1,050MW Coal Fired Power Plant

Hydrology Study

Report Prepared for

Amu Power Company Limited

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10 July 2016

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1 Introduction

There are prospects for Coal Power plant in Kwasasi area in Lamu County. The project area is located within the floodplains of seasonal rivers with low elevation and a flat terrain pools and ponds indicative of low ground water level. The threat to flooding and water logging due to prevalent seasonal high rainfall in the area and tidal effects of high and low tides due to maritime influences. There is therefore need to identify likely flood and water logging risk areas to aid in informed development of mitigation measures to reduce negative impacts of such events before Lamu Coal Power Plant development commences.

It is for this reason that Client has request for hydrological assessment of the study area to inform the Social and Environmental Impact Assessment of the project.

1.1 Objectives of the Study

The objective of the study is to assess sensitivity of the baseline hydrological environment and the potential impacts of the proposed Coal Power development upon it and to propose mitigation measures in order to ensure that the potential adverse impacts of the proposed development on the hydrological environment will be slight and neutral.

1.2 Assessment Methodology

The description of the baseline hydrological environment at the subject site and in the surrounding area was by means of a desktop study. This was supplemented by a site surveys and topographical analysis.

This study was undertaken to aid in understanding the underlying hydrology of the project area and to compile, collect and collate relevant supporting information relating to the proposed development. The purposes was to develop thorough understanding of the project activities and to relate its development and operation to hydrological characteristics specific to arae of study in order to:-

- Assess the sensitivity of the baseline hydrological environment at the subject site and in the surrounding area with respect to the proposed project.
- Identify any potential impacts on the hydrological environment in respect to its development and operation.
- Identify any constraints posed by the existing hydrological environment to the proposed development and to;
- Recommend appropriate mitigation measures in order to ensure that the potential impact of the proposed project is slight and neutral.

2 Desktop Study, Modeling and Parameterization

The desk study aimed to collect, collates, analyze and interpret all data and information concerning the project and develop products to inform the ESIA. The ESIA for the project is to identify impacts and propose mitigation measures that assist to reduce negative impacts resulting from implementation of the project.

Information for the study was obtained from topographic maps, relevant institutions and past studies. Relevant reports were reviewed and information extracted for situation analysis. According to the findings, there are no stream flow and other basic hydrological data relating to surface runoff in the project area such as watershed characteristics (area, slope, contours, river length and channel geometry etc). These baseline data had to be derived from Digital Elevation Modeling and extraction from topographical maps. Ground truthing for the same was accomplished through field reconnaissance surveys and personnel communication.

The study area was identified from geo-referenced co-ordinates of its extent and extracted from Digital Elevation Model (DEM) of Kenya. The extracted area was delineated and analyzed using GIS software and representative watershed characteristics determined. The process identified 5No. Key watersheds that represent the physical and flow conditions for the area.

These watersheds so identified are named according to topographic features in the area namely Shaka la Kiboko (16Km2), Jipe/Msuakini (50Km2), Magogoni (3.5km2), Junja/Chomo (72km2 and Ziwa la Malindi (70km2).

Relevant characteristics for each watersheds (slope, catchment area, contour mapping, longest flow length and channel geometry etc) are derived from DEM analysis and also from topographic maps for the area.

Hydrological modeling studies are carried out using two indirect methods of assessing hydrological flow regimes for the 5No. Watersheds. This was necessary due to lack of representative data since the watersheds are not instrumented and therefore un-gauged.

2.1 Transport Road Research Laboratory (TRRL) Method

One of the methods, the Transport Road Research Laboratory (TRRL) Method relates rainfall to stream discharge using empirical methods. It is a form Richards' Method modified for East African conditions. Its data requirements are daily rainfall data, watershed characteristics and area reduction factors. The probable daily rainfall depths for various return periods is used to determine average flow in un-gauged watersheds. This information was collected and analyzed for the representative Lamu Meteorological Station. The period considered for the analysis was from 1974. Rainfall events with 10 yr, 25 yr, 50 yr and 100 yr return period were computed to be 182mm, 220mm, 249mm and 280mm respectively. This data has been used to determine average flows for the study area. For more details of the method see reference section and the Annex.

This information provides an insight of expected flood magnitudes and volumes that may occur when such rainfall events occur. The analysis shows that it is not unusual to expect floods with average discharges of more than 50m3/s - 170m3/s in some of the watersheds in the project.

2.2 Runoff Estimation Method

The other method uses a runoff ratio is the Runoff Estimation Method. This method estimates potential runoff or flows using the product of this ratio, watershed area and probable rainfall of the specified return period. Peak floods for each of the watersheds are analyzed using a runoff ratio of 0.32, probable rainfall depth for specific return period as determined for Lamu Meteorological Station and watershed catchment area to estimate the expected flow volume over the entire watershed. A runoff ratio of 0.32 means 32% of rainfall is converted to direct streamflow and 68% satisfy evaporation and seepage deficits.

The difference between the two methods is that the Runoff Ratio Method assumes a runoff coefficient of 0.32 while the TRRL Method computes flood peak using pre-defined parameter computation procedures.

2.3 Results of Hydrological Modeling

Delineation of the study area identified 5No. Watersheds. The watersheds were used to model the rainfall - runoff process and to estimate the respective flow regimes.

Table 2-1 provides results for the Transport Road Research Laboratory (TRRL) Method for each of the watersheds in the project for probable rainfall amounts of 10 year, 25 year, 50 year and 100 year Probable Rainfall at various return periods as observed at Lamu Meteorological Station are shown below.

Table 2-1: Average flows (TRRL Method) for Lamu Coal Project Watersheds

Watershed Name	Area, Km2	T-yr Daily Rainfall (Ref: NWMP 1992 Lamu Met Station No. 9240001)				Average flows Qa for Event Transport Road Research Laboratory (TRRL) Method			
		10yr_Daily Ppt	25yr_Daily Ppt	50yr_Daily Ppt	100yr_Daily Ppt	Qa10yr (m^3/s)	Qa25yr (m^3/s)	Qa50yr (m^3/s)	Qa100yr (m^3/s)
Shaka La Kiboko	16.12	**181.7**	**220.4**	**249.2**	**277.7**	14.5	17.6	19.8	22.1
Jipe/Msuakini Stream	50.22					42.8	51.9	58.7	65.4
Magogoni stream	3.49					3.5	4.2	4.7	5.3
Junja (Chomo) stream	71.76					31.3	37.9	42.9	47.8
Ziwa La Malindi stream	69.6					49.8	60.4	68.3	76.1

Table 2-2 below shows results for the same watersheds for the same probable rainfall but using the runoff ratio of 32% and catchment area.

Table 2-2: Potential Discharge for Probable Rainfall of Various Return Periods

Watershed Name	Catchment Area, Km2	Runoff Coeff	Potential Discharge (m3/s) for T-yr Ppt			
		0.32	10yr_Ppt	25yr_Ppt	50yr_Ppt	100yr_Ppt
Shaka La Kiboko	16.12		10.848	13.159	14.878	16.580
Jipe/Msuakini Stream	50.22		33.796	40.994	46.351	51.652
Magogoni tream	3.49		2.347	2.846	3.218	3.586
Junja (Chomo) stream	71.76		48.292	58.577	66.232	73.806
Ziwa La Malindi stream	69.6		46.838	56.814	64.238	71.585

2.4 Interpretation of Analysis Results

The TRRL Method shows that the intermittent river channels in the project area may be transformed into flowing rivers in the likely chance that a 10 year rainfall event occurs, flows exceeding 14m^3/s, 43m^3/s, 3.5m^3/s and over 30m^3/s are likely to occur at Shaka la Kiboko, Jipe/Msuakini, Magogoni and nearby watersheds of Junja/Chomo and Ziwa la Malindi watersheds. Similarly, a 25 year rainfall event occurs may generate flows exceeding 18m^3/s, 50m^3/s, 4.2m^3/s and over 30m^3/s in the same watersheds. Higher flow are generated by events of 50 year and 100 year events.

On the other hand, the Runoff Ratio Method generates flows exceeding 10m^3/s, 35m^3/s, 2.5m^3/s and over 45m^3/s should a 10 year event occur. A 25 year rainfall event generates flows exceeding 13m^3/s, 40m^3/s, 2.8m^3/s and over 55m^3/s and so on.

The estimated average flows by the two methods are of the same order of magnitude. This shows the modeling results provide some useful insight of flow regimes in the study area.

2.4.1 Preview

Two hydrological methods have been used to assess the magnitude of average flows expected in the project area in the likely event that 10 year, 25 year, 50 year and 100 year probable rainfall occurs in the project area.

Indications are that the flows are likely to cause flooding, water logging and inundation of the floodplains of some of the watersheds of Lamu Coal Power Plant project Kwasasi area. These watersheds have been classified as having high, medium or low risk.

A map to this effect has been developed for visual interpretation of the level of risk to flooding and water logging for each of the selected watersheds.

It is recommended therefore that any developments within the watersheds should mitigate any likelihood of damage due to water logging and flooding by identifying and implementing measures that mitigate impacts and damage to property.

2.4.2 Description of the Transport Road Research Laboratory (TRRL) Method

Transport Road Research Laboratory (TRRL) Model which has been found to provide representative estimates of flow conditions for watersheds of similar sizes in East Africa and beyond.

The Transport Road Research Laboratory (TRRL) Model methodology is a generalized application of Richard's Method which is used Worldwide to estimate runoff conditions in un-gauged watersheds for peak flow design of bridges and culverts. It was re-developed for East African conditions early in the relations established for East Africa applications sometime in the early 1960s. It has been found useful for watersheds less than 100km2.

The parameter computation procedures are summarized as described below:-

2.4.3 Total Runoff Volume (RO)

The Peak flow is estimated for average flow during a pre-computed base time of the flow discharge - time graph (hydrograph) according to the formula below:-

The total volume of runoff is given by:

RO = (P - Y).Ca.A.1000 cubic metres ---(1)

where

P = Storm rainfall (mm) during time period equal to the base time, Y = Initial retention (mm)

CA = Contributing area coefficient, A = Catchment area (km2)

The average flow (c) is therefore given by:

Q= (0.93 . RO)/(3600 . TB)--(2)

where

TB = Hydrograph base time (hrs), Y = Initial retention, Ca = Contributing area coefficient (CA) each parameter is estimated as described in the following paragraphs.

2.4.4 Contributing area coefficient (Ca) and Time base Tb

Four factors influence the size of the contributing area coefficient. These are soil type, slope, type of vegetation or Ianduse (particularly in the valley bottoms) and catchment wetness. The network of catchments had been selected to cover the range of these factors to be found in East Africa. The effect of slope and soil type was studied by comparing the results of the catchments with grass cover and the storms falling on soil at field capacity.

The effect of antecedent wetness was studied by comparing the runoff volumes resulting from storms occurring at different stages of the rainy season. The reduction in value of CA was assumed to vary linearly with the soil moisture deficit.

Special tables are used to estimate appropriate parameters as described in reference.

The design value of the contributing area coefficient Ca is therefore given by:

CA = Cs. Cw. CL ---8

where Cs = The standard value of contributing area coefficient for a grassed catchment at field capacity, Cw = The catchment wetness factor and CL = The land use factor.

The Catchment lag times (K) is computed from various catchment conditions where the methodology is applied.

2.4.5 Base time

The method of estimating the base time is made up of three parts namely;

(a) The rainfall time

(b) The recession time for the surface flow

(c) The attenuation of the flood wave in the stream system.

The methodology for the computation of this parameter from rainfall time and catchment properties including area rainfall reduction for varying rainfall intensities is described in reference. Iterative procedures are used to optimize outputs for final computation of the peak flood from average flow obtained in preceding computations.

2.4.6 Flood Risk Map for Lamu Coal Power Plant Watersheds (Kwasasi, Lamu County

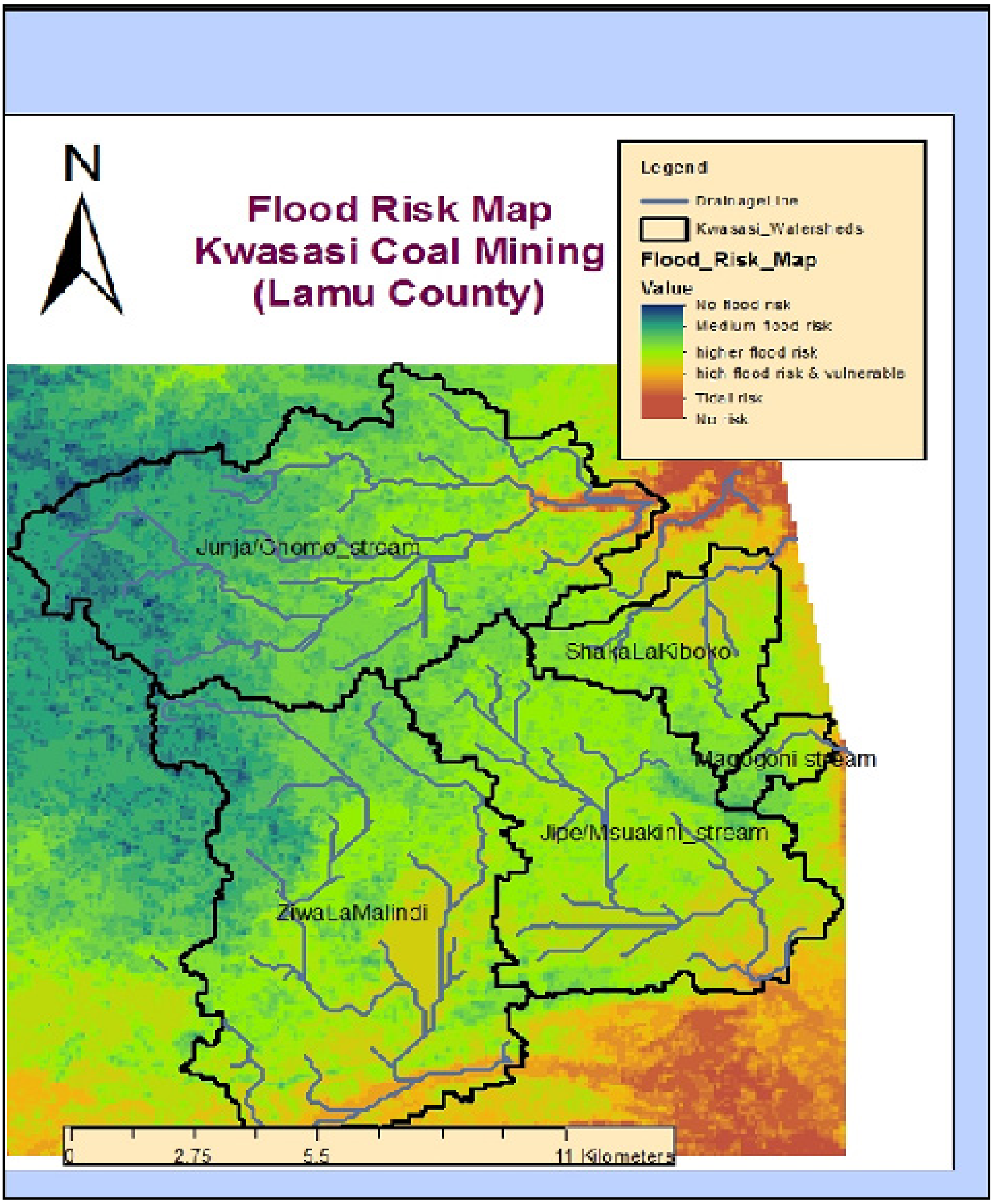
A Flood Risk Map for the study area has been developed based on topographical, digital elevation mapping at 2 metre interval and drainage ability of the identified watershed to drain expected average flows as determined by the Runoff Ratio and TRRL Model outputs.

The mapping is informed by inference of properties such as the slope, longest flow length, attenuation speed and other factors such as soil and land use cover that affect the runoff process.

The map indicates areas where water logging and flooding is likely to occur for the selected watersheds. It provides visual estimation of location and areas which are most likely to experience flooding should an extreme event occur. In addition, it also shows vulnerable areas as identified from modeling and topographic interpretation.

Accordingly, the upper reach (22 - 18m asl) has a lower risk of flooding, the middle reach (18 - 14m asl) has medium risk. However, areas below below 14m asl have highest risk of water logging and flooding.

2.4.7 Flood Risk Map for Lamu Coal Power Plant Watersheds (Kwasasi, Lamu County)



Likelihood of Flood and Water Logging around Lamu Coal Power Plant, Kwasasi Watershed

Table 2-3: Indicative Flood and Water Logging Risk Areas

Watershed Name	Area (Km^2)	Length (Km)	Width (Km)	Channel properties & flow direction (Km)	Flood likelihood
Shaka La Kiboko	16.12	4.69	3.44	>0.5, North Eastwards flowing	Low Risk
Jipe/Msuakini Stream	50.22	4.47	11.23	flat, mild slope, 2 - 3km wide & South Easterly flowing	Medium Risk
Magogoni stream	3.49	3.78	0.92	Narrow valley & Easterly flowing	Not likely to flood
Junja (Chomo) stream	71.76	12.94	5.54	Wide flat valley/Easterly flowing	Localized water logging and Flood Risk in Middle and Lower reach
Ziwa La Malindi stream	69.60	5.83	11.93	mild slope upper reach, flatter slope_ middle reach, flat lower reach & South Easterly flowing	Localized water logging & Flood Risk in the middle reach. Higher Risk in the lower reach

Figure 2-1: Lamu Coal Power Plant Site

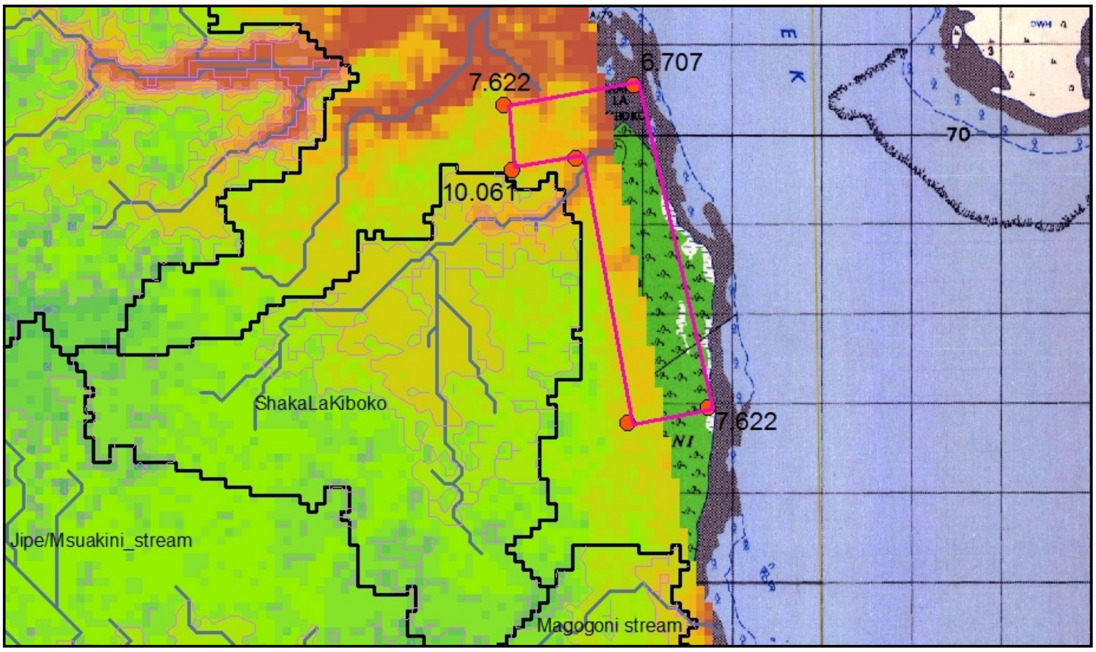
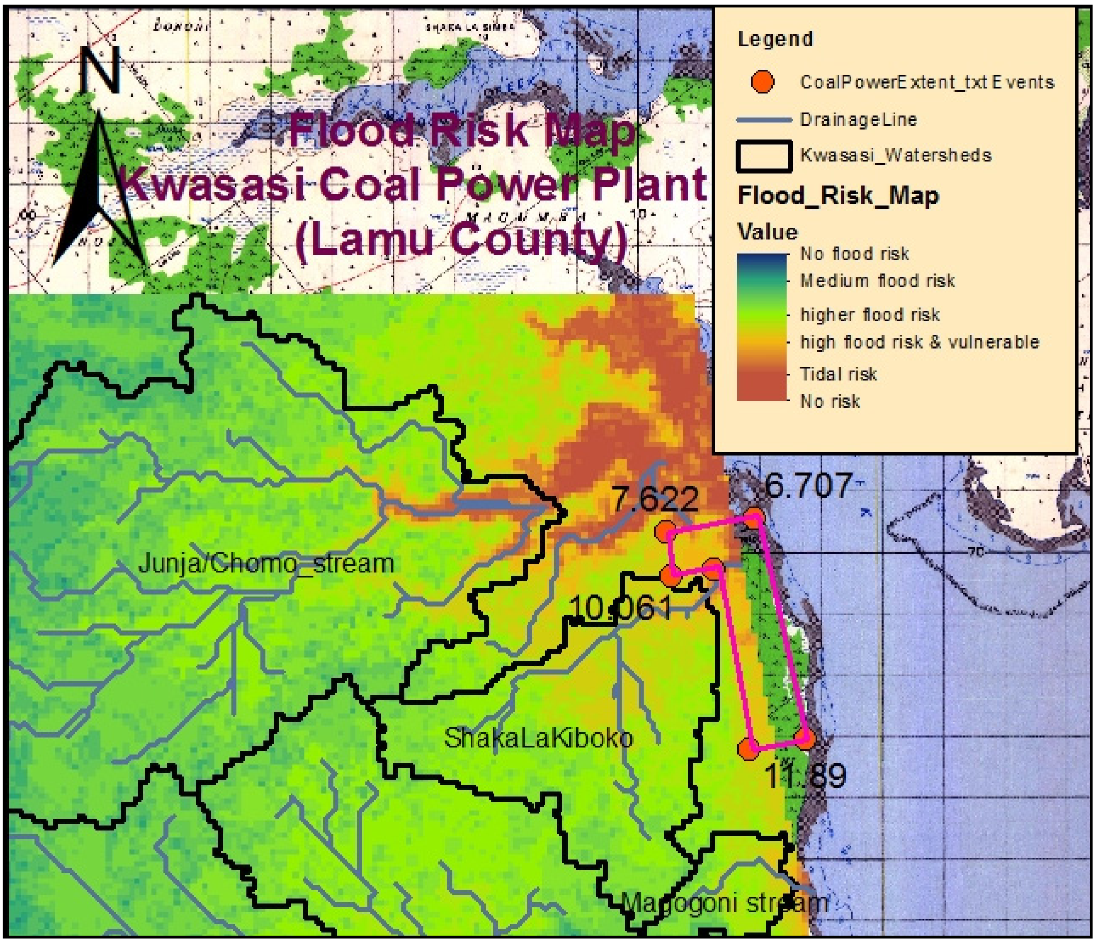


Figure 2-2: Lamu Coal Power Plant Site



3 Baseline hydrology environment

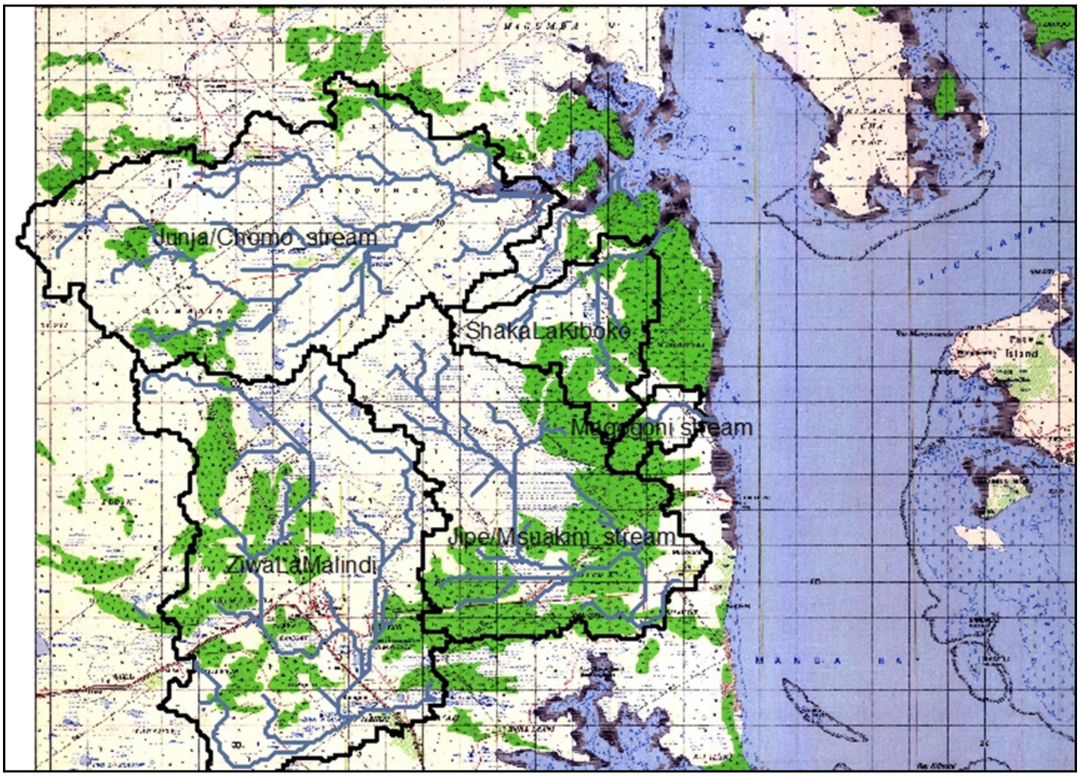
3.1 Overview of hydrology of Kenya on National Scale

3.1.1 Hydrological Setting

The hydrological setting of the project area is determined by the topography, geology and soils. Arising from analysis of topographic maps, it is observed that the land surface rises gradually from sea surface to about 20masl within a short inland distance of about 15 kilometers. Hence the average slope is low ranging from 0.1% to 0.2%. Being a flat area, the project area has a high potential for flooding and water logging especially in times of intense storms.

Figure 1 presents the location and drainage system of the project area.

Figure 3-1: Location and Drainage System



3.2 Hydrology of the project area and its environs

The hydrology of the project area is governed by the climate, geology, soils and drainage system. Climatic data is obtained from Lamu Meteorological Station No. 9240001. Lamu area has a wet and humid tropical maritime type of climate. This type of climate is responsible for the dense forests cover as well as the mangrove forest near the ocean.

Average annual rainfall data for the period 1993 to date is about 1000mm. The lowest rainfall observed was 684mm in 2012 and the highest was 2242mm in 1996. Monthly variation has the typical bi-modal distribution with mean long rains depth of 250mm in May and the short rains depth of about 100mm in November. The months in between have minimal rainfall and are drier.

Figure 3-2: Climatology of Mean Monthly Rainfall

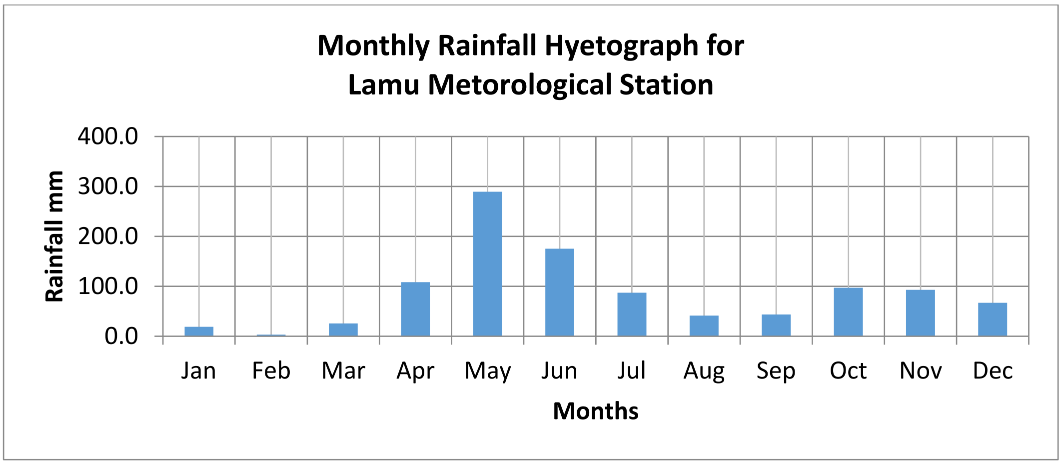
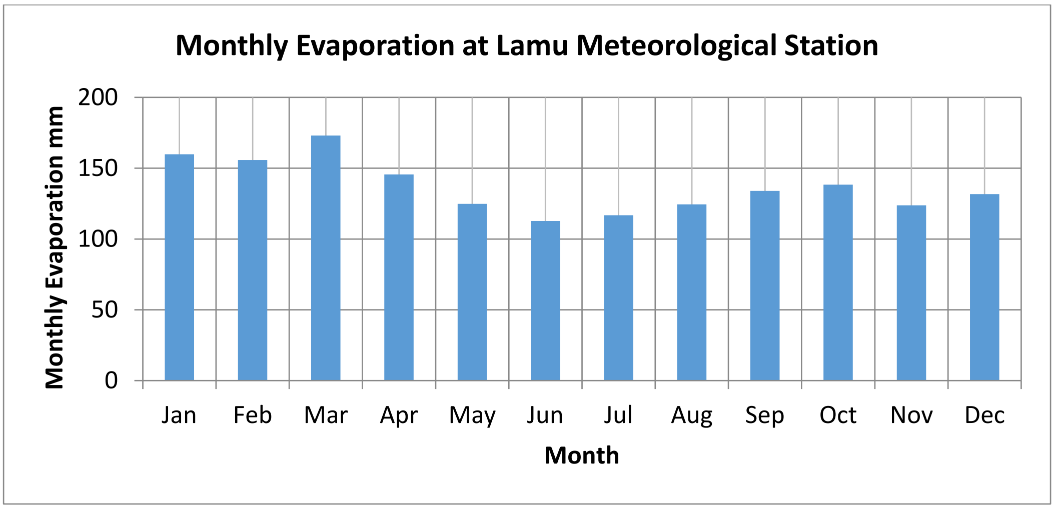


Figure 3-3: Monthly Evaporation



Relative humidity is high ranging from about 65% in the rain seasons to above 80% in the drier months and annual mean evaporation exceeds 1600mm. Mean annual evaporation is therefore higher than mean annual rainfall.

Seasonal storms have high intensity and are often accompanied by thunderstorms. The outcome of such heavy rainfall is localized water logging and flooding of the floodplain. Pools of standing water and ponds are left after rains. These make up for the limited drainage system comprising mainly seasonal streams and shallow but intermittently flowing water into the Indian Ocean. There are no perennial rivers in the area.

3.3 Existing Surface Water Resources

There are no perennial streams. Hydrological surveys are therefore nonexistent. Most stream are intermittent. Drinking water is obtained from shallow wells and pools. However, the area has potential for rain water harvesting.

4 Assessment of the Impacts

4.1 Impact in respect to hydrological flow regime

Topographic maps and DEM contour mapping has shown that elevation differences between the upper reach and the lower parts of the drainage system in all watersheds delineated in the project area is low. The altitude of the highest point is about 20masl and lowest the ocean at 0m asl. Mean elevation is about 15masl. The highest points are generally about 20 kilometers inland. The slope is therefore very low at 0.1% - 0.2% in more than 50% of the landscape. Most of the watersheds are rather flat and have wide floodplains with soils that may not be able to drain all waters generated in the watershed.

In fact, the project area receives quite high rainfall on average. Intense and heavy storms of over 200mm in a day are very common in the wet season. This amount of rainfall has potential to generate enormous volumes of flow which are likely to cause water logging, flooding and bank erosion. According to the flood mapping, this will certainly happen in the middle and lower reach with the consequent of enhance transport of particulate matter, river bank erosion and effluents attenuation thereby enhancing pollution.

4.2 Predicted Impacts and Mitigation Measures

The potential impacts on the water environment from the proposed development, in the absence of suitable mitigation measures, are considered to be as follows:

- Direct impacts of the Coal Power Plant construction on the hydrological environment due to contamination of surface water from the spillage/leakage of fuels from vehicles and fuel/chemical/waste storage areas.
- Direct impacts from excavated areas where vegetation has been removed. This has the effect of releasing silt or sediment laden surface water runoff into local watercourses and enhance soil erosion from loose excavated soil. Clearing vegetation leads to an increase of surface water runoff.
- Direct impacts of Coal Power Plant operation on the hydrological environment. Coal Plants operation produces waste water, oils, leaks from storage areas which may reach surface water and cause pollution to the resource.

In essence, the predicted impacts on the hydrological setting of the project area concern all phases of Power Plant development namely the Development Phase, Operational Phase and Decommissioning or Post - Operation Phase. The impacts and mitigation measures differ from phase to phase.

4.2.1 Predicted Impacts - Development/Construction Phase

During project development phase work involves site preparation and construction activities. land is cleared of vegetation and terrain shaping using heavy machinery such as earth movers, lorries and so on. This activity modifies the drainage pattern because the vegetative cover of the soil is removed together with the compacted soils. There is increased surface water runoff due to the introduction of impermeable surfaces such as site compounds and roads, and the compaction of soils. It also enhances sediment generation and transport. The overall infiltration capacity reduced thereby leading to an increase of the rate and volume of direct surface runoff. Consequently, the river course and its drainage system are modified and sometimes completely changed. In effect modification of the water course may increase channel erosion, sediment loading and flood risk.

Plant operators require water to meet their domestic demands. Similarly, construction of working facilities; warehouses, garages and other structures use cement, ballast and sand as well as large volume of water for mixing and dust control. All these activities produce solid wastes and waste water of varying amounts. These demands creates pressure on available supply leading to more abstraction to fill the demand supply gap. Further, waste water from the plant may contaminate available surface or groundwater.

Other activities that are likely to impact on the flow regime include construction of camp site and on-site housing, access roads, power line etc which have the effect of accelerating water speed velocity at bridge/culvert crossing and occasionally creating backflow and accelerated runoff downstream. The camp site and on-site housing creates conducive conditions for water logging, contamination from waste water and effluent from such sites. In addition, water logging may provide breeding sites for disease transmitting vectors.

Transportation, storage and handling of construction materials, fuels and chemicals and to and from the plant may pre-dispose water resources including ground water to contaminants when there are fuel leaks, spills and poor chemical storage and handling

4.2.2 Proposed Mitigation Measures – Development/Construction Phase

This section outlines proposals for mitigation measures aimed at ensuring that the construction of the proposed development does not result in noticeable or significant negative impact on the hydrological environment. The measures should be implemented before, during and after the construction phase. These measures include but are not limited to the following:-

- Obtaining requisite Permits for Works from WRMA and NEMA.
- Developments along and inside watercourse should be approved by WRMA and a Permit issued for the same.
- Effluent discharge approval and permits should be approved by both NEMA and WRMA before commencement of works.
- Stokepiles must be managed to minimize potential for generation of silt laden runoff, leaks and spillage to safeguard impact on water quantity and water quality.
- Waste water treatment ponds with sufficient retention time be constructed to enable sufficient time for self-treatment and settlement of suspended solids to settle from the surface water collected in the silt pond thereby minimizing potential for release of silt laden surface water into surrounding drains.
- Attenuation of release of surface water runoff from construction site to ensure that it does not result in localized flooding further downstream.

- When excavating, the trenches need to be open for the shortest practicable time to minimize potential for the generation of silt laden surface water runoff.
- Construction of Troughs and Acceptable equipment to arrest oils/fuels arising from accidental spills and/leaks to stop leakage towards surrounding water courses.
- Regular inspection of dewatering drains to ensure that they work efficiently.
- Directing surface water runoff away from and around access tracks by implementing a suitably designed drainage system. Watercourse crossings to comprise culverts of suitable design.
- Dumping sites should be approved by NEMA and any other regulating body.

4.2.3 Predicted Impacts and Mitigation Measures - Operational Phase

The predicted impacts of the proposed Coal Power Plant at its Operational Phase is expected to have significant impacts on the underlying hydrological environment during normal operating conditions. It will require enormous amounts of water for its cooling, cleaning of plants and tools and discharge thermal water among others to the environment.

Most water used in the life cycle of a vast majority of power generation technologies occurs during the operational phase. This phase places high demands for water for purposes of operation of cooling systems and cleaning among other uses. Condensed steam is returned to the boilers and re-cycled. The heated water is normally discharged back to the source water or nearest receiving water bodies (i.e., river, lake, estuary, or the ocean).

If the demand is not satisfied, then it necessitates more water withdrawals from water bodies. The withdrawal of large quantities of water has the potential to compete with other important uses such as agricultural irrigation or drinking water sources.

This create competition and conflict with other water uses and users. Plant demands, consumption and thermal discharges determine the level of impact and vulnerabilities to surrounding environment, water courses and water resources.

Plants dispose material emanating from dredging of ponds and effluents discharges from cooling towers. This solid waste and waste water disposal may cause water quality degradation to receiving waters and into ground water recharge aquifers through leaching and percolation. Gaseous products, carbon dioxide, water vapour and other combustion products etc emitted by the plant into the atmosphere may dissolve in rain water and fall back as "acid rain" in future.

In addition, routine inspection and maintenance is also likely to impact on the environment through minor localized contamination to surface water bodies in the unusual event of the leakage of oil/fuel from maintenance sites, vehicles and storage facilities. Vehicles plying access roads and tracks will loosen soils and generated dust and enhance erosion and silting of receiving water sources. These are however moderate impacts.

4.2.4 Mitigation Measures - Operational Phase

The mitigation measures proposed are aimed at ensuring that the operation phase does not result in noticeable or significant negative impact on the hydrological environment. The measures should be implemented before, during and after the construction phase. These measures include but are not limited to the following:-

- Thermal discharge should be designed to ensure that discharge water temperature does not result in exceeding prescribed ambient water quality temperature for receiving water bodies and avoid being detrimental to the surrounding ecosystem

- A water recycling plant should be established alongside the development of the Coal Power Plant to guarantee efficiency in steam from boilers, condensed water, waste water and other sources of water is re-cycled and re-used in the operation of the plant.
- Disposal of materials and other contaminants should be directed to dumping sites and treatment facilities to avoid contamination of water resources and wetlands.
- Routine maintenance and inspection of plants and equipment to avoid leaks and spills.
- Vehicles should be maintained to serviceable standards through routine maintenance and inspection.
- Access tracks should be constructed and maintained to best engineering standards to reduce erosion.
- Drainage systems must be designed with sufficient capacity to surface water during floods and any other accidental spills.
- Regular maintenance of bridges, culverts and road crossings to avoid localized flooding and water logging caused by blockages.

Gaseous emissions should meet air quality standards that ensure low concentration of gaseous products.

Implementation of these mitigation measures during the operational phase will result in long-term, slight and neutral impact on the hydrological environment.

4.2.5 Decommissioning/Post-Operational Impacts

Removal or decommissioning of structures and buildings involves demolishing of facilities, and transportation. Dust, loose soil, damaged structures, spills and solid and liquid waste characterize decommissioning phase. These activities lead to increased run-off, soil compaction and changes in vegetative cover. Sediment and associated contaminants is transported and deposited to river courses and impact negatively surrounding water courses and environment.

4.2.5.1 Mitigation Measures-Decommissioning/Post-Operational Impacts

Appropriate mitigation measures should be put in place to minimize negative impacts of decommissioning. Such measures should ensure minimum dust and erosion generation by implementing appropriate soil and water management practices.

4.3 Cumulative Impacts

Prolonged release of gaseous products may accumulate in the air and lead to acid rain precipitation with adverse effect on human health, flora and fauna thereby impacting negatively the environmental setting. It is important therefore that state-of-art technology is used in the development and operation of the plant. All emissions and effluents from the plant must meet safety standards that preserve environmental integrity.

However, if the proposed development were not to proceed, a status quo would be maintained and hydrological environment would remain at the current level.

5 Future Monitoring Requirements

Future monitoring should aim at comparing with (future) and without project (baseline) or prior to disturbance conditions to gauge impact of the project.

In order to be able to carry out this task a baseline scenario of the conditions before commencement of the project must be established.

An evaluation of the current environmental setting in terms of surface water status, availability, distribution, quantities, water quality, sources, uses and users as well as stakeholder as well as an inventory of all stakeholders is therefore necessary.

In this regard, all nearby rivers, streams, wetlands, lakes and other water bodies should be identified as well as current uses of the water.

Additionally, existing relevant historic hydrometorological data in the area of influence should be collected, compiled and analyzed for development of standards and threshold for comparing trends in quantity, quality, timing as well as frequencies and fluctuations in space and time.

The thermal plants consumptive and non-consumptive uses by types and volume and water balance and needs should be assessed and quantified. Its waste water discharges, including thermal discharges data should be augmented by the results of a surface water quality monitoring program conducted at specific sites in the project area.

Indicators should be developed for continuous monitoring and evaluation (M&E) of changes in watershed characteristics, flow characteristics, drainage patterns and run-off characteristics, soils, vegetation, impervious area, floodplain etc. assist in gauging impact of the development.

To this end monitoring stations and discharge points should be mapped and regularly.

6 Summary of Impacts and Mitigation Measures

Table 4 summarizes the expected impacts and mitigation measures at each phase of Lamu Power Plant development and Operation.

Table 6-1: Potential hydrology impacts and mitigation measures

Phase	Impact	Mitigation Measure
Development/ Construction Phase		
Water quantity	Modification of drainage pattern of streams, rivers and the crossings	Planning & implementing sustainable landscape management
	Enhanced stream flow due to changes in vegetative cover & soil compaction	Ensure minimal land cover disturbance
	Reduced flows due to source destruction; wetlands and swamps	Adhere to WRMA Permit Threshold Abstraction Approval
	Enhanced water consumption - extra demands for construction, domestic and plant cooling	Adhere to WRMA Permit Allocation Approval
	Depletion of nearby water sources due to enhanced demand	Maintain Water Balance & Demand Management Scenarios
	Enhanced source development	Development be guided by thorough Water Assessment Study
Water quality	Enhanced sediment, silt generation and contaminant transport	Planning & implementing sustainable landscape management, Construction of landfill sites and Waste water Treatment facilities

Phase	Impact	Mitigation Measure
	Potential for spills and leaks due to enhanced activities on transportation	Inventory and construct hazardous material containment facilities & prepare and implement a spill prevention and response plan including HR capacity building
	Potential for acid rain due to plant emissions	Limit emissions to acceptable standards; update & adopt to new efficient technologies
	Degradation due to plant effluent, waste water and human refuse	Construction of landfill sites, Waste water Treatment facilities and sanitation systems
Cross-cutting	Enhanced conflicts on allocation due to scarcity and competing uses and users	Assess availability, allocation and manage demand thro' Stakeholder consultation
Operational Phase		
Reservoirs for cooling water	Raised water levels and enhanced potential for water logging and flooding	Develop and implement a Water, Soil and Drainage Conservation Plan
	Enhanced groundwater recharge through leaching and percolation	Continuous Monitoring and Evaluation of quantity, quality and impact to hydrological environment
Water quantity	Enhanced water withdrawals for plant operations, cleaning, effluent material conveyance and ash washout	Water Conservation Management: Water harvesting, recycling, waste water management and re-use, enhance water saving devises,
Water quality	Degrading due to contamination from dredged ponds, effluent from cooling systems, fuel spills and leaching, combustion	Construct landfills and Surface impounding reservoirs for high volume wastes, Dry handling,

Phase	Impact	Mitigation Measure
	products; ash, sludge and residue disposal	recycling of solid and liquid plant wastes
	Increased water temperature from effluent discharges	Recycling as much as possible and adhere to WRMA &EMCA Permit Thresholds for ecosystem integrity, adjust outfall location
Decommissioning/Post-Operational Phase		
Demolition, removal and transport of machinery and equipment	Water quality contamination from disposal of wastes, spills and leaks	Adhere to Spill prevention and Response plan
	Enhanced soil erosion due to transporting activities	Optimize and minimize transport activities
	Enhanced runoff due to soil compaction and changes in vegetative cover	Direct runoff to surface impoundments and treatment works before discharge to receiving waters
	Enhanced sedimentation, silting and associated contaminants into river courses	
Restoration of terrain and vegetation	Reduced erosion	Positive response to be encouraged
	Improved water quality	
	Enhanced runoff and recharge	

7 Conclusions and Recommendations

The descriptions above have highlighted the possible impacts of Coal Power Plant development and operation to the overall hydrological environment of Lamu County and its environs. It is therefore recommended as follows:-

- That all mitigation measures at each phase of the project cycle should be implemented to safeguard the hydrological environment;
- That any negative impacts should be addressed immediately after detection;
- That all development must strictly adhere to Constitutional and legal provisions as spelt out by the Constitution of Kenya (CoK, 2010), Water Act 2012, EMCA Act, 1999 and WRMA Regulations including all other relevant Acts that safeguard environmental integrity.
- That all works, emissions, effluent discharges, waste water must meet requisite approved standards, necessary approvals and permits from relevant institutions.

The Coal Power Plant is expected to have minimal impact to the hydrological environment if the measures spelt above are implemented.