality degradation, deforestation of the new area to be flooded shall be done. Deforestation Regulatory Procedures should be developed. Some recommendations follow: - Clear field demarcation of the new FSL at 1,105 masl for authorised and regulated collection and clearance of vegetation and wood by local population; - All trees or bushes taller than knee-high should be cleared; - A fair and clear set of rules should be negotiated with local traditional authorities in order to define roles and responsibilities, areas to assign to each village, timber quotas, timings and restrictions, amongst other issues. Timber is quite a valuable resource and so it could be seen as part of the compensation for the flooded land; - Strict regulation and field control of tree clearance by local communities should be enforced; - In order to mitigate possible secondary impacts on soil erosion and ecology, deforestation should be performed as close as possible to the programmed date of the construction finish, outside the main breeding season of the dry season (June to November).	Planning and design; Pre-construction/ Preparation for construction works	Lilongwe Water Board and Contractor; Department of Forestry, Department of Water Resources, Land Resources & Soil Conservation Department, Traditional authorities, village leaders should be involved	Because it is proposed that vegetation clearance is to be performed by local communities, no operational costs are associated. <i>250.000 MWK for Preparation and control costs</i>
Terrestrial and Aquatic Ecology	- Habitat alteration/destruction - Habitat contamination - Disturbance of faunistic communities	Scheduling the construction works for the months within the dry period (June to November) in order to avoid the most critical months to fauna, namely the reproduction and migration seasons. This measure however must be assessed with other measures of security and operational conditions of the construction works.	Planning and design; Pre-construction/ Preparation for construction works	Detailed Design Consultant, Lilongwe Water Board and Contractor	Not applicable
		The routes assigned for construction purposes (existing and new ones) should avoid ecologically sensitive areas, namely woodlands and wetlands.	Planning and design; Pre-construction/ Preparation for construction works	Detailed Design Consultant, Lilongwe Water Board and Contractor	



Activity	Environmental Impacts	Mitigation/ Enhancement Measure	Time Target/ Period for implementation	Institution / Persons responsible for implementation of the mitigation measures	Estimated cost
Socioeconomics and Public health	– Loss of buildings and other structures – Loss of agricultural land – Loss of crops – Disruption of accessibilities and mobility (loss of roads and bridges) – Increased water management and supply capability	• Development of a Compensation and Resettlement Action Plan. The following principles should be followed: – Not allowing new occupations/developments in areas directly affected by the project as soon as the planning and pre-construction phase, to reduce costs with monetary compensations or resettlements; – Collect detailed information about agricultural production (e.g., production, quantity, and destination) and house conditions; – Develop a thorough survey on affected land, houses and infrastructures according to a detailed project design; – Determination of the fair value of agricultural lands and households, to pay for the agricultural land and houses lost, respectively; – Replacement land, houses and infrastructures for resettlement of permanently lost assets should be acquired and delivered to the affected people. Three methods can be adopted: (i) Direct replacement of allotments and houses built for the affected people; (ii) Cash/land compensations; (iii) Alternative compensations, such as improvements to villages/ communities or alternative income sources for affected owners. – Farmland owners should be timely notified to prevent the plantation and loss of crops due to the water reservoir raising, so as to minimize compensation values; compensation or resettlement land should be made available as soon as possible to prevent loss of income and seasonal crops; – Temporary losses in crop production should be compensated, in accordance to local government established prices and productivity rates (cash compensations); – Helping farmers in the re-establishment of agricultural activities; – Potentially affected graveyards must be relocated to new burial sites, in articulation with local leaders and governmental authorities; – Replacement houses should be made using local resources and materials and integrated on local aesthetics; – The resettlement process should be preferably in neighbourhood areas or communities, at a short distance from their original site; – The resettlement process should compensate for lost assets but also for the affected people's livelihood, providing better housing conditions, adequate access to water supplies, agricultural fields, cattle grazing areas, and roads.	Planning and design/ Pre-construction	Lilongwe Water Board, in cooperation with Lilongwe District Assembly and the Lands & Valuation Department of the Ministry of Lands, Housing and Urban Development and involving local authorities (TAs, local leaders, village committees or others)	<i>Included in the ESIA assignment – Compensation and Resettlement Action Plan to be developed in a subsequent consultancy phase</i>



Activity	Environmental Impacts	Mitigation/ Enhancement Measure	Time Target/ Period for implementation	Institution / Persons responsible for implementation of the mitigation measures	Estimated cost
Socioeconomics and Public health	– Loss of buildings and other structures – Loss of agricultural land – Loss of crops – Disruption of accessibilities and mobility (loss of roads and bridges) – Increased water management and supply capability	• Construction or rehabilitation of boreholes and manual pumps, as well as of schools or roads, are forms of collective compensation to consider as a way of extending project benefits to affected villages.	Planning and design	Lilongwe Water Board, in cooperation with Lilongwe District Authorities and the Lands & Valuation Department of the Ministry of Lands, Housing and Urban Development and involving local authorities (local leaders, village committees or others)	<i>To be estimated by the Detailed Design Consultant and/or Compensation and Resettlement Action Plan</i>
		• Villages surrounding KD1 should benefit in some extent from the new reservoir that will flood part of their land. Therefore, if feasible, the project should incorporate provisions for some kind of water supply facilities (irrigation, drinking) in order to compensate for permanent losses. These proposals should first be discussed with local village leaders.	Planning and design	Lilongwe Water Board, in cooperation with Lilongwe District Authorities and the Lands & Valuation Department of the Ministry of Lands, Housing and Urban Development and involving local authorities (local leaders, village committees or others)	
		• Temporary disruption or disturbance of accessibilities/mobility should be mitigated by providing adequate alternative paths, before full construction begins. Plans should be previously submitted to the relevant authority for approval whenever there is a foreseeable need for traffic diverting.	Pre-construction/ Preparation for construction works	Detailed Design Consultant, Lilongwe Water Board and Contractor; Lilongwe District Assembly, Roads Authority and local authorities (local leaders, village committees or others) should be involved	<i>To be estimated by the Contractor and included in the bidding budget</i>
Cultural Heritage	– Affecting heritage sites	• Potentially affected heritage/archaeological sites do not have a touristic value, only a scientific value. It would therefore be appropriate to allow for archaeological excavations prior to inundation to ensure that no scientific information is lost. Also, test pits are proposed in order to assess the nature and integrity of the affected sites and to evaluate the need of further extensive excavations in case of evident significance. Each case is detailed next: – Excavation for sites KD-30 and KD-40; – Excavation if inundated for sites KD-01, KD-27, KD-31; – Test pitting for sites KD-02, KD-03, KD-06, KD-13, KD-14, KD-15, KD-20, KD-25, KD-28, KD-34, KD-35; – Test pitting if inundated for site KD-38; – Allow continued access to <i>nyau dambwes</i> if no impact occurs; – Relocation to new burial site under RAP guidelines and procedures.	Pre-construction/ Preparation for construction works	Contractor and Lilongwe Water Board (via an archaeological specialist team)	15.000.000 MWK (archaeological excavations and test pits) <i>To be defined in the Resettlement Action Plan (for relocation to new burial site nyau dambwes)</i>



Table 124 – ESMP: Construction phase measures

Activity	Environmental Impacts	Mitigation/ Enhancement Measure	Time Target/ Period for implementation	Institution / Persons responsible for implementation of the mitigation measures	Estimated cost
General mitigation measures and recommendations	<i>(All measures and recommendations proposed refer to transversal issues that are applicable to several impacts and environmental and social components, as well as to general good practices, procedures and actions to be undertaken at construction works)</i>	Limit activities of deforestation, removal of vegetation cover, soil cleaning and stripping strictly to the needed construction areas.	Construction	Contractor	Not applicable
		Clearance and collection of vegetation/ trees within the future flooded area (exclusively), to occur during construction phase, must comply with the Deforestation Regulatory Procedures.	Construction	Lilongwe Water Board and Contractor	Because it is proposed that vegetation clearance is to be performed by local communities, no operational costs are associated.
		Before excavation and general earthworks start, the fertile topsoil layer must be removed and stored in haystacks for later reuse in the recovery of affected areas. Appropriate maintenance and handling of topsoil is essential to achieve this objective.	Preparation for construction works/ Construction	Contractor	<i>To be estimated by the Contractor and included in the bidding budget</i>
		Earthworks should start as soon as the soil is cleared to avoid the repetition of the clearing actions on the same areas.	Construction	Contractor	Not applicable
		Significant earthworks (embankments and excavation) should be avoided during the high precipitation periods to avoid soil erosion by run-off. Proper precautions must be ensured for slope and trench stability and to prevent sliding.	Construction	Contractor	
		If applicable and possible, materials from excavations should be used in the necessary rehabilitation backfills and landfills (embankments), in order to mitigate the quantity of surplus land to be carried out to final disposal sites and minimize the use of borrow material.	Construction	Contractor	
General mitigation measures and recommendations	<i>(All measures and recommendations proposed refer to transversal issues that are applicable to several impacts and environmental and social components, as well as to general good practices, procedures and actions to be undertaken at construction works)</i>	If applicable, excavation products that cannot be reused or are in excess shall be used as backfill to rehabilitate used borrow pits. Additionally, the topography of these areas should be modeled reproducing the natural conditions. Native vegetation should be planted on top. If even so surpluses still remain, they should be stored in suitable alternative deposit sites. See previous measures for guidelines on disposal site selection criteria.	Construction	Contractor; Lilongwe Water Board; Land Resources & Soil Conservation Department and Waste management authorities should be involved	<i>To be estimated by the Contractor and included in the bidding budget</i>
		In case there are excavation materials with traces of contamination, these must be stored in locations that prevent contamination of soil and groundwater, either by infiltration or stormwater runoff, until these materials are routed to an appropriate disposal site.	Construction	Contractor; Waste management authorities should be involved	



Activity	Environmental Impacts	Mitigation/ Enhancement Measure	Time Target/ Period for implementation	Institution / Persons responsible for implementation of the mitigation measures	Estimated cost
		Vegetable biomass and other produced wastes must be removed and properly forwarded to a final disposal site. Reuse of these wastes should be promoted, if feasible. Wood may be handed to local villages, under supervision of village headmen.	Construction	Contractor; Waste management authorities and local authorities (local leaders, village committees or others) should be involved	
		Define and implement a Waste Management Plan, considering all the waste likely to be produced in the construction works, including its identification and classification according to local laws, the definition of management responsibilities and the identification of the final disposal sites more adequate to each category of waste.	Construction	Contractor; Waste management authorities should be involved	
		Ensure the correct temporary storage of the produced wastes, accordingly to their typology and with the local laws and regulations. Contention / retention of eventual run-off/spills must be foreseen. Waste deposition in the riverbanks, watercourses and groundwater high infiltration areas shall not be allowed, even if only temporary.	Construction	Contractor	Not applicable
		Provision of proper sheltered storage facilities for oils, diesel and other hazardous substances in construction yards, equipped with safety and spillage control measures like retention basins, spill kits, fire extinguishers, etc. An adequate drainage system should be implemented in these areas, in order to collect and restrain potentially contaminated run-off.	Construction	Contractor	<i>To be estimated by the Contractor and included in the bidding budget</i>
		Machinery and vehicles' maintenance and refuelling activities should be performed only in adequate workshops to be located in a specific and equipped area of the construction yards. Emergency repairs outside the yards should be performed using impermeable sheets or portable retention basins underneath machines/vehicles and absorbent material should be available. Oil changes and refuelling shall not be allowed near watercourses or other sensitive areas.	Construction	Contractor	Not applicable
General mitigation measures and recommendations	<i>(All measures and recommendations proposed refer to transversal issues that are applicable to several impacts and environmental and social components, as well as to general good practices, procedures and actions to be undertaken at</i>	Used oils, lubricants, fuels, paints, glues, resins and other hazardous substances must be stored in adequate and sealed containers, for posterior conduction to a proper final destination, preferably for recycling.	Construction	Contractor; Waste management authorities should be involved	<i>To be estimated by the Contractor and included in the bidding budget</i>
		Whenever chemical product spills occur in the soil, the contaminated soil must be promptly collected, with the help of an adequate absorbing product if necessary (sand, for instance), and must be stored and sent to a proper final disposal site.	Construction	Contractor; Waste management authorities should be involved	<i>Contractor's responsibility</i>



Activity	Environmental Impacts	Mitigation/ Enhancement Measure	Time Target/ Period for implementation	Institution / Persons responsible for implementation of the mitigation measures	Estimated cost
	construction works)	Ensure adequate collection and storage/treatment facilities for domestic wastewater resulting from the construction yard, according to the local laws – a common solution is a septic tank or equivalent. Effluents should be periodically collected and transported to adequate disposal sites. As an alternative, provide appropriate latrines to workers, which shall be adequately sealed and recovered when they are no longer needed.	Construction	Contractor; Waste management authorities should be involved	<i>To be estimated by the Contractor and included in the bidding budget</i>
		Keep an up to date record of the produced waste amounts and of the respective final disposal, based on waste management guidelines.	Construction	Contractor	Not applicable
		Moderate speeds must be practiced whenever passing by Malingunde, Kapininga and other villages, in order to minimize dust generation and noise.	Construction	Contractor	
		Ensure the transport of particulate or powdery construction materials or residues with an adequate load cover, in order to prevent/restrain the dispersion of particulate matter. Additionally, the transport vehicles should not circulate with excessive loads.	Construction	Contractor	
		Perform the necessary repairs, maintenance and regular inspections of all machinery and vehicles used for the construction works, in order to maintain normal functioning conditions and ensure mitigation of gaseous and noise emissions standards, and lower the risk of accidental spillages.	Construction	Contractor	<i>Contractor's responsibility</i>
		Open air burning of wastes shall be forbidden.	Construction	Contractor	Not applicable
		Properly decommission the area affected by construction works, dismantling the construction areas and removing all the equipment, machinery, borrow and surplus disposal sites, among others. Proceed to the cleaning of these sites, achieving at least the existing conditions prior to the works.	Construction/ Decommission	Contractor	<i>To be estimated by the Contractor and included in the bidding budget</i>



Activity	Environmental Impacts	Mitigation/ Enhancement Measure	Time Target/ Period for implementation	Institution / Persons responsible for implementation of the mitigation measures	Estimated cost
General mitigation measures and recommendations	<i>(All measures and recommendations proposed refer to transversal issues that are applicable to several impacts and environmental and social components, as well as to general good practices, procedures and actions to be undertaken at construction works)</i>	• Soil recovery and reforestation on construction degraded areas (remaining construction clearance area, construction yards and temporary roads), borrow pits and soil surplus disposal sites, through: – Backfilling (preferably using excavation surplus); – Terrain modelling; – Superficial coverage with stockpiled topsoil; – Reestablishment of the natural infiltration conditions, by means of soil scarification; – Reforestation with indigenous trees and grass species, especially ones that can contribute to erosion control and/or to enhance habitats, since they are better adapted to local abiotic and biotic factors.	Construction/ Decommission	Contractor; Land Resources & Soil Conservation Department should be involved	<i>To be estimated by the Contractor and included in the bidding budget</i>
		• Affected roads and pathways should be returned to its original state (or improved).	Construction/ Decommission	Contractor; Lilongwe Water Board and local authorities (local leaders, village committees or others) should be involved	
		• Ensure the reposition or replacement of infrastructures, equipment or services existing in the construction site and surrounding areas, which might have been affected during the works.	Construction/ Decommission	Contractor; Lilongwe Water Board and local authorities (local leaders, village committees or others) should be involved	
		• Ensure the removal of any obstruction and cleaning of all hydraulic drainage facilities which might have been affected by construction works.	Construction/ Decommission	Contractor	
Geology	– Soil erosion and siltation (for construction areas) – Creation of borrow pits	• Erosion/runoff control barriers should be installed along the excavation/ embankment areas. Silt fences or check dams should be constructed on the slopes (check dams) or on the riverside (silt fences); appropriate maintenance of these barriers is required during construction. Collected soil should be redistributed to those areas most affected by erosion.	Construction	Contractor	<i>To be estimated by the Contractor and included in the bidding budget</i>
Soils	– Soil loss	• Before excavation and general earthworks start, a fertile topsoil layer must be removed and stored in haystacks for later reuse in the recovery of affected areas. Appropriate maintenance and handling of topsoil is essential to achieving this objective.	Preparation for construction works/ Construction	Contractor	<i>To be estimated by the Contractor and included in the bidding budget</i>
		• In regard to piles of earthfilling material or soil surplus, measures to reduce mobilisation of soil such as covering stockpiles and constructing silt fences around them should be undertaken where necessary. Soil stockpiles should be restricted to a maximum of 2 m in height to prevent compaction under its weight.	Construction	Contractor	
Hydrogeology	– Groundwater contamination	• Clearance of vegetation, excavations and compaction of soils and earthworks should be kept to strictly necessary areas, in particular when nearby boreholes or wells.	Construction	Contractor	Not applicable



Activity	Environmental Impacts	Mitigation/ Enhancement Measure	Time Target/ Period for implementation	Institution / Persons responsible for implementation of the mitigation measures	Estimated cost
Hydrogeology	– Groundwater contamination – Deactivation of boreholes	• If there is exposure of the water table during excavations (e.g. “Fixed raising with side channel” option), actions that imply risk of contamination should not be performed or at least be restricted.	Construction	Contractor	Not applicable
		• Situations where excavations imply the drawdown of the water table level should be fully studied and understood in order to mitigate effects in productivity of nearby wells or boreholes.	Construction	Contractor and Lilongwe Water Board; Department of Water Resources should be involved	<i>To be estimated by the Contractor and included in the bidding budget</i>
		• Construction water supply should be preferably from surface water instead of groundwater. Groundwater should only be used for domestic and potable water at the construction yards, if no other supply source is available, following abstraction and sustainability testing and appropriate permits from the relevant authorities.	Construction	Contractor and Lilongwe Water Board; Department of Water Resources should be involved	Not applicable
		• In case a well or a borehole is deactivated due to the project, construction of a new one in a proper and close location is mandatory; it should follow the requirements of the Malawi Standard 733:2005: Borehole and shallow well water quality – Specification.	Construction	Contractor and Lilongwe Water Board; Department of Water Resources should be involved	<i>To be estimated afterwards, if needed</i>
		• Groundwater quality and levels are to be monitored in the surrounding wells and boreholes (cf. Hydrogeology Monitoring Plan).	Construction	Contractor and Lilongwe Water Board	4.000.000 MWK
Surface Water Quality	– Water quality degradation	• Special care must be taken when working near major river sites used by local population for washing/bathing/fishing.	Construction	Contractor	Not applicable
		• Existing licensed raw water abstractions in Kamuzu Dam I at Malingunde, such as the Water Falls Lodge, the LWB/ Land Conservation Department offices, the Youth Camp and the KIX nursery school, shall be adequately protected during construction, accounting for possible accidental spillages of oils and hydrocarbons and increased turbidity or faecal contamination. For example, hydrocarbon floating booms can be installed around the intakes, if needed.	Construction	Contractor	<i>To be estimated by the Contractor and included in the bidding budget</i>
		• If water contamination around the site is confirmed from monitoring activities or in case of accidental spillages, the affected area and uses shall be immediately interdicted and authorities, local communities and water users shall be informed of the risks. Causes are to be investigated and adequate actions shall be taken to restore the situation as soon as possible. Until complete restoration, new water sources and/or safe areas with adequate water quality should be investigated and proposed as an alternative to local users.	Construction	Lilongwe Water Board and Contractor; Department of Water Resources, local authorities (local leaders, village committees or others) should be involved	<i>Contractor's responsibility</i>



Activity	Environmental Impacts	Mitigation/ Enhancement Measure	Time Target/ Period for implementation	Institution / Persons responsible for implementation of the mitigation measures	Estimated cost
Noise	– Noise emission from construction activities and heavy machinery operation – Noise emission from construction traffic	• Restriction of the work schedule to daytime period (7-20h) when working near populated areas. This rule is also recommended for the circulation of heavy construction vehicles and machinery; if there is a specific imperative necessity to extent the construction works beyond the designated period, in those areas, local authorities and the exposed population must be previously informed.	Construction	Contractor and Lilongwe Water Board; Local authorities (local leaders, village committees or others) should be involved	Not applicable
		• If needed, the use of explosives to dismantle rocky patches shall be done only during daytime, from 8 to 17h, and accordingly to local regulations or internationally defined safety standards.	Construction	Contractor	
		• Promote acoustic isolation of stationary equipment that represent significant noise sources (diesel generators, pumps, etc.) near sensitive receptors, through the installation of soundproofed or enclosure devices, such as canopies or acoustic hoods.	Construction	Contractor	<i>To be estimated by the Contractor and included in the bidding budget</i>
Air Quality	– Particulate matter emissions – Gaseous emissions	• Regularly sprinkle water where needed through the construction site, particularly during dry and windy periods, in order to mitigate dust dispersion. Workers shall wear adequate protective gear.	Construction	Contractor	<i>To be estimated by the Contractor and included in the bidding budget</i>
		• Unloading of the transported powdery materials should be performed recurring to drop-height regulation equipment, ensuring the lowest drop-height possible in these operations.	Construction	Contractor	Not applicable
		• Onsite concrete production facilities (including raw materials storage areas), if needed, should be as far away from existing human settlements as possible. The concrete plant shall be equipped with dust emission control features, such as filters.	Construction	Contractor	<i>To be estimated by the Contractor and included in the bidding budget</i>
Terrestrial and Aquatic Ecology	– Habitat alteration/destruction – Disturbance of faunistic communities	• The awareness of the ecological relevance of natural resources should be transmitted to the workforce, in order to prevent an off-take of natural resources, like woody biomass.	Construction	Contractor and Lilongwe Water Board	<i>To be estimated by the Contractor and included in the bidding budget</i>
Socioeconomics and Public health	– Traffic disruption – Increased risk of accidents – Loss of buildings and other structures – Loss of agricultural land	• Roads and bridges included within the designed maximum water level must be timely replaced to assure connection between territories and margins. If not feasible, alternative road accesses must be planned and provided, without worsening the accessibility and mobility of villages.	Construction/ Operation	Detailed Design Team, Contractor and Lilongwe Water Board; Lilongwe District and Roads Authority should be involved	<i>To be estimated afterwards, if needed</i>



Activity	Environmental Impacts	Mitigation/ Enhancement Measure	Time Target/ Period for implementation	Institution / Persons responsible for implementation of the mitigation measures	Estimated cost
	– Loss of crops – Disruption of accessibilities and mobility (loss of roads and bridges)	• Local roads with maintenance needs should be repaired by the promoter, as a way to compensate the community.	Construction	Contractor and Lilongwe Water Board; Lilongwe District and Roads Authority should be involved	<i>To be estimated on the Resettlement Action Plan</i>
Socioeconomics and Public health	– Creation of employment and new opportunities to local business – Influence of external workforce in local communities – Increase of sexually transmitted diseases – Spread of communicable diseases – Traffic disruption – Increased risk of accidents – Loss of buildings and other structures – Loss of agricultural land – Loss of crops	• Ensure proper compliance of safety and signalling standards on the public roads, taking the safety of population into consideration and to mitigate disruption of their everyday activities.	Construction	Contractor	<i>To be estimated by the Contractor and included in the bidding budget</i>
		• Construction yards, storage, disposal and borrow sites, machinery operation areas or any other area that can pose some sort of danger to local people (particularly children) and livestock should be properly fenced, in order to mitigate the risk of accidents.	Construction	Contractor	
		• Prioritise recruitment of local workers for construction jobs, mitigating the influx of migrants and increasing income for local families.	Construction	Contractor; District Labour Officer should be involved	Not applicable
		• Construction job opportunities should be given to local workers affected by the project, directly and indirectly. Try to fit as many as possible in job vacancies for operation phase.	Construction/ Operation	Contractor and Lilongwe Water Board; District Labour Officer should be involved	
		• Equal job opportunities should be given to men and women. No child-labour shall be allowed.	Construction	Contractor; District Labour Officer should be involved	
		• Give preference to legally established local services/enterprises, to maximize local income and indirect job creation.	Construction	Contractor	
		• To minimize social conflicts originated by the expected influx of outside workers, a campsite for displaced workers should be created in the construction yard, offering adequate conditions for group accommodation in terms of housing conditions, water supply, sanitation and hygiene.	Construction	Contractor	<i>To be estimated by the Contractor and included in the bidding budget</i>
		• Settlements around the construction yards and site should not be allowed (or at least it should be controlled/ restricted).	Construction	Contractor and Lilongwe Water Board; Lilongwe District Assembly should be involved	
		• Houses that do not require resettlement but are located nearby the construction site should be signaled and protected in order to avoid accidental affectations.	Construction	Contractor	
		• To minimize the risk of spreading of STIs, HIV/AIDS and communicable diseases, as a result of the influx of the working population, it is recommended to carry out regular awareness actions, informing and advising on ways of transmission and prevention of these diseases, both to workers and the local population; guidelines from Malawi's national HIV prevention program, promoting behaviour change should be followed and regular condom distribution should be made available.	Construction	Contractor and Lilongwe Water Board; Health authorities and District HIV/AIDS Coordinator should be involved	1,500,000 MWK



Activity	Environmental Impacts	Mitigation/ Enhancement Measure	Time Target/ Period for implementation	Institution / Persons responsible for implementation of the mitigation measures	Estimated cost
		To minimize any increased pressure on the local health system due to the influx of migrant workers, project sponsor or contractor should contribute, in coordination with local health authorities, to strengthen the response capacity of the local health system.	Construction	Contractor and Lilongwe Water Board; Health authorities should be involved	Not applicable
Socioeconomics and Public health	– Creation of employment and new opportunities to local business – Influence of external workforce in local communities – Increase of sexually transmitted diseases – Spread of communicable diseases – Loss of buildings and other structures – Loss of agricultural land – Loss of crops	- A temporary health and first aid post should be available in the construction yard. The post should also perform regular HIV tests to workers (as usually performed by the Voluntary Counselling and Testing (VCT) centres from Malawi), or other kind of health tests (malaria, etc.). - Adequate training in safety, health, social and environmental procedures and measures should be provided to construction workers. Considers extending this to local villagers as well. Health and safety gear should be distributed to workers. Proper usage should be regularly monitored through audits and inspections.	Construction	Contractor and Lilongwe Water Board; Health authorities and District HIV/AIDS Coordinator should be involved	400.000 MWK
Socioeconomics and Public health		Pools of stagnant water created by construction activities should be promptly disabled to control mosquito proliferation and insect-borne diseases (e.g., malaria).	Construction	Contractor	<i>To be estimated by the Contractor and included in the bidding budget</i>
Socioeconomics and Public health		In collaboration with the local authorities, measures of immediate relief have to be taken to protect people who will have their low incomes or livelihood suddenly affected by the project's construction. These measures should include the provision of food supplements for people that will lose their crops or jobs at agricultural activities and that rely on them for getting most of their nourishment.	Construction/ Operation	Lilongwe Water Board; Social and health entities and Social NGOs should be involved	2,000,000 MWK



Table 125 – ESMP: Operation phase measures

Activity	Environmental Impacts	Mitigation/ Enhancement Measure	Time Target/ Period for implementation	Institution / Persons responsible for implementation of the mitigation measures	Estimated cost
General mitigation measures and recommendations	<i>(All measures and recommendations proposed refer to transversal issues that are applicable to several impacts and environmental and social components, as well as to general good practices, procedures and actions to be undertaken at construction works)</i>	Maintenance activities in the operation phase should follow the applicable general mitigation measures recommended for construction, tuned accordingly to the magnitude and duration of such activities.	Operation	Lilongwe Water Board	<i>In LWB annual budget for operation activities</i>
		- Enforce the maintenance and control of protection buffer zones around the reservoir (General Mitigation Measure for the Operation Phase): - Zone 1: FSL to 15 m beyond estimated 100-year floodline (SMEC, 2015) – no activities should be allowed within the protection buffer zone unless they are for conservation (riparian and protective vegetation); - Zone 2: beyond the 15 m protection buffer zone – agriculture, settlements, wastewater infrastructures and other development activities can only be placed 15 m further away from the estimated 100-year floodline.	Operation	Lilongwe Water Board	Not applicable
		Implement a riparian and protective vegetation buffer within Zone 1 and demarking it, using soil bioengineering techniques, in order to prevent riverbank erosion and water quality degradation. Recommendations on section 6.3.2 of the ESIA Report	Operation/ Construction	Lilongwe Water Board and Contractor	4.500,000 MWK
		Restricted dam or dangerous zones shall be signalled.	Operation	Lilongwe Water Board	200.000 MWK



Activity	Environmental Impacts	Mitigation/ Enhancement Measure	Time Target/ Period for implementation	Institution / Persons responsible for implementation of the mitigation measures	Estimated cost
Soils	– Soil erosion – Soil contamination – Soil pollution	• Soil conservation measures and techniques should be promoted around the reservoir area, to be adopted accordingly with the local context, characteristics and potential, such as: – Ensure a permanent soil cover, either with adequate crop rotation, or with the use of crop residues over bare soil (like maize stalk, also enhancing the soil's organic matter, promoting infiltration); – Minimize the use of mechanical equipment, under the principle of minimum soil disturbance; – Minimize or prevent the use of herbicides and pesticides, thus preventing soil pollution; – Contour ridging – although this technique is disseminated in the area, it is not always used efficiently (in slope areas, the improper ridges accumulate water until their destruction and the formation of rills and gullies); – Box/tied ridging – creates micro-catchments for capturing rain water and enhances the infiltration into the root zone; – Raising of foot paths – in order to prevent the formation of deep gullies in those areas (due to superficial water erosion); – Gully reclamation – creation of barriers inside the gullies to promote the sedimentation of materials, raising the gully level over time; – Hedge row planting – to be used especially near the riverbank where slopes are steeper and the soil is more exposed to erosion; – Creation of storm drains – to direct the excessive rainwater without affecting the cultivated land and enhancing its water erosion.	Operation	Lilongwe Water Board in collaboration with the Land Resources and Soil Conservation Department, College of Agriculture, Chitedze Research Station and local authorities/village leaders	10.000.000 MWK
Hydrogeology	– Groundwater contamination – Increase of water table level	• Groundwater quality and levels are to be monitored in the surrounding wells and boreholes (cf. Hydrogeology Monitoring Plan).	Operation	Lilongwe Water Board	1.000.000 MWK /year
Hydrology	– Decrease of flow downstream Lilongwe water treatment plant	• Operating rules of the water treatment plant and of Kamuzu Dam II should be defined considering the environmental flow. The environmental flow should be assessed and evaluated through the application of different methodologies, namely hydrological (with emphasis on the one defined by the Ministry of Agriculture, Irrigation and Water Development) and habitat simulation methodologies, such as IFIM.	Operation	Lilongwe Water Board	5.000.000 MWK



Activity	Environmental Impacts	Mitigation/ Enhancement Measure	Time Target/ Period for implementation	Institution / Persons responsible for implementation of the mitigation measures	Estimated cost
Hydrology	– Decrease of flow downstream Lilongwe water treatment plant – Increase in trap efficiency/ sediment deposition	• A stream flow gauge should be installed downstream of the Lilongwe water treatment plant to measure the available flow after abstraction and monitor the environmental flow releases.	Operation	Lilongwe Water Board	1.500.000 MWK
		• Awareness meetings focusing on the need for catchment conservation and forestation should be conducted.	Operation	Lilongwe Water Board	<i>In LWB annual budget for operation activities</i>
		• Bi-annual surveys should be carried out to determine the trapped sediment volume; when the volume surpasses the Kamuzu Dam I's needed storage capacity dredging should be done.	Operation	Lilongwe Water Board	1.500.000 MWK/ Year
Surface Water Quality	– Water quality degradation	• Raise awareness and collaborate with relevant authorities for promoting sanitation improvements of settlements located around the Kamuzu Dam I reservoir.	Operation	Lilongwe Water Board; local authorities (local leaders, village committees or others) should be involved	<i>In LWB annual budget for operation activities</i>
		• Enforce the use of environmentally friendly agro-chemicals registered with the Pesticide Board of Malawi in the reservoir's protection area.	Operation	Lilongwe Water Board; Lilongwe Agriculture Development Division (Crops Department), Land Resources & Soil Conservation Department and local authorities (local leaders, village committees or others) should be involved	<i>In LWB annual budget for operation activities</i>
		• Promote sessions with farmers to raise awareness on the impacts of using fertilizers and pesticides on the reservoir water quality and inform about environmentally friendly available alternatives for increasing farming yield. Train farmers on proper storage, handling and use of agro-chemicals.	Operation	Lilongwe Water Board; Lilongwe Agriculture Development Division (Crops Department), Land Resources & Soil Conservation Department and local authorities (local leaders, village committees or others) should be involved	400,000 MWK



Activity	Environmental Impacts	Mitigation/ Enhancement Measure	Time Target/ Period for implementation	Institution / Persons responsible for implementation of the mitigation measures	Estimated cost
Surface Water Quality		Improve the current water quality monitoring programme in the Kamuzu Dam I and II reservoirs (see monitoring plan for guidelines).	Operation	Lilongwe Water Board	2,000,000 MWK [Monitoring equipment for LWB]; 2,000,000 MK [Pre-construction/ construction]; 700,000 MK/year [Operation; additional to current LWB monitoring programme)
Terrestrial and Aquatic Ecology	– Habitat alteration/destruction – Habitat contamination – Loss of terrestrial habitats – Aquatic habitat alteration – Proliferation of invasive species	Promote and disseminate more efficient methods of cultivation and less demanding crop varieties in order to increase agricultural production through optimization of the employed techniques rather than through an expansion of cultivated areas.	Operation	Lilongwe Water Board, in articulation with the Land Resources and Soil Conservation Department, College of Agriculture, Chitedze Research Station and local authorities and village leaders	400.000 MWK
		Raise awareness among the local communities on sustainable resource utilization, in order to enhance forestry management.	Operation	Lilongwe Water Board, in articulation with Department of Forestry and local authorities and village leaders	
		Protection of sensitive areas from grazing, biomass extraction and cultivation.	Operation	Lilongwe Water Board	150.000 MWK
		Clear reservoir of aquatic vegetation and reduce nutrient inflow to the water body to prevent eutrophication.	Operation	Lilongwe Water Board	1,500,000 MWK/year
		Regulation of fishing activities on the reservoir in order to assure sustainable fisheries; raise public awareness on the role of exotic species in the depletion of native fishes and habitat degradation.	Operation	Lilongwe Water Board, in articulation with local authorities and village leaders	750.000 MWK



Activity	Environmental Impacts	Mitigation/ Enhancement Measure	Time Target/ Period for implementation	Institution / Persons responsible for implementation of the mitigation measures	Estimated cost
Socioeconomics and Public health	– Loss of buildings and other structures – Loss of agricultural land – Loss of crops – Creation of employment – Increased water management and supply capability	• Resettlement and compensation should be closely monitored during their implementation and for at least the first year after its completion, in order to accommodate eventual adjustments.	Operation	Lilongwe Water Board, in articulation with local authorities and village leaders and other concerned entities	<i>To be defined on the Resettlement Action Plan</i>
		• Provision of social protection and assistance to resettled families and vulnerable people's groups.	Operation	Lilongwe Water Board; Social and health authorities and Social NGOs should be involved	
		• Preference should be given to recruit local people for job positions necessary in the operation phase (management, maintenance, surveillance, etc.), especially the ones whose jobs may have been affected during construction. Equal job opportunities should be given to men and women.	Operation	Lilongwe Water Board	Not applicable
		• For operation and maintenance outsourcing needs, preference should be given to legally established local suppliers and contractors (legal permits for conducting the proposed activities should always be checked before acceptance).	Operation	Lilongwe Water Board	



7.1.5. Occupational Health and Safety

Occupational Health and Safety deals with the welfare of workers in the workplace, through a strong component in hazard prevention. Sometimes workers are exposed to risk factors; those risks may lead to cancers, accidents, musculoskeletal diseases, respiratory diseases, hearing loss, circulatory diseases, stress related disorders, communicable diseases and others (WHO, 2015). Some of these risk situations were identified and handled in this section.

Construction workers spend much time on elevated structures above the ground. Falling from temporary structures is one of the most common causes of injuries in construction sites. To avoid this risk, regular maintenance and training of workers is required. Daily checks of weather conditions is also advised in order to prevent accidents caused by strong winds or heavy rains, which often disrupt temporary structures.

Falling objects from higher levels can cause severe injuries to the workers below. To avoid this, construction safety hats must be used by all employees at all times and regular equipment check-ups should be performed.

Accidents with heavy machinery may cause serious injuries and in some cases the loss of limbs or even death. Cranes, for example, represent one of the equipments that when handled incorrectly leads to serious accidents. Adequate safety training for workers, in particular heavy machinery operators, restraining the work area and ensuring a suitable ground area is imperative to prevent accidents.

Road traffic at a construction site constitutes on its own a danger for the workers. With the increasing volume of vehicles circulating in the yard and lack of defined road structures, extreme caution must be taken and security measures should be considered, such as the implementation of safety signs.

Electrical wires may constitute a danger for construction personnel if they are left exposed and inappropriately located. Wires should be labelled and isolated and should be moved away from busy areas.

Working under extreme conditions may cause exhaustion or dehydration, leading to a lack of focus that may cause various mishaps on the construction site. An adequate diet, with a lot of hydration and an appropriate amount of



sleeping hours can help mitigate these effects. Worker supervision is also very important, in order to timely detect such cases of exhaustion.

With the additional presence of new construction workers also comes a typical increase in the spreading of communicable diseases. Their effects can be constrained with the help of awareness sessions and the distribution of information (such as flyers) alerting to the hazards associated with those diseases. Hiring workers from the project implementation area, in addition to raising local employment, also avoids conflicts and the spreading of diseases between the local population and workers from foreign regions.

Ensuring the safety and welfare of the construction workers requires the implementation of worker training sessions, safety rules and emergency procedures, as well as regular equipment maintenance in order to minimize risks. Further measures and rules can be consulted in the Occupational Safety, Health and Welfare Act (1997) of Malawi.

7.1.6. Waste management plan

7.1.6.1. Introduction

The construction site wastes and building materials must be properly managed and disposed of to reduce the risk of pollution in elements such as soil, ground water and air. Trash disposal, recycling, proper material handling, spill prevention and clean up measures should be adopted as practices to prevent these risks.

Construction yard operation and management will generate several types of residues like metal, wood, used oil, lubricants and other oil derivatives, tyres, plastic, paper and cardboards, glass and organic waste. Construction machinery requires periodical mechanic maintenance, as well as fuel supply. These operations, if performed at construction yard and sites, will generate mainly hazardous waste. In social areas and campsites, residues equated to urban solid waste are also expected.



7.1.6.2. Waste produced in construction works and yard

The project proponent should identify, in an early phase, the residues that construction works and the construction site will produce, for the correct implantation of waste management measures. It would be expect to include the following categories:

- Hydraulic oils and lubricants used in machinery maintenance;
- Packages/wrappers of paper, cardboard, plastic, wood, metal, glass, composite or mixture;
- Package residues contaminated by hazardous substances;
- Contaminated wastes and oil filters;
- Used tyres;
- Metal scrap;
- Lead accumulators;
- Residues of Construction and Demolition:
- Non-contaminated surplus soil and rock (inert material);
- Plant residues;
- Concrete, bricks, ceramic materials and other demolition material;
- Wood, glass and plastic;
- Metals and alloys;
- Solid urban waste mixture and similar.

7.1.6.3. Waste management measures

The correct management and disposal of wastes should be practiced at the construction site to reduce de risks of pollution. The following measures must be applied in the site and explained to all collaborators.

Solid Wastes

- Create a waste collection area on the site;
- The waste collection area should have containers that allow the correct separation of recyclable materials from non-recyclable materials. The following containers to recyclable materials should exist on the site:
 - Package residues container;
 - Glass residues container;



- Paper residues container;
- Plant residues container;
- Aluminium container;
- Guarantee that containers have lids to prevent odours and protect from natural events like rain;
- Schedule waste collection to prevent overfilling the containers;
- Clean up spills immediately after the spill using absorbent materials such as sawdust or kitty litter to contain the spill;
- During demolition phases provide extra containers and schedule more pickups.

Dispose all construction wastes at authorized disposal areas. To perform this the local environmental agency should be contacted.

Hazardous Wastes

- Consult local waste management authorities about the requirements for disposing materials;
- Empty and clean hazardous waste containers before use, to prevent leaks;
- Do not remove the label from hazardous products package because it contains safety information. Following the manufacturer method of disposal is recommended, which is printed on the label;
- Never mix excess products disposing of them, unless specifically recommended by the manufacturer.
- To guarantee proper disposal of contaminated soils, contact local solid waste agencies, private operators or some Landfills that might accept this waste.

Petroleum Products

- Store new and used products in covered areas with berms and dikes to contain any spills;
- Contain and clean up any spill, with absorbent materials.



7.1.6.4. Recommendations

Create a viable waste management system requires promotion of the hazards of improper storage, handling and disposal of wastes among workers. The only way to be sure that waste management practices are being implanted correctly is to be aware of worker habits and to inspect storage areas on a regular basis.

To ensure the correct implementation of waste management system the responsible parties should be nominated and each process must have an identified authority inside the construction area.

To make sure that the wastes are correctly handle inside the yard and that have a correct deposition when they leave the site, local environmental and waste management authorities must be consulted.

Waste management practices are efficient only when they are practiced at the construction site. In storage and use areas post guidelines for proper handling, storage and disposal of wastes. Train workers in these practices to ensure that everyone is knowledgeable enough to participate.



7.2. Environmental and Social Monitoring Plan

One of the major components associated with the ESMP consists in the monitoring and verification of the implementation degree of defined environmental and/or minimization measures as well as their effectiveness. These tasks allow for the identification of occurring deviations, the adoption of necessary corrective measures and prevention of non-compliant occurrences in relation to the environmental performance defined as adequate for the project.

Therefore, recommendations and guidelines should be defined. These are aimed at the management and regular monitoring of the different activities likely to have significant impacts on the environment, either by visual inspections or by using analytical sampling methods. The level of implementation of the mitigation measures established under the EIA and the ESMP should also be monitored, ensuring its full compliance and supported by the monitoring structure (sections 7.1.2 and 7.1.3).

In view of the above, the Environmental and Social Monitoring Plan (ESMoP) set for the raising and rehabilitation of Kamuzu Dam I is presented in the following sections. Included factors for monitoring are:

- Surface water quality;
- Groundwater level and quality monitoring;
- Socio-economics and Health.

The possibility of an ESMoP revision should be safeguarded within the planned monitoring by adjusting the proposed plans or by enabling other monitoring and management arrangements.

Detailed information and specific guidelines for monitoring activities are presented next.



7.2.1. Surface Water Quality Monitoring Plan

7.2.1.1. Introduction

The Project is considered to have several negative impacts on surface water quality in the construction and operation phases, for which mitigation measures were proposed, lowering the significance to an acceptable level. However, monitoring is the only way to confirm these predictions and provide factual information about the post-raising reservoir's water quality.

The Lilongwe Water Board already has a monitoring programme for both Kamuzu dams, the affluent Katete River, and the Lilongwe River itself, with several monitoring sites downstream of KD2 up to the water intakes at Lilongwe City.

Besides impact monitoring for the construction phase this plan aims to upgrade the LWB's current programme, giving the institution a much better control of the raw water quality supplying the city.

Surface water quality monitoring's main objectives are:

- Following the evolution of water quality in Kamuzu Dams I and II in the construction phase;
- Assuring that water users are informed of water suitability for intended uses and alerted when human or livestock health risks exist;
- Adjusting mitigation measures according to surface water quality evolution and changes in water uses;
- Upgrading LWB's current monitoring programme in order to provide adequate monitoring data for an efficient management of the city's raw water supply.

7.2.1.2. Sampling parameters

The tests which are proposed to be performed in surface water quality monitoring are:

- Pre-construction/baseline and Construction phases: Hydrocarbons (mg/l), Oils and greases (mg/l), Lead ($\mu\text{g/l}$), Cadmium ($\mu\text{g/l}$), T ($^{\circ}\text{C}$), pH,



Suspended solids (mg/l), Turbidity (NTU), Electrical conductivity ($\mu\text{S}/\text{cm}$), Total dissolved solids (mg/l), Chlorides (mg/l), Faecal coliforms (counts/100 ml), Dissolved oxygen (mg/l), BOD (mg/l), Nitrates (mg/l), Phosphates (mg/l);

- Operation phase: Lead ($\mu\text{g}/\text{l}$), Cadmium ($\mu\text{g}/\text{l}$), Fe (mg/l), T ($^{\circ}\text{C}$), pH, Suspended solids (mg/l), Turbidity (NTU), Electrical conductivity ($\mu\text{S}/\text{cm}$), Total dissolved solids (mg/l), Hardness (mg/l), Chlorides (mg/l), Faecal coliforms (counts/100 ml), Dissolved oxygen (mg/l), BOD (mg/l), Nitrates (mg/l), Phosphates (mg/l), Chlorophyll-a (mg/l).

The collection of water samples must be accompanied by dam levels or river flow measurements in the sampling sites, if possible.

7.2.1.3. Sampling sites

The monitoring of surface water quality should be performed in current LWB sampling sites in Katete River, Kamuzu Dam I and II (raw water) for both the construction and operation phases. Some additional and/or relocated sites are also proposed, configuring the following scheme:

- For the pre-construction/baseline and construction phases: C1) LWB's Kamuzu Dam I raw water sampling site (at least two depths should be sampled: surface and water intake depth); C2) New sampling site at Kamuzu Dam II's reservoir, 100 m downstream of Malingunde/Kapaninga; C3) LWB's Kamuzu Dam II raw water sampling site (at least two depths should be sampled: surface and water intake depth).
- For the operation phase: O1) Relocate current Katete river sampling site immediately upstream the new FSL, where viable; O2) New sampling site in Lilongwe river, upstream of KD1's reservoir; O3) New intermediate sampling site in the reservoir, where Katete and Lilongwe river channels meet (at least two depths should be sampled: surface and -10m); O4) LWB's Kamuzu Dam I raw water sampling site (at least two depths should be sampled: surface and water intake depth); O5) New sampling site at KD2 reservoir, 100m downstream of Malingunde/Kapaninga; O6)



LWB's Kamuzu Dam II raw water sampling site (at least two depths should be sampled: surface and water intake depth).

7.2.1.4. Sampling frequency

The monitoring programme should be developed along three phases:

- Pre-construction/baseline phase;
- Construction phase;
- Operation phase.

If feasible, during the pre-construction/baseline phase, one sampling should be made in the wet season, coincident with the statistically maximum precipitation period (January-February) and another sampling in the dry season, coincident with the statistically minimum precipitation period (August-October) in order to establish an adequate baseline.

For the Construction phase at least two samples *per year* are recommended to be collected. The number of samples in this phase depends on the exact duration of the Construction phase.

For the Operation phase, sampling is proposed to be made at least twice a year as a general rule, one in the dry season and another in the wet season. For the first two years after the raising's completion three samples *per year* should be collected, two in the dry season and one in the wet season, in order to assess possible impacts from flooding of the new areas.

If significant changes are detected in one sampling parameter the frequency should be increased, e.g. each trimester, until the causes for the water quality changes are assessed and adequate mitigation measures are adopted.

7.2.1.5. Data collection and analysis methods

The methods and analytical techniques to be used should be compatible with specifications in the Water Resources (Water Pollution Control) Regulations (G.N. 31/1978) and in specific standards:



- MS 682-1:2002: Guidance on the design of sampling programmes and sampling techniques;
- MS 682-3:2002: Guidance on the preservation and handling of water samples;
- MS 682-4:2002: Guidance on sampling from lakes, natural and man-made;
- MS 682-6:2002: Guidance on sampling of rivers and streams;
- ISO 19458: Microbiological sampling.

After each sampling campaign a field report should be prepared, with water quality results and sampling conditions.

These results should be compiled and adequately analyzed regarding the Project's impacts, mitigation measures' efficiency and precipitation and river flow conditions in a report due at the end of each year of sampling. Non-compliances should be assessed with the following standards / guidelines for water quality:

- MS 691:2005: Tolerance limits for domestic sewage effluents discharged in land surface waters – specification;
- MS 214:2005: Drinking water – Specification;
- WHO (2011): Guidelines for Drinking-water Quality;
- WHO (2003): Guidelines for safe recreational water environments, Volume 1: Coastal and fresh water.
- FAO (1985): Water Quality for Agriculture.

Additionally, UNESCO's *et al.* (1996) "Water Quality Assessments – A Guide to Use of Biota, Sediments and Water in Environmental Monitoring" recommendations should be considered.

These reports and monitoring data should be considered in assessing the need for changes in the development of the monitoring program, particularly when concerning the number of sampling points and frequency of sampling: whenever required in the Project's lifetime, the monitoring program should be adjusted.



7.2.2. Hydrogeology Monitoring Plan

7.2.2.1. Introduction

Since there is a potential for contamination of soils and afterwards of groundwater due to spillage accidents, especially during construction phase, and also the potential interference with the water table levels, a monitoring procedure of the groundwater's resources potentially affected by the project is recommended.

The goal of monitoring groundwater is to follow the evolution of the water table levels and the quality of local groundwater, in order to support any additional mitigation that might be needed.

The present plan was designed to be applied to the pre-construction, construction and operation phases.

The following sections describe the proposed groundwater monitoring procedures.

7.2.2.2. Sampling stations and monitoring parameters

Groundwater should be sampled at existent wells and boreholes or, in areas where these do not exist, through the construction of specific piezometers. Sampling should be done in an area around the Kamuzu Dam I (downstream and immediately upstream) and for this purpose the boreholes and wells identified in Figure 180 should be considered.

The following parameters should be analysed in groundwater samples:

- Chemical components: CO_3 ; HCO_3 ; Cl; SO_4 ; NO_3 ; F; Na; K; Ca; Mg; Fe; Cu; Zn; Pb; Cd; Cr; PAHs (polycyclic aromatic hydrocarbons); oils and fats;
- Physicochemical parameters: pH; temperature; colour; electric conductivity; turbidity;
- Microbiological parameters: total coliforms; faecal (thermotolerant coliforms); faecal *Streptococci*; Sulphite reducing *Clostridia*; Colony counts.



The parameters above represent the essential parameters. However, monitoring parameters on groundwater should firstly follow the Malawian Standards, specifically those referred in MS214: Drinking water – specifications and MS733: Borehole and shallow wells – specifications.

The collection of samples should also be accompanied by the measurement of the static water level.

While chemical, physicochemical and biological parameters should be determined in groundwater samples collected in an area similar to that of Figure 180, static water levels should be recorded in a wider area (~2 km² with the central point in the Kamuzu Dam I) in order to infer a more accurate water table surface.

7.2.2.3. Sampling frequency

The monitoring program should occur throughout three distinct phases:

- Pre-construction phase
- Construction phase
- Operational phase

The first monitoring campaign, to be made before the beginning of the construction, aims to define baseline conditions. Therefore these results will be particularly important for assessing the evolution of water quality and water levels during the subsequent phases.

Considering that the construction is estimated to last 10 months, a minimum of two campaigns should be done in this phase. Sample collection should be performed by the end of the rainy and dry seasons (end of April and September, respectively).

In the first year of the operation phase one sampling campaign should be made by the end of the rainy season. However, if the results show a drastic change of any parameter, the monitoring campaign should continue until the cause for that change is determined.



7.2.2.4. Material and methods

The methods and analytical techniques to be used in testing of groundwater quality should be compatible with specifications from the Water Resources (Water Pollution Control) Regulations (G.N. 31/1978) and from specific standards:

- MS 214: Drinking water – Specification;
- MS 678: Drinking water quality – Control and surveillance of water in public supply networks;
- MS 733:2005 – Borehole and shallow well water quality - specifications;
- MS 682-18, Water quality — Sampling — Part 18: Guidance on sampling of groundwater at contaminated sites;
- ISO 19458, Water quality — Sampling for microbiological analysis;
- MS 675: Water quality – Physical methods of test;
- MS 676: Water quality – Chemical methods of test;
- MS 677: Water quality – Microbiological methods.

7.2.2.5. Outcomes from the monitoring programme

The results obtained through the different campaigns should be analysed, interpreted and resumed in reports. As such, the data acquired during the monitoring program should always consider previous data allowing the progress assessment of groundwater conditions throughout the project.

In case of groundwater quality problems or even important changes in groundwater flows due to the project, solutions for improving water quality and/or for optimising the project (e.g. relocation of a given borehole) should be studied.



7.2.3. Socio-Economics and Health Monitoring Plan

7.2.3.1. Introduction

According to the previously carried out impact assessment, this subchapter presents recommendations for socio-economic and health management and monitoring. The recommendations focus on the major predicted impacts (loss of land, crops and houses, employment opportunities and health risks).

7.2.3.2. Pre-construction/ Construction phase

Due to the consequences on the livelihood of local households and farmers directly affected by the project (loss of land, loss of crops and loss of houses), it is necessary to carry out monitoring actions of the compensation and resettlement process, in accordance with the Compensation and Resettlement Action Plan to be prepared, ensuring that compensations were effective and no risk (of food privation or severe impoverishment) situations are identified along the affected community. The Compensation and Resettlement Process should start before the beginning of the construction works, thus minimizing the exposure of the affected population at the time the water reservoir rises, and should progress through the operation phase.

The number of complaints from local people, either about compensation, resettlement or about construction activities, should also be an indicator to monitor, as well as the resulting resolutions. A record should be kept for each complaint, stating the author, reasons of complaint, allocated resources, responsibility and deadline to solve it, the adopted final solution and verification of effectiveness, communication to complainer, among other issues.

The number of local people employed at the project construction as well as local suppliers and contractors used in the construction stage, will be other important indicators to monitor, in order to measure positive impacts.



Still at the construction stage, considering the importance of diseases arising from temporary migrant influx, particularly sexually transmitted infections and HIV/AIDS, regular health screening actions are recommended. The contractor should therefore perform quarterly monitoring, during the time predicted for construction, of the number of cases of the following diseases among workers: Malaria; Bilharzia; Cholera; Diarrhoea; STI's and HIV/AIDS.

Data on the incidence of these same diseases in Lilongwe City and Lilongwe Rural should be collected from the local health authorities, in order to correlate the results. Reports should be prepared and submitted to the Lilongwe Water Board and local health authorities, stating detected cases among workers and/or local population.

In the specific case of HIV/AIDS the relationship between the evolution of the number of cases on workers and local population and the degree of implementation and effectiveness of recommended awareness actions should be assessed in the reports. Additional measures should be defined in the reports and immediate action should be taken in terms of sanitation, health and/or HIV/AIDS prevention scheme, if monitoring results show unacceptable levels of disease incidence.

7.2.3.3. Operation phase

Due to the possible long-term consequences on the livelihood of local households and farmers directly affected by the project, it becomes necessary to extend monitoring of compensation and resettlement process to the operation phase, at least during the six to twelve months after actions are concluded.

Detailed monitoring actions and responsibilities will be drawn on the Compensation and Resettlement Action Plan.

Improvement of housing hygiene, concerning access to water and sanitation, as well as improvement of road conditions and other collective compensations, if not provided on short-term and during the construction phase, should be demanded and monitored during the operation phase, at the scope of the Resettlement Action Plan, seeking effective benefits and compensations on-site from the implemented project.



8. Conclusions and Recommendations

The ESIA begins with a project revision (Chapter 2) of the three initial options considered on the preliminary design stage (Aurecon, 2013a). Latter on the ESIA's preparation process a fourth project option (Option E) was included as result of the initial work of the assigned Detail Design Consultant (SMEC, 2015), as described in section 2.2.10. General description was followed by the legislative and regulatory framework (Chapter 4) and by the compilation of available bibliographic research, map information and field surveys in order to achieve a baseline situation of the study area (Chapter 5 and Appendices).

Subsequently, the project's environmental and social likely impacts were identified, justified and assessed by a team of specialists according to pre-defined evaluation criteria (Chapter 6). Mitigation and monitoring needs were then listed and extensive Environmental and Social Management and Monitoring Plans were prepared (Chapter 0).

From all the developed work, global conclusions point out to limited negative impacts from Kamuzu Dam I's raising and rehabilitation, most of whom can be adequately mitigated by the recommended measures, with highlight to the development and rigorous implementation of a thorough Resettlement and Compensation Action Plan. On the other hand, the project will generate several important positive impacts, mainly on the socio-economic sphere, actively contributing to a general development of the region, and more specifically to an improved water management and water supply capability.

Overall, between the three initial alternatives Option 1/A is assessed as the most favourable project alternative, pondering all environmental and social impacts and after mitigation, compensation and enhancement measures effects are accounted for. On the other hand, Option 2/B has the highest negative effects, especially regarding the loss of agricultural and social assets.

Preferred project Option E presents itself as the most favourable solution regarding technical and economic viability, providing additional benefits when compared to the three alternatives, namely:

- lowest estimated cost;
- simplest construction;



- improved hydraulic conditions;
- 100% local supply;
- low foundation demands;
- low durability and maintenance demands; and
- simplified contractual arrangements.

In the environmental and local resources' issues it is expected to assume an intermediate positioning considering all options. Assuming that the 100-year estimates (SMEC, 2015) for each of the now four project options, determines the extension of territorial impacts of the dam's raising, Options 1/A and 3/C are the most favourable options and Option 2/B the option with more extensive impacts. The difference in assessment of permanent impacts to Option E is however not determinant for choosing one against the other. Although all project options can potentially achieve a similar positive net result in terms of environmental and social viability, there's an economic and social cost that will weigh in on the least favourable options, with increased risks of disrupting and negatively influencing local populations.

With the proper implementation of all the recommended measures, the proposed development, in the configuration of the technical and economic preferred Project Option E, is environmentally and socially viable. In fact, this ESIA anticipates that in those conditions the project may result in an overall environmental benefit.

However, construction in fragile environments such as riverbanks and nearby human settlements will implicate proper adherence to good environmental management and working practices and further highlights the need to strictly enforce the recommended measures in order to avoid disruptions and to support the overall ESIA conclusions. Also and with special regard, the losses originated by the increased water reservoir of the dam must be properly compensated and resettled, ensuring that the affected populations regain similar or even improved conditions.

The increased capacity of the Dam, in order to meet growing demand and pressure from Lilongwe City's water supply system, is undoubtedly a very important beneficial impact in the medium-term, and on which will definitely occur during the project's operation phase. However, in order to promote social equity, the project should also contribute in some way to improving water supply



(or other commodities) to villages nearby and upstream of the Kamuzu Dam I, widening the impact's significance (see enhancement measures, Table 123).

As final considerations, some key recommendations are highlighted to ensure an adequate provision and validity of the achieved global conclusions:

- The detail project design and the decision on the preferred project option should assume as a key dimensioning factor the minimization as feasible as possible of the non-overspill crest. That is, project design should limit as much as possible the maximum water level of the dam and the subsequent impacts on the soil, habitats, agricultural land, houses and other infrastructures' losses.
- Detail project design should prevent/minimise as technically feasible the impact over local population's houses, assets, as well as other private owners and public and communal infrastructures, especially regarding embankments design, topographic/terrain modelling, necessary work areas, construction methods, specific design measures for some affected structures (walls or small embankments)
- Perform a thorough inventory of the wells and boreholes directly affected by the project, ensuring their replacement.
- Villages surrounding KD1 should benefit in some extent from the new reservoir that will flood part of their land. Thus, if feasible, the project should incorporate provisions for some kind of water supply facilities (irrigation, drinking), in order to compensate for permanent losses. These proposals should first be discussed with local village leaders.
- As a preventive measure, deforestation of the new area to be flooded shall be done. Deforestation Regulatory Procedures should be developed, including:
 - Clearance of the field demarcation of the new FSL at 1,105 masl for authorised and regulated collection and clearance of vegetation and wood by local population;
 - All trees or bushes taller than knee-high should be cleared;



- A fair and clear set of rules should be negotiated with local traditional authorities in order to define roles and responsibilities, as well as which areas to assign to each village, timber quotas, timings and restrictions, amongst other issues. Timber is a quite valuable resource and thus could be seen as part of the compensation for the flooded land;
 - Strict regulation and field control of tree clearance by local communities should be enforced;
 - In order to mitigate possible secondary impacts on soil erosion and ecology, deforestation should be performed as close to the programmed date for the construction's finish as possible, outside of the main breeding season of the dry season (June to November).
- Fair compensation and resettlement shall be provided to cases that cannot be avoided, under the guidelines of the Compensation and Resettlement Action Plan that will define compensation and resettlement measures for the affected land, socio-economical activities, housing and other household assets. Assistance and monitoring should also be ensured throughout the process.
 - Roads and bridges included within the designed maximum water level must be timely replaced to assure the connection between territories and margins. If not feasible, alternative road accesses must be planned and provided, without worsening the villages' accessibility and mobility.
 - Prior to inundation, archaeological excavations should be allowed. The need for rescue archaeology at other sites will depend on the exact determination of the inundation area and further testing of the site's significance (through digging of test pits).
 - Enforce the maintenance and control of protection buffer zones around the reservoir (General Mitigation Measure for the Operation Phase):
 - Zone 1: FSL to 15 m beyond estimated 100-year floodline (SMEC, 2015) – no activities should be allowed within the protection buffer zone unless they are for conservation (riparian and protective vegetation);



- Zone 2: beyond the 15 m protection buffer zone – agriculture, settlements, wastewater infrastructures and other development activities can only be placed 15 m further away from the estimated 100-year floodline.
- Implement a riparian and protective vegetation buffer within Zone 1 and demarking it, using soil bioengineering techniques, in order to prevent riverbank erosion and water quality degradation. Recommendations on section 6.3.2 of the ESIA Report
- It is recommended that urgent preventive land use measures should be taken to avoid or stop encroachment within the study area, especially around KD1's site. Land uses should be closely monitored by the Lilongwe Water Board and some kind of legal measures should be considered to prohibit or at least control new developments in this area.
- The Environmental and Social Management Plan (ESMP), defined in the present ESIA shall be integrated as part of the Terms of Reference (ToR) for the construction's bidding process. The developer and the contractor shall thereby be contractually obliged by the ESMP to implement all the identified mitigation and monitoring measures according to the planned schedule.



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Appendix I – Maps



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(see attached Map 1 – Administrative framework)



(see attached Map 2 – Estimation of current and future full supply levels)



(see attached Map 3 – Elevation map)



(see attached Map 4 – Slope map)



(see attached Map 5 – Geology and Hydrogeology)



(see attached Map 6 – Surface Water Resources)



(see attached Map 7 – Habitats Map)



(see attached Map 8 – Project Option E)



Appendix 2 – Sedimentation and Water Quality Modelling



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I. Introduction

Concerning the raising of Kamuzu Dam I, a set of models were developed and implemented specifically to:

- study the evolution of sedimentation in the reservoir for the next 15 years and;
- evaluate the impact of removing or not the vegetation from the areas that are going to be flooded due to the dam's raising. The following sections describe the models used, the implementation, including data sources used and the results obtained.



2. Water Balance

Water balances were calculated using the following equation:

$$Q_{\text{inm}} + Q_{\text{inu}} + \text{Prec} = V_{\text{dif}} + Q_{\text{outu}} + \text{Evap}$$

where:

- Q_{inm} is the total discharge measured in inlets;
- Prec and Evap are monthly evaporation and precipitation obtained from meteorological stations situated in the vicinity of the reservoir (Kamuzu Dam II station);
- V_{dif} is the monthly variation in reservoir volume;
- Q_{inu} and Q_{outu} are the unmeasured input from the catchment without stream inlet and the output from the reservoir, respectively.

The net value of Q_{outu} and Q_{inu} was determined monthly by adjusting the water balance, if $V_{\text{dif}} > Q_{\text{inm}} + \text{Prec}$, then Q_{inu} equals to the difference; otherwise, Q_{outu} is equal to the difference.

Measured inflow is the monthly average from Aurecon (2013b), while V_{dif} , Precipitation and Evaporation is the monthly average calculated from data measured at Kamuzu Dam II station.



3. Sediments

Reservoir sedimentation is the process of sediment deposition into a lake formed after a dam construction. A dam causes reduction in flow velocity and consequently the turbulence, which causes the settling process of the materials carried by the rivers. There are many causes of reservoir sedimentation; however, watershed, sediment and river characteristics are the main natural contributing factors. The dominant factors that influence the rate of silting in a reservoir are: (a) Capacity to Inflow Ratio (C/I), (b) sediment content in the water flowing in, (c) texture and size of the sediment, (d) trap efficiency (T_e) of the reservoir, and (e) the method of reservoir operation (Arora and Goel, 1994). Some reservoirs are filled very rapidly, while others are hardly affected by sedimentation.

Methods to predict reservoir sedimentation have been the subject of several empirical studies since the 1950's. Prediction of reservoir useful lifetime is the final target of all reservoir designers making the issue as an important subject within hydraulic research (Lagwankar *et al.* 1994). Most of the empirical methods considered T_e as the important parameter for estimating sedimentation in reservoirs.

3.1. Trap efficiency estimation

Heinemann (1981) considered the T_e to be the most informative descriptor for reservoir sedimentation estimation. T_e is the proportion of the incoming sediment that is deposited or trapped in a reservoir and is often expressed in percentage as given in eq. 1.

$$T = \frac{V_i - V_o}{V_i} \times 100\%$$

where, V_i is the inflowing sediment load and V_o is the outflow sediment load. The T_e , even though it is estimated from inflow and outflow of sediment actually T_e is dependent on several parameters, including sediment size, distribution; the time and rate of water inflow to the reservoir; the reservoir size and shape; the location of the outlet structure and water discharge schedules (Morris and Fan, 1998; Verstraeten and Poesen, 2000; Campos, 2001; Yang, 2003).



Many empirical studies (Brown, 1944; Churchill, 1948; Brune, 1953; Borland, 1971; Dendy, 1974; Gill, 1979; Heinemann, 1981) showing the relation between reservoir storage capacity, water inflow and T_e have been conducted.

The Brune (1953) is probably the most widely used method for estimating sediment retention in reservoirs. Brune (1953) curves were drawn based on data from 44 normal ponded reservoirs in the United States. Brune (1953) plotted the T_e against the reservoir C/I . The Brune (1953) graph is composed of three curves, one median and two envelop ones.

Borland (1971) added the data from desilting basins and semi-dry reservoirs to Churchill's curve and concluded that there was good correlation between observed data and Churchill's curves.

A comparison between the Churchill (1948) and the Brune (1953) was made by Trimble and Carey (1990) for 27 reservoirs in the Tennessee River Basin. The sediment yield was calculated based on the two T_e curves and sediment accumulation data for these reservoirs. The estimated T_e values according to Brune (1953) were estimated equal to or higher than the T_e values according to Churchill (1948), but, in general, the two values were similar (Trimble and Carey, 1990). It was concluded that, for a system of reservoirs, the Churchill method, which accounts for sediment received from an upstream reservoir, provides a more realistic estimate of sediment yields than the Brune method.

Bube and Trimble (1986) used the original data of Churchill (1948) and those added by Borland (1971) to revise the curves proposed by Churchill (1948). Trimble and Bube (1990) revised these curves again by decreasing the variance of the local sediment yields as calculated by these curves through the use of an optimization technique. Although the use of the Churchill curves may give a better prediction of T_e than the Brune curves, it is very difficult to obtain the input data for calculating the sedimentation index. This is probably the reason why Brune's approach is used so extensively as opposed to that of Churchill. Especially for small dry or semi-dry reservoirs where the outlet is located at the bottom of the embankment, it is very difficult to calculate these data as these outlets only operate during infrequent, short-lasting events (Dendy, 1974).



There are a few studies that have attempted to compare the different empirical models discussed above for selected reservoirs and storm events. Rowan *et al.* (1995) indicated that, for one reservoir, the prediction of T_e according to Heinemann (1981) was 30% lower than according to Brown (1944), with Brune (1953) in between the two. For two water supply reservoirs in the southern Pennines (UK), Butcher *et al.* (1992a,b) measured the in- and outflowing sediment for four and five storm events, respectively. A comparative study was carried out between the measured T_e and the T_e predicted by Brown (1943), Churchill (1948), Brune (1953) and Heinemann (1981). Although there is not much difference between the selected models, it was concluded that the Brown (1944) curves are the most appropriate. This is reasonable because the reservoirs had the same hydrologic regime as the ones Brown used in his study. The Brown curves are, of course, the simplest to use, certainly when runoff data is lacking. On other hand, Soler-López (2003a) used Brune (1953) method for estimating T_e of Lago El Guineo and Soler-López (2003b) for Lago Guayabal, Puerto Rico. Siyam *et al.* (2005) compared the trap efficiencies of the five reservoirs (Koka, Roseiris, Girba, Angerib, Nasir) on Nile River using this approach. Gill (1979) developed empirical equations (eqs. 2-4) which provided a very close fit to the three curves proposed by Brune.

3.2. Useful life estimation

The period up to which the reservoir can serve the defined purpose is called usable life, the period after which the cost of operating the reservoir exceeds the additional benefits expected from its continuation is called economic life, design life is generally the useful life, full life period is that when no capacity is available in the reservoir for useful purpose (Murthy, 1980; Kulkarni *et al.* 1994). Useful life is the period during which the sediment collected does not affect the intended primary use of the reservoir (Arora and Goel, 1994; Kulkarni *et al.* 1994, Agrawal and Singh, 1994). In most of the developed countries full life is said to be reached when half of the total capacity of reservoir is depleted. While in case of Trinity River basin reservoirs (Texas), it was considered as the period when the useful storage would be completely destroyed (Arora and Goel, 1994). Useful life is an important design parameter of a reservoir which may affect the economic feasibility and sustainability of a water resources project (Gill, 1979).



A direct method for useful life estimation of a reservoir was proposed by Gill (1979) which correlates the reservoir capacity with age in years algebraically. With the relationship between sedimentation rates, T_e , specific weight of sediment deposited, the storage available after sedimentation for a given period Δt was estimated using the following equation:

$$C_0 - C = \frac{G \times T_e \times \Delta t}{\bar{\gamma}}$$

where, C_0 is the initial capacity of reservoir; C , is reduced capacity of reservoir at any time t ; G , is characteristic weight of annual sediment inflow; Δt is a short interval of time in years in which capacity is reduced from C_0 to C ; and γ is specific weight of sediment deposited.

3.3. Specific weight of sediment deposited

The above Gill (1979) approach has the following drawbacks: (i) it assumed a constant specific weight of sediment deposit, however the specific weight may increase with time due to consolidation which occurs when fresh sediment gets deposited over the old deposited sediment and (ii) the T_e approach does not take into consideration the location of sedimentation, but only gives the quantity of sediment deposited anywhere inside the reservoir. To account for the increase in specific weight of sediments Lane and Koelzer (1953) suggested a widely used formula with time (Yang, 1996).

$$\gamma = \gamma_1 + B * \ln(t)$$

where γ is the specific weight of sediments at an age of t years; γ_1 is specific weight at the end of 1 year; and B is a constant with dimensions of specific weight. Lane and Koelzer (1953) have also given the values of γ_1 and B for different degree of submergence of sediments of different sizes as shown in Table 1.



Table 1 – Values of γ_1 in kg m^{-3} and B for estimating specific weight of reservoir sediments

Reservoir Operation	Sand		Silt		Clay	
	γ_1	B	γ_1	B	γ_1	B
Sediment always submerged or nearly submerged	1550	0	1120	91	416	256
Normally a moderate reservoir drawdown	1550	0	1140	29	561	135
Normally considerable reservoir drawdown	1550	0	1150	0	641	0
Reservoir normally empty	1550	0	1170	0	961	0

Sediments coming to the reservoir are usually mixture of sand, silt and clay in different proportion. The specific weight of this sediment mixture can be determined by adding the fractional weights of sand, silt and clay. Substituting the values of γ_1 , B and t in the above equation, specific weight at the end of t years can be calculated.

3.4. Application and results

The model was applied in two stages. The first stage aims to evaluate the performance of the model. It is known that the sediment accumulation ratio between 1986 and 2001 was about 40 thousand of cubic meters per year, resulting in a loss of capacity of about 0.6 millions of cubic meters (Aurecon, 2013a). The results obtained with the model are summarized in Table 2 (see also Figure 1) and show a considerable agreement with the available estimates. In particular the accumulated sedimentation between 1986 and 2001 was estimated by the model to be 0.558 millions of cubic meters, a value very close to the 0.6 millions of cubic meters observed. The yearly sedimentation rates, range from 31.3 and 42.3 thousand of cubic meters per year, also in agreement with the known mean value of 40 thousand of cubic meters per year.



Table 2 – Accumulated sediment results obtained with the model for the period 1986-2011

Year	Inflow ($10^6 \text{ m}^3 \text{ yr}^{-1}$)	C/I Ratio	Trap Efficiency (%)	Capacity (10^6 m^3)	Sediment Volume ($10^3 \text{ m}^3 \text{ yr}^{-1}$)	Accumulated Sediment (10^3 m^3)
1986	105.69	0.05	0.94	5.06	42.27	42.27
1987	46.65	0.11	0.98	5.02	39.45	81.71
1988	214.86	0.02	0.86	4.98	33.88	115.59
1989	132.08	0.04	0.92	4.95	35.47	151.06
1990	62.32	0.08	0.97	4.91	36.61	187.67
1991	44.73	0.11	0.98	4.88	36.50	224.17
1992	131.42	0.04	0.92	4.84	33.96	258.14
1993	111.99	0.04	0.93	4.81	34.09	292.23
1994	29.1	0.16	0.98	4.77	35.70	327.93
1995	115.55	0.04	0.93	4.74	33.38	361.31
1996	117.17	0.04	0.93	4.71	33.07	394.37
1997	174.6	0.03	0.88	4.67	31.28	425.66
1998	141.99	0.03	0.91	4.64	31.94	457.60
1999	63.07	0.07	0.96	4.61	33.72	491.31
2000	84.26	0.05	0.95	4.58	33.02	524.33
2001	65.27	0.07	0.96	4.54	33.29	557.62
2002	230.42	0.02	0.83	4.51	28.67	586.28
2003	53.39	0.08	0.97	4.48	33.24	619.52
2004	80.11	0.06	0.95	4.45	32.45	651.97
2005	67.57	0.07	0.96	4.42	32.61	684.58
2006	104.07	0.04	0.93	4.38	31.56	716.13
2007	153.48	0.03	0.89	4.35	30.08	746.21
2008	126.66	0.03	0.91	4.32	30.69	776.90
2009	130.81	0.03	0.91	4.29	30.45	807.34
2010	81.25	0.05	0.95	4.26	31.64	838.98
2011	76.79	0.06	0.95	4.23	31.64	870.62

On a second stage the model was run for a period that extends until 2030, assuming that raising will be ready by the end of 2015. Results are compared with a model run for the same period without considering the dam's raising. When extending the runs forward to 2011, inflow data is not available. We can always assume that a particular distribution of flow rates will occur in the future and the results obtained will be representative of that scenario.



Another way is to perform a set of simulations where the distribution of flow rates into the future is chosen randomly from the data set available. In this case we have an ensemble of simulations and the result presented is the year average of the ensemble.

The results show a consistent decreasing in sedimentation rate related with the progressive reduction of the Capacity/Inflow ratio. The sedimentation by 2030 would be around 30 thousand $\text{m}^3 \text{yr}^{-1}$ for the case of no raising and slightly higher when the raising is considered (due to a larger Capacity/Inflow ratio) – See Figure 2 and Figure 3.

The useful life of the reservoir would be larger than 100 years but it should be noted that this type of models does not take into account the spatial distribution of sedimentation. It is also shown that the capacity of the reservoir would be smaller than 4 million of m^3 by 2030 if raising is not considered, that is to say, the capacity would be reduced by about 33% relative to its initial value.



4. Dissolved Oxygen

The dissolved oxygen model consists of a mass balance equation coupled to a thermal model (see Rucinsky *et al.*, 2010). The system of equations was solved numerically using an Euler integration scheme. The mass balance for the n th layer is:

$$\frac{\partial DO_n}{\partial t} = -WCOD_n + \frac{E_{n-1,n}A_n}{zV_n}(DO_{n-1} - DO_n) + \frac{E_{n+1,n}A_n}{zV_n}(DO_{n+1} - DO_n) - SOD_n$$

Where,

DO_n is the dissolved oxygen (mg L^{-1}) in model layer n , $WCOD_n$ is the water column oxygen demand ($\text{mg L}^{-1} \text{ d}^{-1}$) in model layer n , SOD is the sediment oxygen demand ($\text{g m}^{-2} \text{ d}^{-1}$) in bottom layer, $E_{n-1,n}$ is the turbulent dispersion coefficient ($\text{m}^2 \text{ s}^{-1}$) across the interface between layer $n-1$ and layer n , A_n is the interfacial area (m^2) of model layer n , V_n is the volume of model layer n and z is the thickness of model layer n .

The model computes vertical profiles of dissolved oxygen on an hourly basis and operates at the same vertical scale as the thermal model. Mixing rates between layers and temperature profiles were transferred from the thermal model each time-step. A first-order, temperature-corrected deoxygenation rate, termed water column oxygen demand ($WCOD$), was applied to each layer to represent bulk oxygen dynamics (i.e., a combination of photosynthesis, respiration, decomposition, etc.). This rate can vary among layers depending on the light, temperature, nutrient, and other conditions that can affect the oxygen dynamics. The well-mixed epilimnion is strongly impacted by the boundary condition at the surface, thus we only applied the $WCOD$ below the thermocline, where respiration > photosynthesis. Additionally, a temporally constant areal flux is applied to the bottom segment, representing sediment oxygen demand (SOD).

The temperature correction to the $WCOD$ term is illustrated below.

$$WCOD(T) = WCOD(20^\circ\text{C})\theta^{T-20}$$



Where, $WCOD(T)$ is the water column oxygen demand at temperature T , $WCOD(20^{\circ}\text{C})$ is the water column oxygen demand at temperature $T=20^{\circ}\text{C}$, θ is the temperature correction coefficient (1.04) and T is the temperature ($^{\circ}\text{C}$).

The thermal model used is a 1D vertical model based on the two-equation Mellor-Yamada turbulence model which provides the necessary input of temperature and diffusivity to the oxygen model.

4.1. Application and results

The main causes for oxygen depletion are consumption by respiration on the water column and by organic matter decomposition near the bottom. We are interested in future conditions considering two different scenarios for dam raising:

- organic matter is removed in new flooded areas and;
- organic matter is not removed.

In both situations the new flooded areas will be very shallow and therefore under the influence of surface boundary conditions (reaeration). As it is not expected that the reservoir presents a very strong stratification in the upper layers (say 5 m), it is not likely that oxygen depletion occurs in these areas.

However, if the organic matter near the bottom is increased, more nutrients will be available in the water column and therefore an increase in primary production might be expected. Due to horizontal transport it is likely that part of this recycled organic matter will sediment in the deeper areas of the reservoir.

This is to say that the process of recycling organic matter, originally deposited in the new flooded shallow areas, might provide a way to transfer this organic matter to the deeper parts of the reservoir. In these areas, depths are larger than 10 m and the effect of the surface reaeration would be much smaller. Therefore the 1D vertical model is implemented in the deeper part of the reservoir, since it represents the worst possible scenario.



The inputs for the 1D vertical model are: temperature profiles (provided by the coupled thermal model), diffusivity profiles (provided by the coupled thermal model), interfacial area and volume of each layer (estimated from DTM generated from newly-available SRTM 1 Arc Second Global data), water column (*WCOD*) and sediment oxygen (*SOD*) demands, and the surface flux of oxygen from the atmosphere to the water column.

WCOD is generally a calibration parameter of this type of models. For this particular case it is not possible to use it as a calibration parameter since no monitoring data is available. Therefore we have used extreme values of 0.001 and 1 mg L⁻¹ d⁻¹ to evaluate the sensitivity of the model. The lower value would represent a situation where the amount of organic matter in the water column is low (oligotrophic reservoir) and the higher value an eutrophic reservoir.

SOD is another calibration parameter for the model. It represents the oxygen consumption in the bottom layer. Again little information is available for this parameter. Table 3 presents a set of observed values of *SOD* in different lakes/reservoirs around the World. We also used extreme values to represent an oligotrophic lake and a eutrophic lake – minimum value used is 0.06 g m⁻² d⁻¹ and maximum 4.5 g m⁻² d⁻¹. Surface boundary conditions for the model is imposed by setting the surface value of dissolved oxygen to 10 mgL⁻¹.

Table 3 – Values of *SOD* observed in some lakes/reservoirs around the world

Location/Country	<i>SOD</i> (g m ⁻² d ⁻¹)	Reference
Lake Ton-Ton/Uruguay	0.90~1.74	Sommaruga (1991)
Pine Creek Lake/Oklahoma	1.73~4.46	Veenstra and Nolen (1991)
Pat Mayse Lake/Texas	1.86~9.02	Veenstra and Nolen (1991)
Lake Texoma/Texas and Oklahoma	1.03~2.90	Veenstra and Nolen (1991)
Tidal Creeks, NC/USA	0~9.3	MacPherson et al. (2007)
Millstone River, NJ/USA	0.5~2.5	Miskewitz et al. (2010)
Kranji Reservoir/Singapore	1.4~3.3	Gin and Gopalakrishnan (2010)
Yuan-Yang Lake/Taiwan	0.06~4.50	Chen et al. (2012)

The turbulence model also needs initial and boundary conditions. For initial condition we assumed a uniform profile for temperature. Instead of typical heat fluxes, the surface boundary condition is imposed by setting the top layer temperature to the monthly mean value observed at Kamuzu Dam II (meteo



station data provided by LWB). Wind field and correspondent windstress was obtained from data measured at Lilongwe International Airport Station (available through the World Meteorological Organisation website). Monthly mean values were computed from available information.

The model was run initially for periods of 1 year to study the sensitivity to *WCOD* and *SOD* parameters. Combinations of extreme values previously mentioned were adopted. The combination of the lowest values of *WCOD* and *SOD* would represent a situation close to the present one. From available data Kamuzu Dam I is expected to be an oligotrophic lake, since the loads of nutrients are relatively small and the concentrations of nutrients both in Kamuzu I and Kamuzu II are moderate – NO_3 concentration is in average around 1.0 mL^{-1} according to data provided by LWB. It would also represent a future scenario, after raising without organic matter in the bottom layers. On the other hand, the combination of highest values would represent an eutrophic lake originated by the raising without removal of organic matter. The model is very sensitive to *WCOD*, particularly in the hypolimnion. The response to the variation of *SOD* is restricted to the bottom layer – See Figure 4 and Figure 5.

The model is then run for 10 years (say 2015 to 2025) using three different parameterizations of *WCOD* and *SOD* and considering the raising of the dam:

- Using low values of *WCOD* and *SOD* (0.001 and $1 \text{ mgL}^{-1} \text{ d}^{-1}$ and $0.06 \text{ gm}^{-2} \text{ d}^{-1}$, respectively), which correspond to an oligotrophic lake in a condition close to the present state where it is assumed that vegetation would be removed;
- A second scenario would correspond to extreme values of *WCOD* and *SOD* ($0.8 \text{ mgL}^{-1} \text{ d}^{-1}$ and $4.5 \text{ gm}^{-2} \text{ d}^{-1}$, respectively). In this case we would be considering an eutrophic lake affected by high concentration of organic matter in bottom layers;
- A third scenario was run, considering a moderate effect of vegetation on oxygen demand both in water column and in bottom layers. The values of *WCOD* and *SOD* were ($0.05 \text{ mgL}^{-1} \text{ d}^{-1}$ and $0.6 \text{ gm}^{-2} \text{ d}^{-1}$, respectively).

Like in sediment modelling, the uncertainty about future conditions was taken into account by running an ensemble of simulations where, monthly means of wind and surface temperature, and mean values of *WCOD* and *SOD* were perturbed randomly by 20% (e.g. each moderate simulation considered a value



of $WCOD=0.05 \text{ mgL}^{-1}\text{d}^{-1} \pm 20\%$ for each year). The results presented are daily averages of the ensemble.

A common pattern to all the three simulations is the seasonal cycle seen particularly below the surface layer. In the model the only source of oxygen is the reaeration on the surface layer. The model assumes that, within the epilimnion, respiration is balanced by photosynthesis. On the other hand, within the hypolimnion, respiration exceeds photosynthesis. If the vertical diffusion is effective, then the oxygen injected through the surface layer is mixed and the concentration remains relatively high through the water column. This is typically the winter scenario after the turn-over. However, if vertical diffusion is inhibited because the wind weakens and the radiation forcing increases, which typically happens during the Summer, then below the surface layer, there is only consumption of oxygen and the concentration is reduced. The magnitude of the reduction depends on the consumption: the larger the value of $WCOD$, the smaller the concentration within the hypolimnion and the larger its extension.

The results obtained with the “low consumption” parameterization, that seems to suit the present scenario (Figure 6), shows high concentrations of dissolved oxygen in the upper 6 m. During the winter the high values usually extend further down to depths of 10 m. A strong depletion of oxygen is observed in the bottom layers, especially during the summer when values lower than 2 mgL^{-1} can be observed at 10 m depth. The extension of the hypolimnion is increased when using moderate values of consumption, however a strong depletion is only observed below 10 m deep. In the summer peak, concentrations at 2 m can be as low as 6 mgL^{-1} (Figure 7). The scenario becomes worst when considering high consumptions of oxygen, corresponding to an eutrophic situation. In that case, during the summer peak, severe depletion of oxygen might occur just below the surface (Figure 8). This last scenario would correspond to a strong eutrophication state and it is not likely to occur even if organic matter is not removed before the flooding due to the dam’s raising. It would be eventually achieved if nutrient and organic matter loads from the catchment were high which is not the case. However it is an extreme scenario that should be taken into account for planning purposes.



5. Conclusions and Recommendations

The sediment model proved to be accurate since it estimates a sedimentation rate between 1986 and 2001 very close to the known 40 thousand of m^3yr^{-1} . Rates estimated into the future should be slightly smaller, around 30 thousand of m^3yr^{-1} . The useful life of the reservoir, regarding sedimentation rates, and assuming that erosion within the catchment is not going to increase, should be larger than 100 yr. Mitigation measures for sedimentation usually involve the control of erosion processes in the catchment and they are not specifically related with the raising of the dam.

The oxygen model cannot be accessed from a quantitative point of view. It is difficult to develop setup and access a model without data to drive the model properly and to perform a validation. We can only access the model results from a qualitative perspective.

Actually the model develops a relatively weak thermocline as expected in the area. The mixed layer in African tropical lakes frequently exceeds 10 m and values of temperature in the upper 50 m generally exceeds 20°C (see Figure 9 for an example of measured data at Lake Kivu, in DRC/Rwanda). Therefore we may consider that the thermal model is producing a reasonable solution and this means that diffusivities (that play a crucial role in the process) are also reasonably estimated.

The major unknowns are therefore the consumption ratios (*WCOD* and *SOD*), both in the present situation and in future. As no data is available to provide an estimate of consumption rates, 3 scenarios were studied, providing a qualitative assessment of possible evolutions of the reservoir.

Results show that maintaining a status similar to the present – which is thought to be an oligotrophic status according to the few data available for nitrate – the concentrations of dissolved oxygen will remain in acceptable levels throughout the year. If previous to heightening the soil vegetation is not removed, then it is possible that oxygen consumption in hypolimnion increases leading to low concentrations in the deeper parts of the reservoir.



If the amount of vegetation is considerable and the loads of nutrients and organic matter produced in the catchment increase, then it is possible that the reservoir will experience low concentrations of dissolved oxygen throughout the water column during the summer peaks.

As a conservative measure it is recommended that the vegetation in the areas that are going to be flooded by the raising project would be assessed and if possible removed in order to prevent possible problems with dissolved oxygen.



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7. Appended Figures

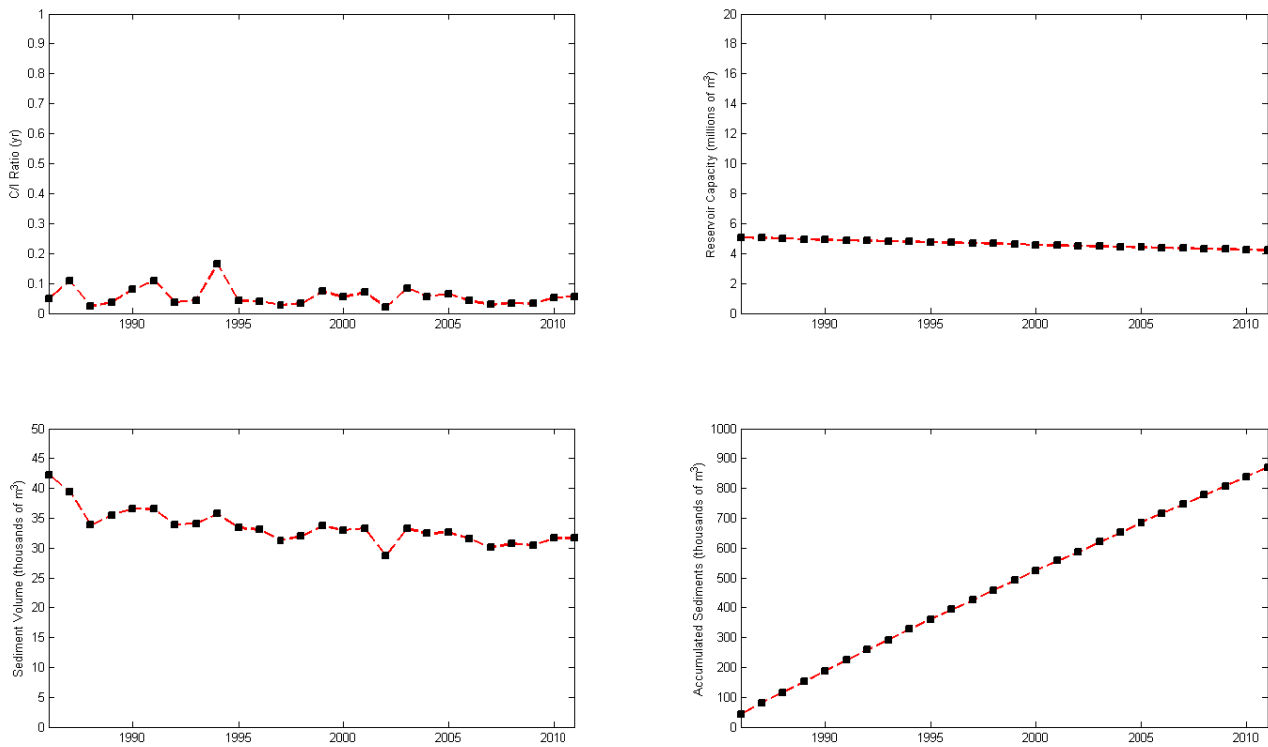


Figure 1 – C/I ratio, Reservoir Capacity, Yearly Sedimentation Ratio and Accumulated Sediments from the numerical experiment considering the period from 1986 to 2011

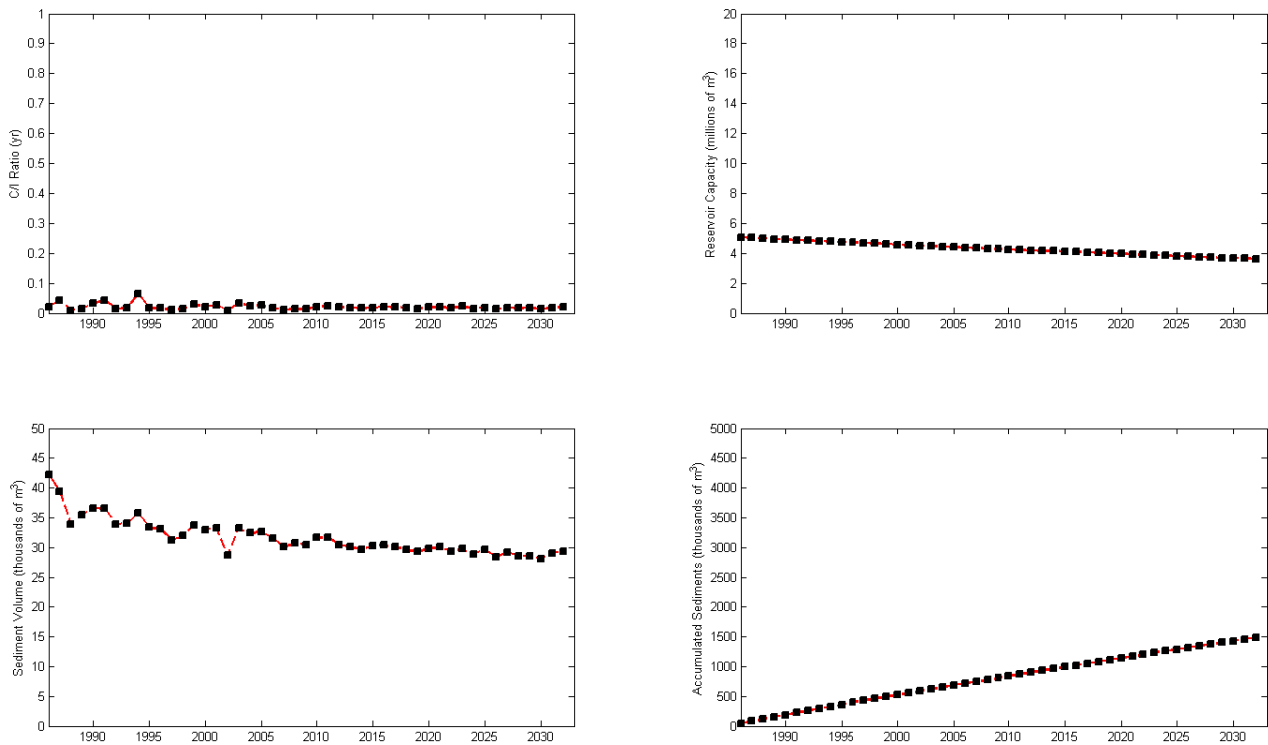


Figure 2 – C/I ratio, Reservoir Capacity, Yearly Sedimentation Ratio and Accumulated Sediments from the numerical experiment until 2030 without the dam's raising

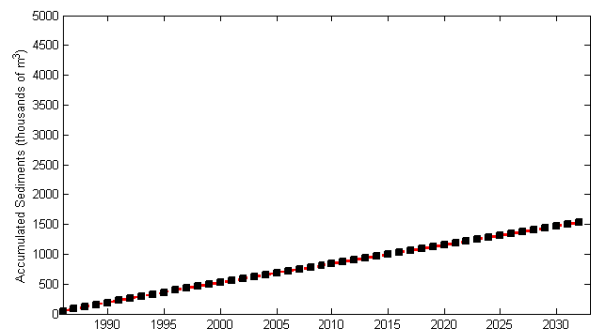
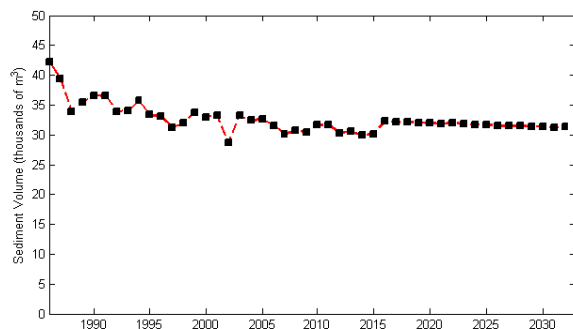
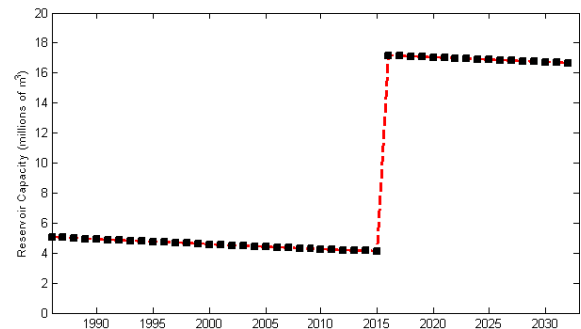
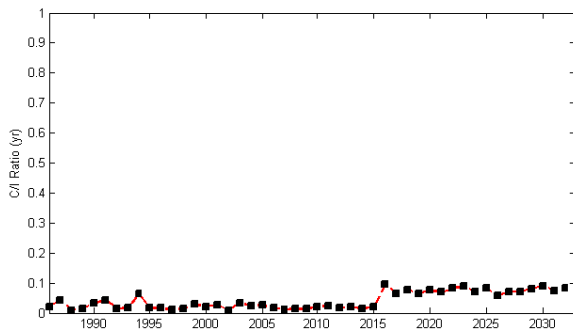


Figure 3 – C/I ratio, Reservoir Capacity, Yearly Sedimentation Ratio and Accumulated Sediments from the numerical experiment until 2030 with raising

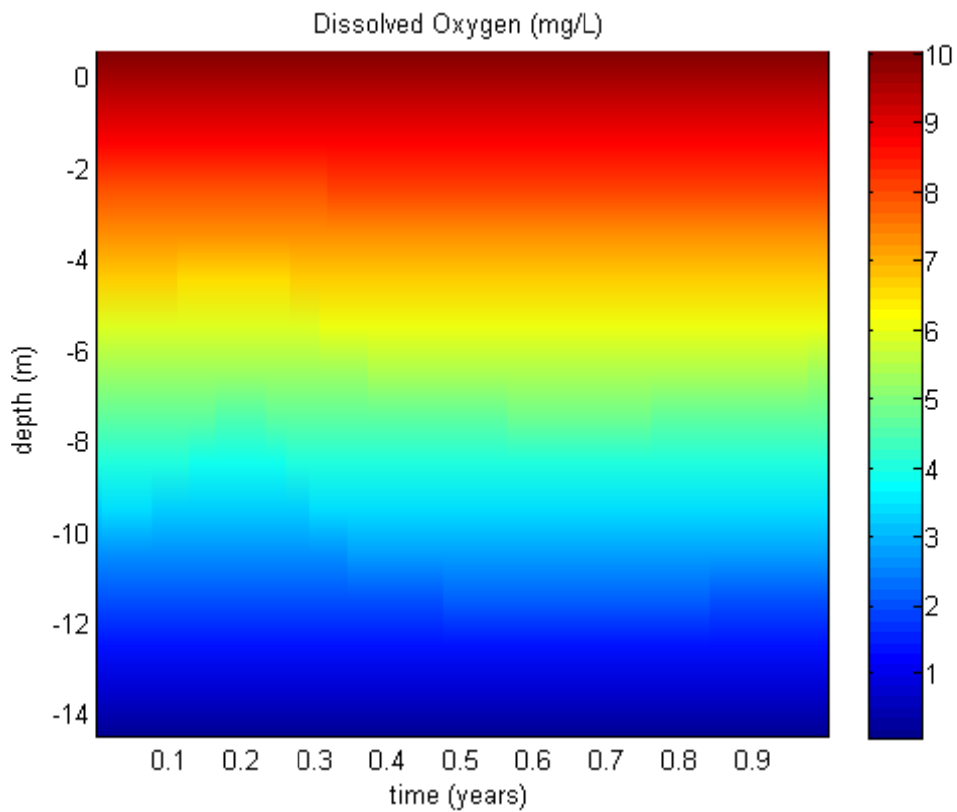


Figure 4 – Evolution of the vertical profile of dissolved oxygen for a typical year considering $WCOD=0.001 \text{ mg O}_2 \text{ L}^{-1} \text{ d}^{-1}$ and $SOD=0.06 \text{ g O}_2 \text{ m}^{-2} \text{ d}^{-1}$ (oligotrophic reservoir representing the present situation or the future scenario with removal of vegetation)

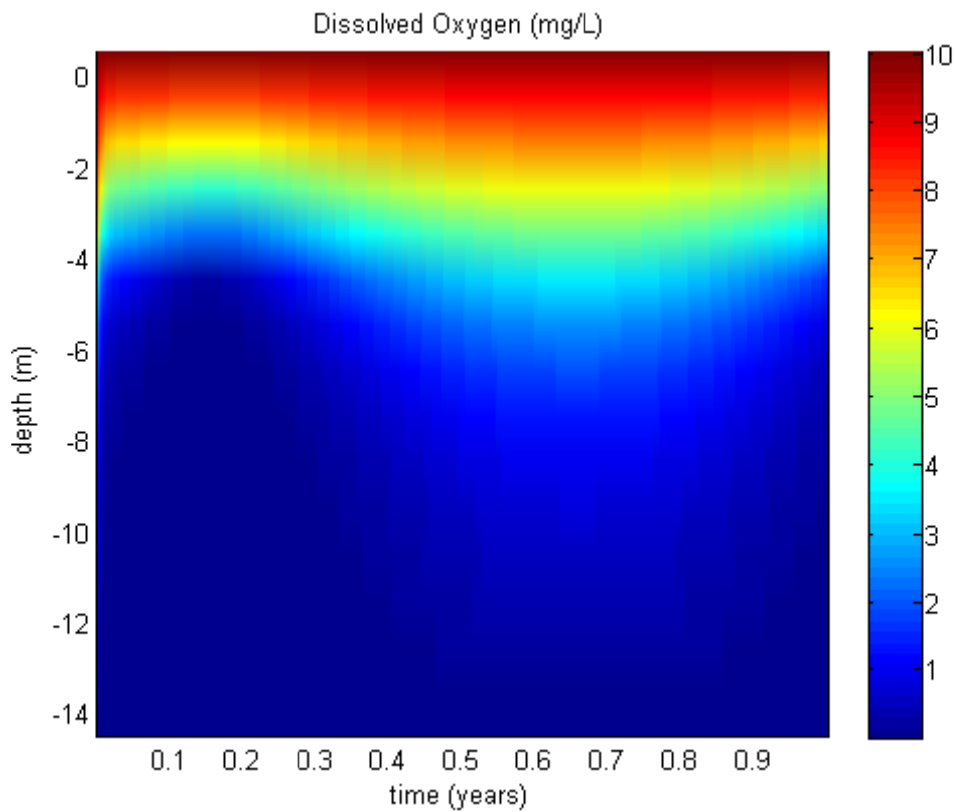


Figure 5 – Evolution of the vertical profile of dissolved oxygen for a typical year considering $WCOD=1 \text{ mg O}_2 \text{ L}^{-1} \text{ d}^{-1}$ and $SOD=4.5 \text{ g O}_2 \text{ m}^{-2} \text{ d}^{-1}$ (eutrophic reservoir representing the future scenario without removal of vegetation)

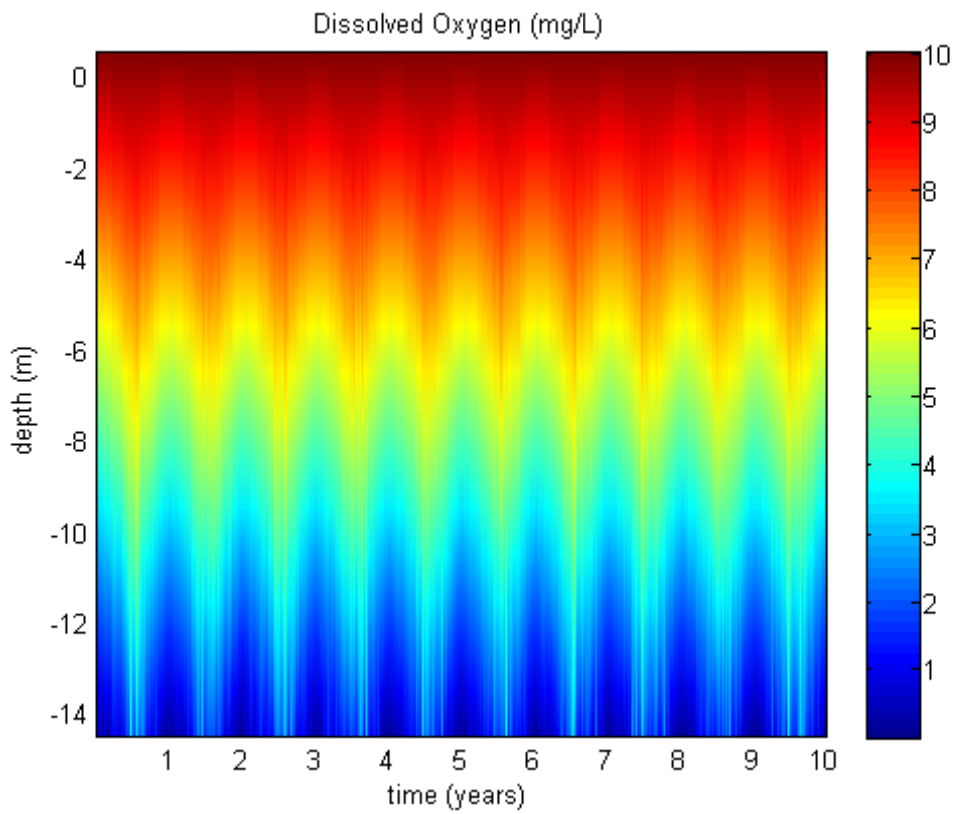


Figure 6 – Evolution of the vertical profile of dissolved oxygen considering a low oxygen demand both in water column and in sediments

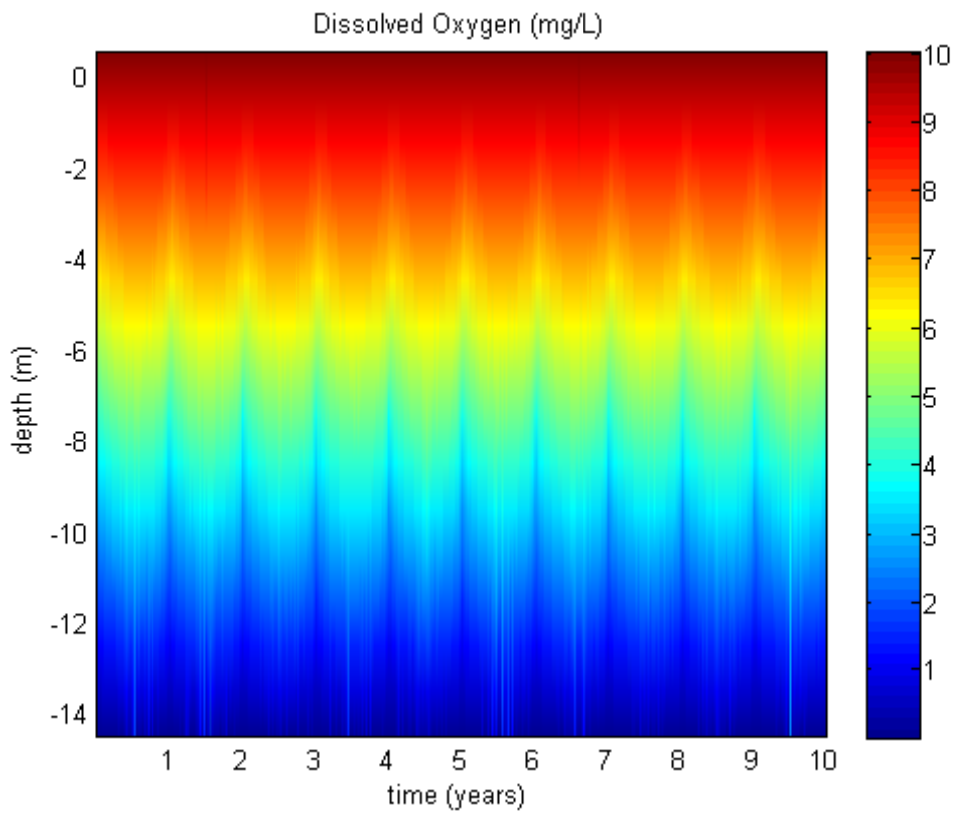


Figure 7 – Evolution of the vertical profile of dissolved oxygen considering a moderate oxygen demand both in water column and in sediments

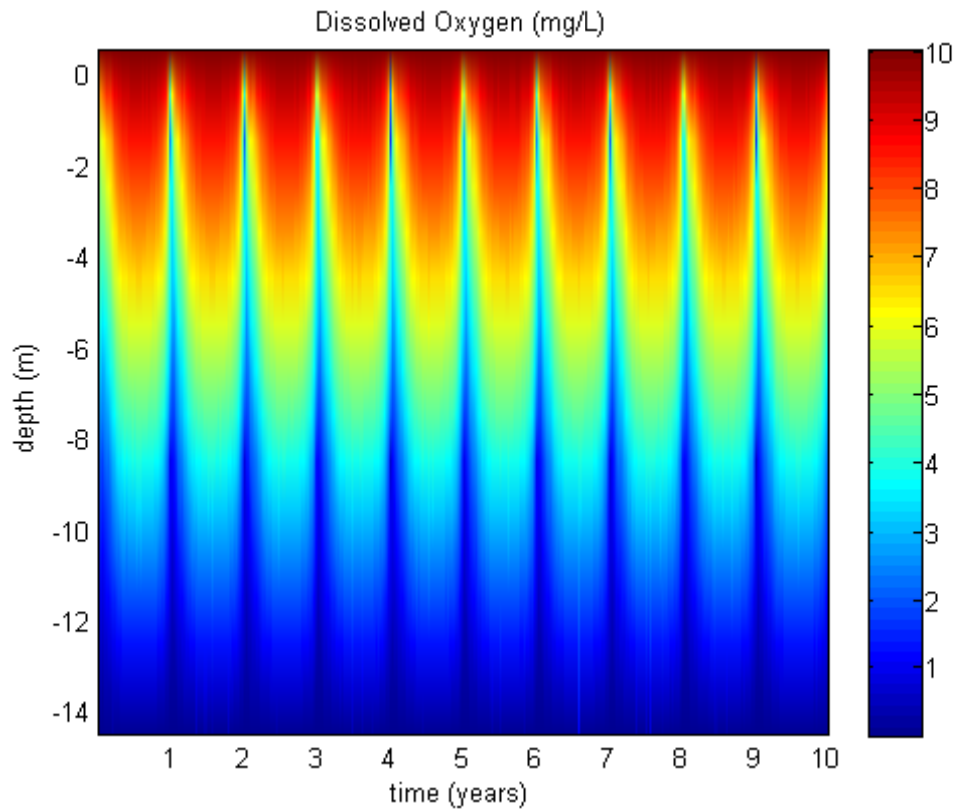


Figure 8 – Evolution of the vertical profile of dissolved oxygen considering a high oxygen demand both in water column and in sediments

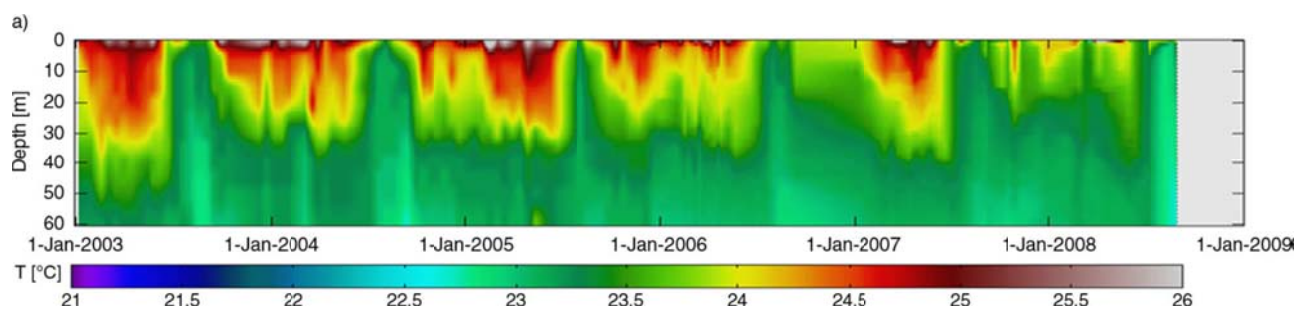


Figure 9 – Lake water temperature at Ishungu (lake Kivu). Adapted from Thierry *et al.* (2014)



Appendix 3 – Identified Heritage Sites/ Findings



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Table 126 – Heritage sites' coordinates

Site No.	Degrees South	Degrees East	Site No.	Degrees South	Degrees East
KD-01a	-14.1729	33.64018	KD-29a	-14.2045	33.61990
KD-01b	-14.1726	33.63983	KD-29b	-14.2041	33.61969
KD-01c	-14.1732	33.63918	KD-29c	-14.2040	33.61971
KD-02	-14.1776	33.63216	KD-30a	-14.2018	33.62180
KD-03	-14.1806	33.63117	KD-30b	-14.2020	33.62243
KD-04	-14.1772	33.62863	KD-30c	-14.2015	33.62242
KD-05	-14.1999	33.61737	KD-30d	-14.2019	33.62305
KD-06a	-14.2066	33.61256	KD-30e	-14.2008	33.62347
KD-06b	-14.2070	33.61280	KD-30f	-14.2014	33.62360
KD-07	-14.2044	33.60561	KD-30g	-14.2022	33.62477
KD-08	-14.2057	33.60315	KD-30h	-14.2030	33.62538
KD-09	-14.1991	33.58906	KD-31a	-14.1987	33.62700
KD-10	-14.1988	33.58813	KD-31b	-14.1989	33.62728
KD-11	-14.1989	33.58223	KD-32	-14.1939	33.62920
KD-12	-14.1992	33.58324	KD-33	-14.1904	33.63061
KD-13	-14.2209	33.61363	KD-34a	-14.1861	33.63168
KD-14	-14.2217	33.61328	KD-34b	-14.1859	33.63150
KD-15a	-14.2231	33.61382	KD-34c	-14.1860	33.63194
KD-15b	-14.2234	33.61407	KD-34d	-14.1859	33.63201
KD-15c	-14.2235	33.61372	KD-34e	-14.1855	33.63192
KD-16	-14.2373	33.60943	KD-35	-14.1847	33.63360
KD-17	-14.2470	33.61013	KD-36	-14.1853	33.63550
KD-18	-14.2392	33.61090	KD-37	-14.1845	33.63522
KD-19	-14.2297	33.61575	KD-38a	-14.1829	33.63558
KD-20a	-14.2290	33.61529	KD-38b	-14.1824	33.63582
KD-20b	-14.2293	33.61543	KD-38c	-14.1822	33.63602
KD-21	-14.2208	33.62008	KD-39	-14.1808	33.63685
KD-22	-14.2202	33.61698	KD-40a	-14.2507	33.61653
KD-23	-14.2190	33.61577	KD-40b	-14.2512	33.61655
KD-24	-14.2137	33.61454	KD-40c	-14.2508	33.61615
KD-25	-14.2064	33.61824	KD-40d	-14.2499	33.61545
KD-26	-14.2065	33.61861	KD-40e	-14.2488	33.61565
KD-27a	-14.2062	33.62056	KD-40f	-14.2490	33.61514
KD-27b	-14.2059	33.62048	KD-40g	-14.2499	33.61527
KD-27c	-14.2061	33.62033	KD-40h	-14.2506	33.61538
KD-28	-14.2064	33.61954	Dwambe	-14.2494	33.62040
			Dwambe	-14.1803	33.63785



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Source: African Heritage (2014)

Figure 198 – KD-01a lithics in section



Source: African Heritage (2014)

Figure 199 – KD-01c



Source: African Heritage (2014)

Figure 200 – Lithics from KD-01c



Source: African Heritage (2014)

Figure 201 – KD-02



Source: African Heritage (2014)

Figure 202 – Crosshatched pottery KD-02



Source: African Heritage (2014)

Figure 203 – KD-03



Source: African Heritage (2014)

Figure 204 – Pottery at KD-03



Source: African Heritage (2014)

Figure 205 – Pottery at KD-05



Source: African Heritage (2014)

Figure 206 – KD-06



Source: African Heritage (2014)

Figure 207 – Pottery and slag from KD-06



Source: African Heritage (2014)

Figure 208 – KD-07



Source: African Heritage (2014)

Figure 209 – KD-09



Source: African Heritage (2014)

Figure 210 – Bifacial core KD-09



Source: African Heritage (2014)

Figure 211 – KD-10



Source: African Heritage (2014)

Figure 212 – Mawudzu/ Nkhudzi Pottery
from KD-10



Source: African Heritage (2014)

Figure 213 – KD-11



Source: African Heritage (2014)

Figure 214 – Core KD-11



Source: African Heritage (2014)

Figure 215 – Levallois Flake KD-12



Source: African Heritage (2014)

Figure 216 – KD-13



Source: African Heritage (2014)

Figure 217 – Weathered comb-impressed decoration at KD-13



Source: African Heritage (2014)

Figure 218 – KD-14



Source: African Heritage (2014)

Figure 219 – KD-15



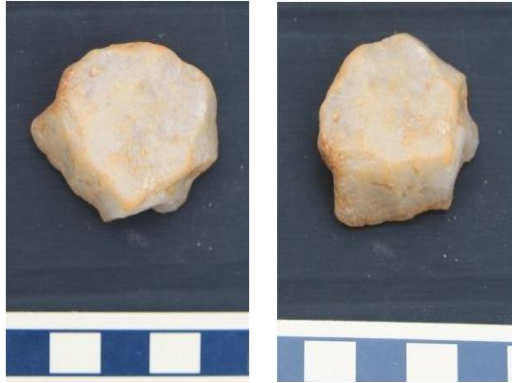
Source: African Heritage (2014)

Figure 220 – Potential Kapeni ware at KD-15



Source: African Heritage (2014)

Figure 221 – KD-16



Source: African Heritage (2014)

Figure 222 – Platform core (KD-16)



Source: African Heritage (2014)

Figure 223 – KD-17



Source: African Heritage (2014)

Figure 224 – KD-19



Source: African Heritage (2014)

Figure 225 – Comb-impressed sherd (KD-19)



Source: African Heritage (2014)

Figure 226 – KD-20, pottery and slag



Source: African Heritage (2014)

Figure 227 – Dagga and slag (KD-21)



Source: African Heritage (2014)

Figure 228 – KD-22



Source: African Heritage (2014)

Figure 229 – Slag (KD-22)



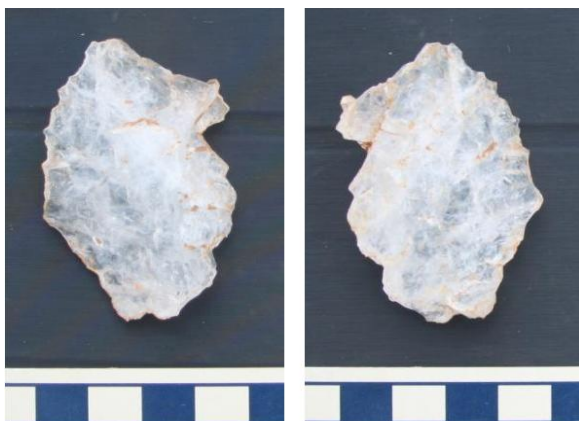
Source: African Heritage (2014)

Figure 230 – Furnace dagga with pole imprint (KD-22)



Source: African Heritage (2014)

Figure 231 – Cross-hatched pottery (KD-23)



Source: African Heritage (2014)

Figure 232 – Quartz Levallois flake (KD-24)



Source: African Heritage (2014)

Figure 233 – Comb-impressed pottery (KD-25)



Source: African Heritage (2014)

Figure 234 – KD-27



Source: African Heritage (2014)

Figure 235 – Tuyere and slag fragments (KD-27)



Source: African Heritage (2014)

Figure 236 – Cross-hatched and comb impressed pottery (KD-27c)



Source: African Heritage (2014)

Figure 237 – Laterite chunks and red-ochre pottery (KD-28a)



Source: African Heritage (2014)

Figure 238 – Dispersed slag mount (KD-28b)



Source: African Heritage (2014)

Figure 239 – KD-30



Source: African Heritage (2014)

Figure 240 – Mawudzu ware (KD-30)



Source: African Heritage (2014)

Figure 241 – Slag and Mawudzu ware (KD-31b)



Source: African Heritage (2014)

Figure 242 – Quartz flakes (KD-32)



Source: African Heritage (2014)

Figure 243 – Slag and pottery (KD-33)



Source: African Heritage (2014)

Figure 244 – KD-34



Source: African Heritage (2014)

Figure 245 – Pottery (KD-34)



Source: African Heritage (2014)

Figure 246 – Slag mount (KD-35)



Source: African Heritage (2014)

Figure 247 – Joined tuyere pipes (KD-35)



Source: African Heritage (2014)

Figure 248 – KD-36



Source: African Heritage (2014)

Figure 249 – Piled furnace dagga and tuyeres (KD-36)



Source: African Heritage (2014)

Figure 250 – KD-38



Source: African Heritage (2014)

Figure 251 – Incised pottery (KD-39)



Source: African Heritage (2014)

Figure 252 – Reed impressed dagga (KD-39)



Source: African Heritage (2014)

Figure 253 – KD-40



Source: African Heritage (2014)

Figure 254 – Comb-impressed pottery (KD-40)



Source: African Heritage (2014)

Figure 255 – Mawudzu ware and tuyere (KD-40)



Source: African Heritage (2014)

Figure 256 – Consolidated laterite bedrock



Source: African Heritage (2014)

Figure 257 – Survey in progress



Appendix 4 – Stakeholders and Public Consultation Activities



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Stakeholders and Public Consultation Activities

General strategy and programme

The following appendix constitutes a summarized report of the ESIA consultation activities. A full report on the public consultations shall be developed separately.

The consultation process of stakeholders and other interested parties was conceived in a sustained form, extending it throughout the project design and the environmental and social assessment cycle. In doing so, it will contribute to a better project planning, to enhance public confidence in the project and to timely notice difficulties that may occur regarding public acceptance of the project.

Consequently, the programme has its major features timely planned in order to coincide with significant planning and decision making activities. Specifically, stakeholders and general public consultations were undertaken during the following phases:

- Initial site visit and workshop;
- Fieldwork and gathering of baseline information;
- Execution of the ESIA/RAP;
- Draft ESIA report;
- Fieldwork and data collection for RAP;
- Draft RAP report.

In an early stage, a set of relevant authorities and selected interested parties were invited to a workshop meeting in order to provide an overall briefing on the studies and tasks that are going to be performed and to assure the early involvement, participation and articulation, when relevant, of/with such stakeholders.

The subsequent stage of public meetings included the fieldwork and the gathering of baseline information, which came after developing a better knowledge of the study area and discussing the main concerns and impacts of the project implementation at the initial workshop.



The initial stakeholders consultation sessions and activities took place in the following:

- Initial workshop – 5th November 2014, at the Lilongwe District Council;
- Community meetings – 12th and 13th November 2014, at Chisauka School (TA Masula) and TDC-Malingunde (TA Masumbankhunda);
- Surveys and questionnaires – between 10th and 15th November 2014, within the study area (TAs Masula and Masumbankhunda).

The present section concerns the middle ESIA consultation activities – Execution of the ESIA/RAP and Draft ESIA report. The method employed to consult stakeholders in this phase was through a set of public meetings. Three public consultations were held for the presentation of the Draft ESIA Report.

These meetings represent structured gatherings to inform the local communities and the general public about the project and ESIA/RAP procedures and exchange information, views, concerns and suggestions. All contributions from stakeholders during the process would then be integrated in the Final ESIA Report.

The public consultation sessions were supported by the following informative elements:

- PowerPoint presentation;
- Large-format maps.

According to the steps described above and the ESIA work plan, the stakeholders consultation sessions for the presentation of the Draft ESIA Report took place as follows:

- Public meeting – 7th April 2015, at the Lilongwe District Council;
- Public meeting – 8th April 2015, at TDC-Malingunde (TA Masumbankhunda);
- Public meeting – 8th April 2015, at Chisauka School (TA Masula).



Photograph 1 – Public Consultation at the Lilongwe District Council



Photograph 258 – Initial workshop at the Lilongwe District Council



Photograph 3 – Community meeting at Chisauka School (TA Masula)



Photograph 4 – Public Consultation at Chisauka School (TA Masula)

Public meetings

The main objective of the meetings held in Lilongwe and both affected TAs was to inform stakeholders and the general public on the progress of the project and to present the ESIA Draft Report, while also inquiring about environmental and socio-economic issues that might not have been properly addressed and gathering local knowledge and further useful information for the completion of the ESIA report.

The meetings' scheduling in both affected TAs was facilitated by the Traditional Authority Chiefs, promoting the presence of group village headmen and village headmen of the potentially affected areas around the Kamuzu Dam I reservoir. Secretaries and tsabwalos (spokesmen that usually convene traditional court sessions) of local leaders and some village members also attended the meetings.

All meetings were open to public and LWB assisted in translations and clarifications when needed. Typical meeting format corresponded to an initial presentation of the ESIA Report by the consultant, followed by a discussion period where attendees could express their views and concerns. The meetings were heavily attended, as interest for the local populations is very high.



Meetings programme was as follows:

- Brief project justification and description;
- Key legal and regulatory framework description;
- Explanation of baseline situation;
- Brief project description and presentation of estimated flooded areas;
- Presentation of the ESIA Report;
- Description of mitigation measures and Environmental and Social Management Plan;
- Conclusion, recommendations, discussion and opinions on the ESIA Report.

Many people expressed their concerns over the course of the three public meetings. The major concerns and expectations are summarized below:

- Some participants considered the matter of Archaeological and Sacred Sites not properly addressed;
- Some questions remain on the relocation of cultural sites;
- Potential cultural tourism was questioned;
- Some worries about socio-culture disturbance still exist;
- There are still some concerns about the chosen project option, in particular when regarding the high population increase rate of Lilongwe, climate change and deforestation rate;
- There are some doubts about bridge stability in cases of overflowing after the raising of the dam;
- The involvement of the local people was further emphasized;
- The project is welcomed and seen as a benefit for Lilongwe residents;
- Because of hunger and poverty issues, the loss of land and limiting water access for animal drinking and grazing will greatly impact populations;
- General concern about unfulfilled compensation and possible job offer promises for this process: in past experiences, other projects (namely Kamuzu Dam I past projects) brought expectations and promises that weren't carried out;
- Underestimates for compensation values are a decisive issue; the community is open to alternative compensation measures by the LWB, such as building schools, alternative income sources for owners and communities, potable water supply;



- Advantages: increased water storage, more accessible water for common uses like human consumption and washing;
- Disadvantages: loss of houses, farmland, trees (used as fuel and as construction material) and graveyards (Manyenje and Kapininga);
- The scarcity of available land presupposes that resettlement and land compensation will result in a net loss of land for affected owners.

Conclusion

NEMUS and Lilongwe Water Board believe involving the stakeholders and seeking their guidance and participation is a crucial step to the project's success. Engagement with stakeholders and general public was therefore pursued since the earliest stages of the ESI/RAP preparation and followed along all its major steps.

Information, data, guidance and validation provided by stakeholders along the process is of great importance to achieve adequate and consistent final documents, taking into consideration stakeholder's concerns and expectations.

From these meetings, we gathered that there is a general concern about the mitigation of archaeological, sacred and generally cultural sites. While some feel there might be a potential opportunity for cultural tourism, others are uncertain of the exact relocation of sites and their possible socio-cultural disturbance among the population.

Once again it was stressed that the local people remain as involved as possible with the project. Local authorities, leaders and population emphasised an uneven distribution of project benefits, as the increased water supply availability will only be felt in Lilongwe City. On the other hand, all the disadvantages and project impacts remain in the vicinity of the Kamuzu Dam I and reservoir, affecting rural populations and land of TAs Masula and Masumbankhunda. Major concerns for the local populations are water availability, employment or unemployment compensation and land compensations.

In Lilongwe, the general consensus on the ESI/RAP is good and the project is welcomed. The public agrees that the project may generate very positive impacts and that through proper mitigation negative impacts can be minimised or even erased.