Republic of The Gambia
Ministry of Fisheries and Water Resources

Consultancy Services for the National Water Sector Reform Studies for The Gambia

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Framework for a Water Quality Monitoring Programme

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prepared by

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SUMMARY

As part of the consultancy services under the National Water Sector Reform Studies, the current situation concerning water quality monitoring should be assessed and against this background recommendations for an improved water quality monitoring framework required for effective water resources management should be proposed.

Water quality monitoring is one of the foundations for water resource management as it provides the information needed to make informed managerial decisions and actions. Therefore, a water quality monitoring framework for both groundwater and surface water has been designed. The monitoring programme considers the purpose and rationale of water quality monitoring, defines the water quality parameters to be monitored, and the location and frequency of monitoring.

As The Gambia currently has not conducted an extensive examination of water quality in the country, it is proposed to initiate the monitoring programme with a baseline survey. The baseline survey comprises of comprehensive and intensive testing of groundwater and surface water quality and provides thorough background data on which to design subsequent long-term monitoring schemes. The groundwater quality monitoring is to include monitoring boreholes distributed countrywide, although more focussed in the western region, where industrial activities, tourist developments and dense human settlements (urbanization) are prevalent, and the majority of the population obtains their drinking water. Surface water quality monitoring is proposed to include both the saline/brackish section and the freshwater section of the River Gambia as well as three coastal streams, although the result of the proposed baseline survey may alter this overall scheme set-up.

The long-term water quality parameters to be monitored will be based on the results of the baseline study for both groundwater and surface water. The monitoring of the saline section of the River Gambia, however, is proposed to be limited to salinity as water quality is largely determined by the Atlantic Ocean and saline water is not exploited for water supply (potable) or irrigation uses. Groundwater monitoring is given a higher priority, as it is used for drinking water and thus can have direct implications on human health. A more intensive monitoring programme in terms of number of monitoring sites and frequency is therefore designed for groundwater as opposed to surface water monitoring.

In order to deliver reliable results, it is proposed to follow the International Organisation for Standardization (ISO) 5667-1-17 series that provides a comprehensive breakdown of sampling procedures in terms of the design of sampling programmes, sampling techniques, and preservation and handling of samples. It is also recommended that the Department of Water Resources (DWR) water quality laboratory, which will be responsible for the collection and analysis of water samples, undertake internal and external quality assurance programmes to ensure laboratory accreditation.

It is important that the water quality monitoring framework is reassessed periodically to ensure that the objectives of the monitoring are still being met and the framework is not in need of upgrading. Improvements could be in terms of the water quality parameters analysed, number and location of monitoring sites or monitoring frequency.

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ACRONYMS AND ABBREVIATIONS

AfDB	African Development Bank
AOX	Absorbable organic halides
AWF	African Water Facility
BOD	Biochemical Oxygen Demand
CCC	Criterion continuous concentration
CMC	Criteria maximum concentration
COD	Chemical Oxygen Demand
DLS	Department of Livestock Services
DO	Dissolved Oxygen
DSA	Deep sandstone aquifer
DWR	Department of Water Resources
EC	Electrical Conductivity
GBA	Greater Banjul Area
HDI	Human Development Index
ISO	International Organisation for Standardization
IWRM	Integrated Water Resources Management
KMC	Kanifing Municipal Council
LID	Lowest ineffective dilution
MDG	Millennium Development Goals
MoFWR	Ministry of Fisheries and Water Resources
NAWEC	National Water and Electricity Company Ltd.
NWSRP	National Water Sector Reform Project
NEA	National Environmental Agency
SSA	Shallow sand aquifer
TDS	Total dissolved solids
TOC	Total organic carbon
ToR	Terms of Reference
TSS	Total suspended solids
UN	United Nations
USEPA	United States Environmental Protection Agency
VWSS	Village water supply system
WHO	World Health Organization

1. INTRODUCTION

1.1 Background

Water is a fundamental part of human life and was, along with sanitation, recently acknowledged as a human right at the United Nations (UN) General Assembly. The Millennium Development Goals (MDG), developed by world leaders in 2000, made protecting the environment a priority by developing Goal 7, which aimed to ensure environmental sustainability. Goal 7(a) is focused on integrating the principles of sustainable development into country policies and programmes aimed at reversing the loss of environmental resources. (UN, 2010)

To ensure the sustainable use of water resources in a country, the development of an Integrated Water Resource Management (IWRM) programme can be beneficial. IWRM is an approach which encourages the coordinated development and management of water, land and other relevant resources in order to maximize economic and social welfare in an equitable manner without compromising environmental sustainability and vital ecosystems. IWRM provides a cross-sectoral policy approach as an alternative to the traditional sector-by-sector, top-down management approach, by recognizing the interconnected nature of finite hydrological resources.

The importance of managing a country’s water resources has been recognized in The Gambia. The Government of The Gambia approved a new Water Policy in 2007 that focuses on a comprehensive framework for the management of water resources in a sustainable manner. The principles of IWRM are to be employed to help meet the ever increasing demands for domestic water supply and sanitation and irrigated agriculture while simultaneously protecting the water resources from the pressures of for example over-abstraction, climate change and urbanization. (NWSRP, 2012)

With the aim of accelerating implementation of the National Water Policy, an IWRM Roadmap for The Gambia was elaborated in 2008. Against this background, the Ministry of Fisheries and Water Resources (MoFWR) obtained the support from the African Water Facility (AWF) of the African Development Bank (AfDB) to provide the means to embark on the National Water Sector Reform Project (NWSRP), which started in 2011.

As part of NWSRP, a consultancy services contract was entered into between MoFWR and the consulting company, NIRAS A/S (Denmark), to carry out the bulk of the activities stipulated under the NWSRP. The main objectives of the consulting services include: (NWSRP, 2012)

1. The revision of the Water Bill of 2004 to provide legislation that fully incorporates the provisions of the new National Water Policy required to establish an IWRM programme.
2. The development of an institutional set up for water resources management
3. The development of an institutional set up for meteorological services
4. The development of a water resources management strategy and implementation plan
5. The development and implementation of a training programme for the Ministry of Fisheries and Water Resources
6. The rehabilitation and improvement of the hydrological, hydro-geological, meteorological and water quality monitoring networks
7. The development and implementation of a water resources management information system
8. The assessment of groundwater resources
9. The development and implementation of a communications strategy

In order to apply an IWRM approach, it is necessary to gather information on the water resources in a country, so that informed decisions and actions can be taken. An important information to gather is that of water quality. Water quality is usually defined by physical, chemical, biological and aesthetic parameters and has great influence on how a water body is used. Water quality is not only important in terms of human health but also in terms of socio-economic activities such as agriculture, fishing, recreation, ecosystems and wildlife habitats and industrial processes.

The assessment of water quality can be carried out sporadically to determine the present-day state, but also consistently, whereby the collection of reliable data from designated monitoring sites can be employed to assess and monitor possible long-term changes due to excessive use, land use activities, climate change among others. Management decisions and action plans for the protection of water resources can be formulated on the basis of these changes.

1.2 Objectives

This report focusses on the establishment of a framework for a groundwater and surface water quality monitoring network. The main objectives are as follows:

- Define the purpose of groundwater and surface water quality monitoring and the type of monitoring envisaged.
- Identify a practical approach towards water quality monitoring in terms of number and location of water quality monitoring sites, based on the proposed (and partly under establishment) groundwater and surface water observation/monitoring sites, to be included in the network design.
- Define the parameters to be analysed and the frequency for water sampling and data collection (which also will take due consideration to prevalent budget means and importance/priority of expected issues/problems at the individual monitoring sites), including mode of sampling (manual, discrete sampling, continuous monitoring etc.).

2. HYDRO-PHYSICAL BACKGROUND

The Gambia is the smallest country on mainland Africa with a total area of 11,300 km^2. It is located on the west coast of Africa, flanked by Senegal on all sides expect for a stretch of Atlantic coastline (Figure 1). The country is located on either side of the Gambia River that flows from Guinea, through Senegal and The Gambia and discharges into the Atlantic Ocean. The capital of Gambia is Banjul and the country has a population of over 1.8 million people. The population density was 176 people/km^2 as recorded in the 2013 census. (Gambia Bureau of Statistics, 2013)

In 2012, The Gambia was ranked 165 out of 187 countries in terms of human development according to UNDP (2013), with a Human Development Index (HDI) of 0.439. HDI measures development according to three basic dimensions: a long and healthy life, access to knowledge and a decent standard of living. In 2011, The Gambia had a GDP per capita of 689 USD (UN Statistics Division, 2014). The agricultural sector accounts for 30% of the GDP, employing approximately 70% of the country's labour force. Services, predominantly re-export trade and tourism, account for another 50 of the GDP, while the manufacturing sector accounts for a further 5%.(Republic of The Gambia-European Community, 2005)

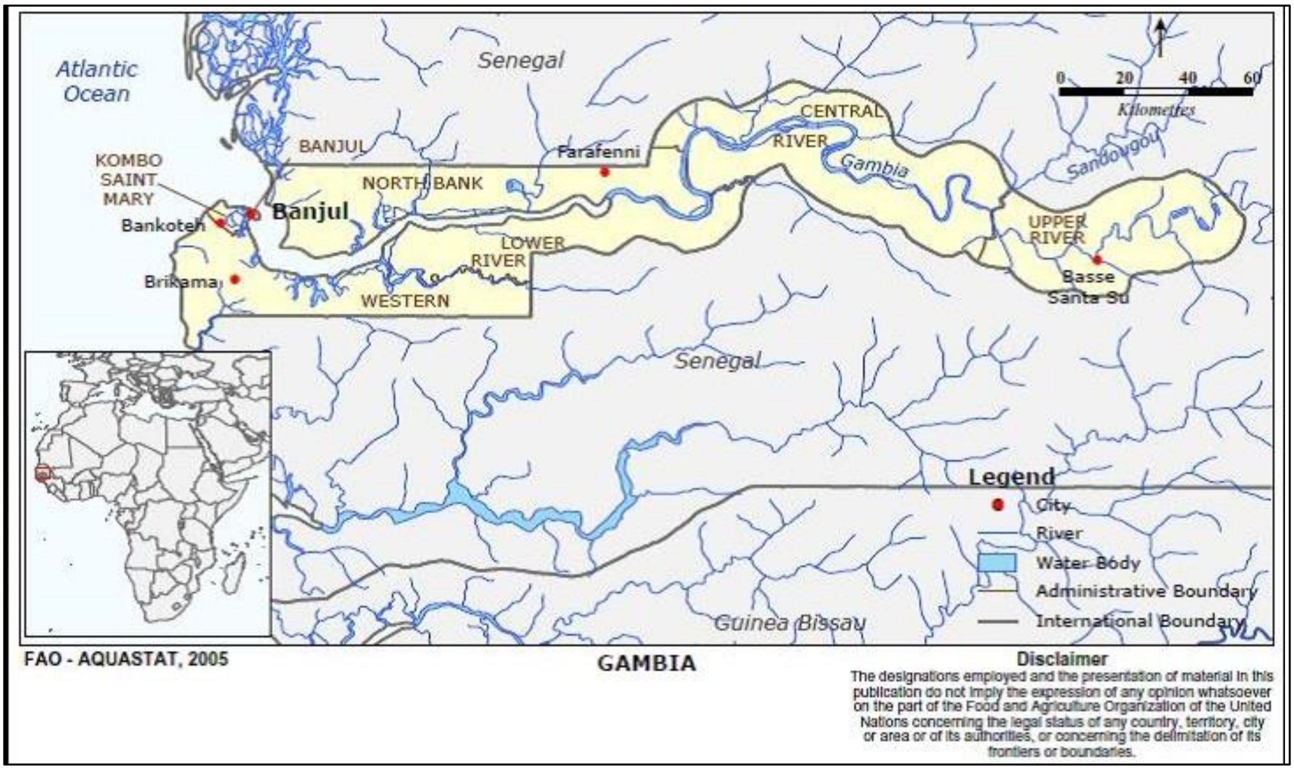


Figure 1: The Gambia country map (FAO-AQUASTAT, 2005)

2.1 Climate

Gambia lies within the tropical, sub-humid and eco-climatic zone, and experiences two distinct seasons, a wet season and a dry season. The wet season is experienced between the months of June and October with precipitation ranging from 800-1200 mm annually. August is typically the wettest month, accounting for as much as nearly 40% in average of the annual precipitation. Rainfall in The Gambia is however highly variable not only temporally but also spatially. The southwest part of the country receives the most rainfall, approximately 1200 mm annually, while the north-northeast part of the country receives the lowest amount of rainfall, approximately 800 mm annually. The dry season lasts for about six to seven months between November and April, and is dominated by dry and dust-laden winds originating from the Sahara Desert. (Jaiteh and Sarr, 2011)

The Gambia has average temperatures ranging from 18-28 °C in January to 23-36 °C in June. Temperatures are usually cooler with minimum temperatures typically below 20°C, at the beginning of the dry season. Generally, the temperatures increase as one moves eastwards with mean maximum temperatures of 43 °C in the summer months. (Jaiteh and Sarr, 2011)

2.2 Topography, geology and soil morphology

The Gambia is situated on the Mauritania/Senegal Basin which is one of the major sedimentary basins in Africa. The basin was formed during the breakup of Gondwana, an ancient landmass in the South Atlantic Ocean in the late Palaeozoic and Mesosoic times. The continental margin experienced repeated step-faulting which led to the subsidence of the basin and continuous deposition of detrital material. The detrital deposits formed a thick sedimentary sequence. A simplified summary of the geological succession and lithology on the onshore portion of the Gambia River basin since the middle of the Cretaceous period can be found in Annex 1.

The majority of the land surface therefore consists of highly-weathered detrital sediment and sandstone. The Gambia has a flat topography. The Gambia River and its tributaries are flanked by extensive floodplains, which are proceeded by upland plateaus that stretch into Senegal. The floodplains consist of a complex pattern of alluvial and fluvial marine deposits. The western soils of the Gambia River valley are highly affected by the tidal action of the sea. The intrusion of saline water into the river and subsequent flooding of the floodplains has resulted in increased salinity of the soils and the potential formation of acid sulphate soils. (SLI, 2005)

2.3 Hydrogeology

2.3.1 Groundwater

There are two main groundwater sources in The Gambia, a Shallow Sand Aquifer (SSA) and a Deep Sandstone Aquifer (DSA).

<u>Shallow Sand Aquifer (SSA)</u>
The SSA is found at depths between 15 and 120 m below ground level and is geologically of Mio-Pliocene age (Howard Humphreys Ltd and Saihou Ceesay and Sons, 1987). The SSA consists of unconsolidated sand, primarily of medium to coarse sand grains. The SSA is subdivided into an upper phreatic aquifer and a lower semi-confined aquifer, which are separated by a 15-30 m thick clay-silt aquitard. The aquitard still allows some degree of hydraulic connection between the two sections of the aquifer. Rainwater infiltration is the primary source of SSA recharge in The Gambia, marginally reinforced by lateral flow from neighbouring Senegal. Abstraction of groundwater in The Gambia, is solely from the SSA, where the upper phreatic aquifer is exploited mainly through numerous dug wells, while the lower semi-confined aquifer is utilized through boreholes. (NIRAS, 2013a)

<u>Deep Sandstone Aquifer (DSA)</u>
The DSA occurs at average depths of about 250 to 300 m below ground level and is separated from the SSA by a shale-marl aquiclude 200-300 m thick. The DSA consists of Palaeocene and Maastrichtian sandstones. The Palaeocene sandstone occurs in the western part of the country and

in the eastern part of the country but is seemingly absent in the central section. In the central part of the country, Palaeocene sandstone is replaced by marl and limestone. (Howard Humphreys Ltd and Saihou Ceesay and Sons, 1987). A study with focus on Senegal indicated the presence of mainly three independent zones with differing hydraulic characteristics and groundwater flow direction, namely the eastern, central and western zones (Figure 2). The groundwater flows in eastern zone show a centripetal pattern, but most of the recharge stems from the south and south-eastern edges of the basin. (Cowi, Polyconsult and SGPRE, 2001).

It is estimated that the DSA is recharged by lateral flows from the southern part of Senegal at a rate of 1.75 Mm^3/year. (Howard Humphreys Ltd and Saihou Ceesay and Sons, 1987). The geological structure of the central zone blocks lateral flow and the water are stagnant and saline. The western zone is therefore geologically basically isolated from the rest of the Maastrichtian aquifer and recharge is therefore primarily by deep infiltration of rainwater, which is currently undermined by the exploitation of the overlying SSA. The DSA is not currently exploited in The Gambia. (NIRAS, 2013a)

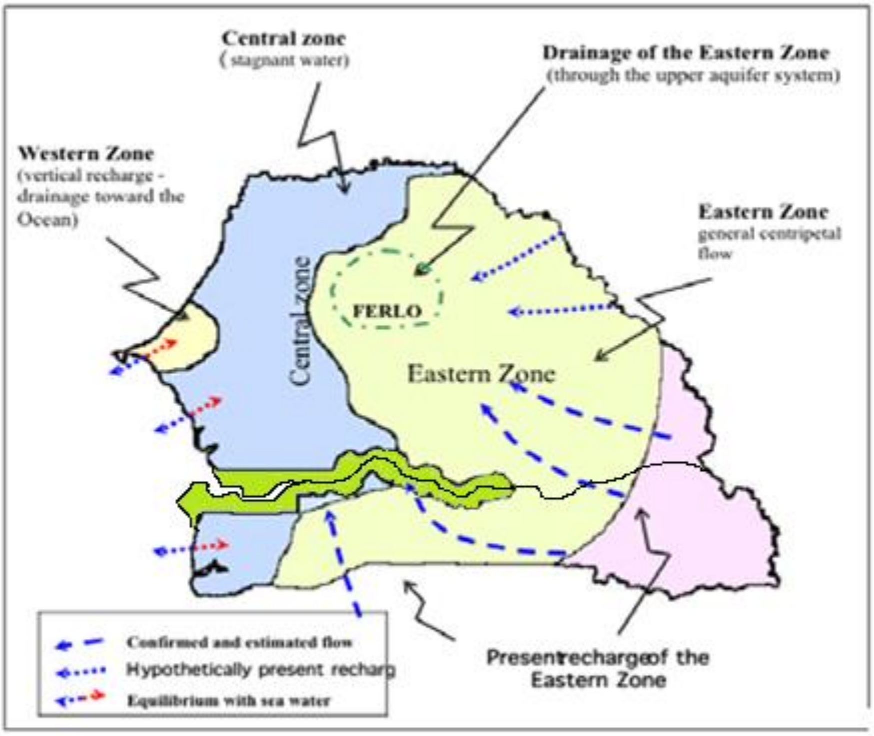


Figure 2: Groundwater flow direction in the deep sandstone aquifer in the Senegal (Cowi, Polyconsult, and SGPRE, 2001). The Gambia is indicated in green.

2.3.2 Surface waters

The surface waters in The Gambia lie within the Gambia River basin. The Gambia River basin stretches between 11° and 15° North latitude, and 11° and 17° West longitude in the semi-arid Sudano-Sahelian zone of West Africa (Figure 3). The Gambia River and its tributaries drain approximately 77,850 km^2 of territory in four countries, The Gambia, Senegal, Guinea and Guinea-Bissau. It has its source in north Guinea at a level of 1,125 m above sea level, from where it flows in a north-westerly direction through the southern part of Senegal where after the flow turns westwards through the entire Gambia and into the Atlantic Ocean. The river stretches over a distance of 1,150 km, where approximately 530 km are within The Gambia.

Like the other rivers in the region, the flows in the upper reaches of the Gambia River are highly seasonal, while those in the lower courses are greatly influenced by tidal action. The Gambia River is less than 1 m above sea level throughout its course in The Gambia and can therefore experience sea water intrusion extending up to some 250 km upstream during the dry season and in extreme cases up to 310 km upstream. During the wet season from mid-July to mid-September, the increase in river flow pushes the fresh-salt water interface downstream and lies at around 70-160 km from the estuary mouth.

The major tributaries to the River Gambia all originate in Senegal. The tributaries have meandering courses over swampy mangrove areas and are under the influence of the tides in the lower reaches. These include the Bao, the Mini Minum, the Nianija and the largest tributary, Sami Bolong. (NIRAS, 2013b)

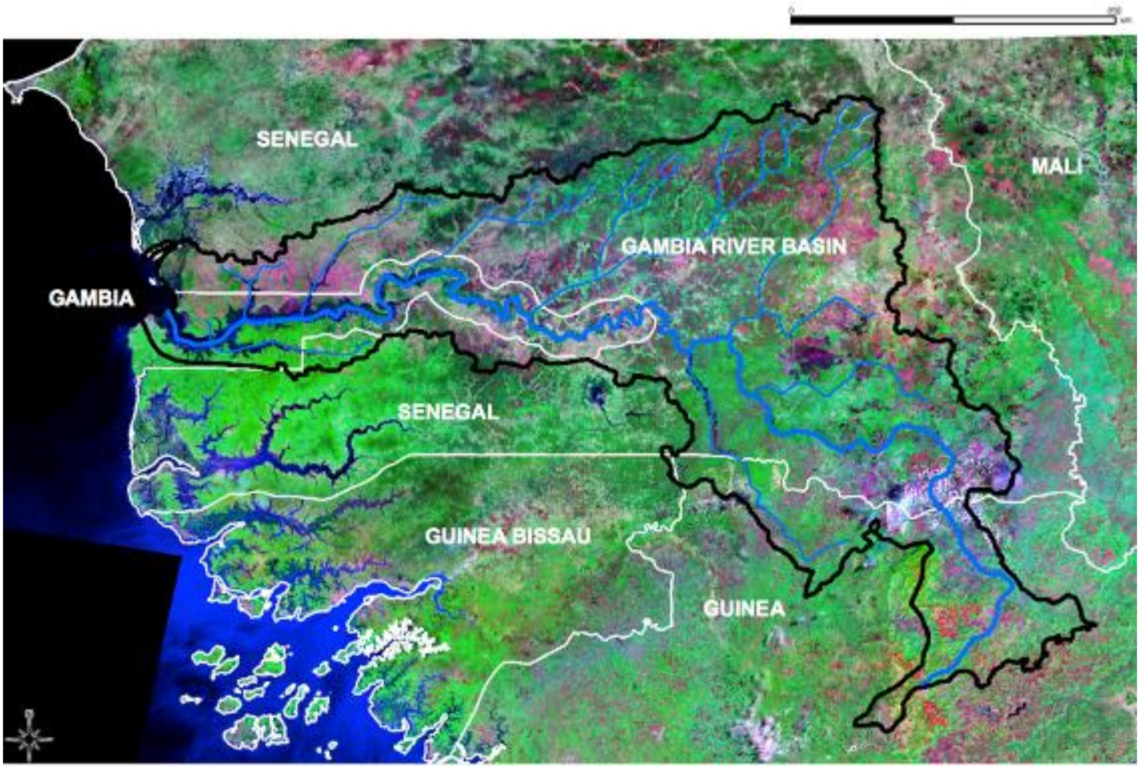


Figure 3: Gambia River Basin (NIRAS, 2013b)

2.4 Land cover and land use in The Gambia

Forested areas make up 43% of The Gambia. Forested areas comprise of open and closed woodlands, savannah woodland, and mangrove forests. Open woodland refers to forests with a canopy cover exceeding 50% and a tree height of at least 11m, while closed woodland refers to forests having a crown cover of 10 to 50%. Savannah areas are areas with a crown cover of less than 10%. Of the forested areas, 7% constitute the 66 national forest parks. (NEA, 2010)

The land use pattern in The Gambia is largely related to the vegetation types across the country. The western half of The Gambia, comprising of the Greater Banjul Area (GBA), the entire western region and the western parts of the Lower River Region, receives higher precipitation rates than the eastern half. The western half therefore has thicker land forest covers of bigger tree species. These areas have attracted the majority of the human settlements in The Gambia, whereby residents mainly engaged in crop farming and logging. On the other hand, the eastern half of the country, receiving lower amounts of rainfall, is mostly covered with shrubs and savannah grasses. These areas are mainly used for crop production and livestock rearing. (NEA, 2010)

2.4.1 Agricultural practices

The agricultural activities in The Gambia account for approximately a third of the land use. The topography of The Gambia is a determining factor for the agricultural practices. There are three distinct zones, the Gambia river with its tributaries and mangrove vegetation along the banks, the floodplains of the river, and the upland plateau of the country which extends into Senegal. The upland plateau is mainly used for the cultivation of crops such as groundnuts, millet, sorghum, and cotton due to the sandy soils (Figure 4). The swampy river floodplains are used for the cultivation of rice. The mangrove forests are ideal for the harvesting of oysters and is also commonly exploited for wood. (NEA, 2010)

The use of fertilizers and pesticides in The Gambia is widespread. Pesticides are not manufactured in The Gambia but are imported and sold. The National Environmental Agency (NEA) registers all the pesticides that enter the country legally but it has been reported that some pesticides are smuggled into the country illegally. A list of the pesticides currently approved for use in the Sahelian region are given in Annex 2. The majority of farmers are also untrained in the proper use of pesticides and this has in many cases resulted in the overuse and/or inappropriate use of pesticides. The storage of pesticides and disposal of containers or applicators contaminated with pesticides is another cause for concern as both some farmers and unlicensed pesticide distributors are unaware of the hazardous impacts of these chemicals. (NEA, 2010)

2.4.2 Urbanisation

The urban areas of The Gambia account for 16% of the land area, on which more than 50% of population lives. This highly populated area – basically constituting the Greater Banjul Area – is therefore prone to poor sanitary conditions, high waste generation and pollution in general. In the urban areas, there is also an industrial sector. The sector is still quite modest in The Gambia and is mostly limited to plastic materials production, agro-based soap production, production of candles, a brewery, bottlers, confectionery production, sand and gravel mining among other small scale industries. (NEA, 2010) These industries can be a cause for concern in terms of water quality, as chemicals and other discharges can pollute surface water and groundwater if not handled appropriately. As development continues the industrial sector is also likely to grow and this is important to consider for future water quality monitoring. As part of this study, the GPS coordinates of some of the main industries were gathered and indicated on a map to facilitate the planning of water quality monitoring activities (Figure 5).

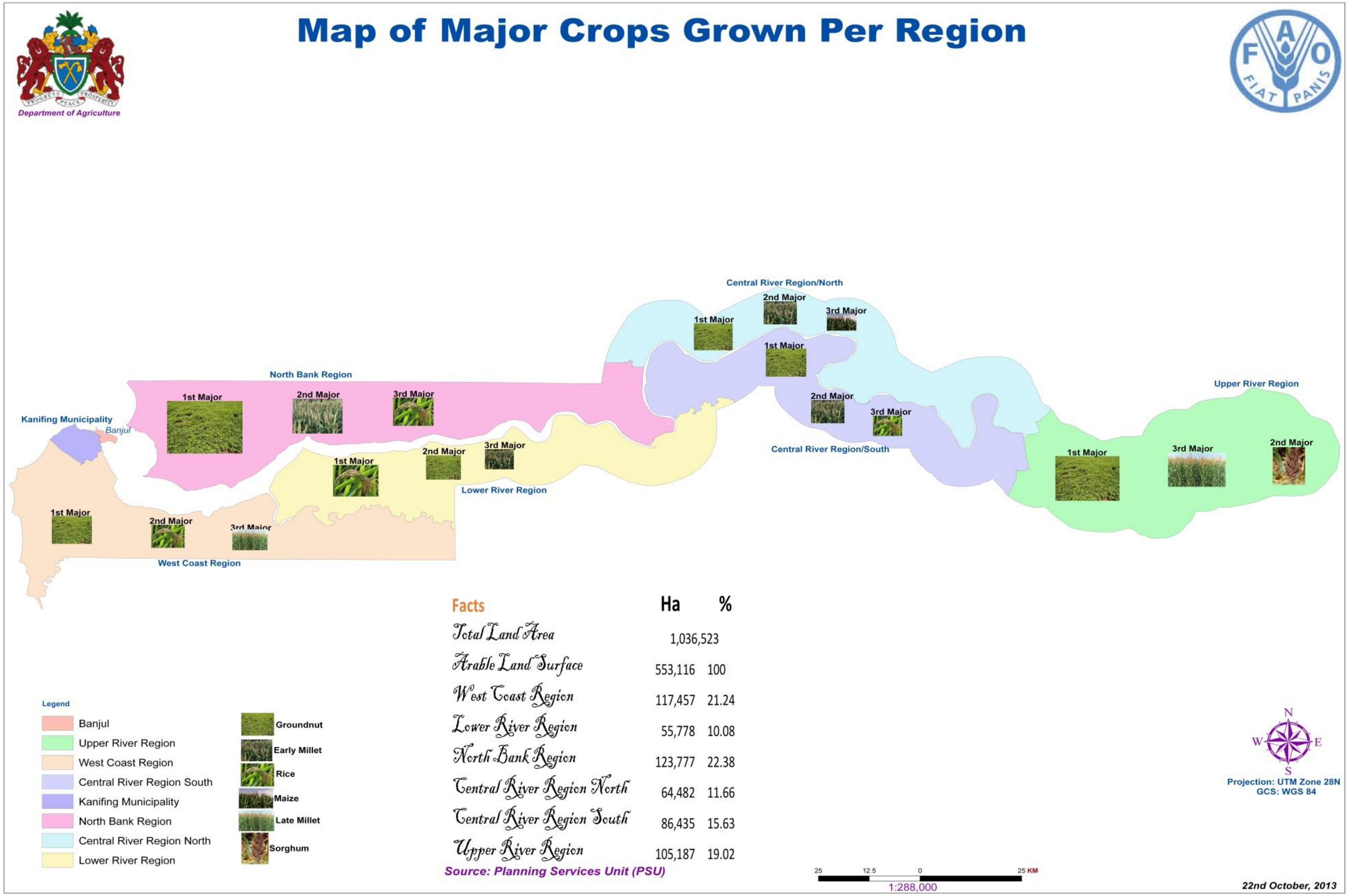
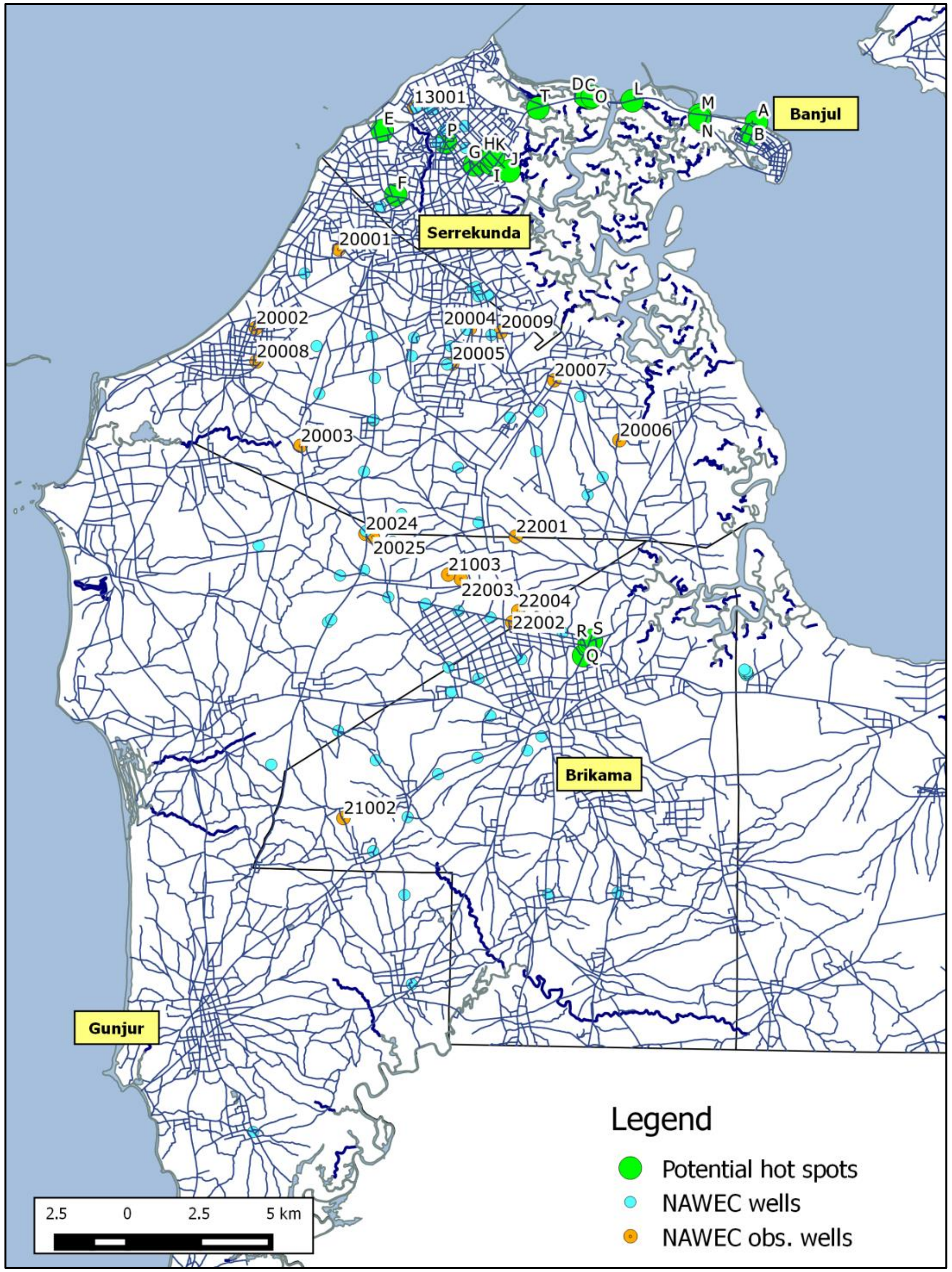


Figure 4: The major types of crop farming associated with the different regions of The Gambia (Department of Agriculture, 2013)



Potential 'hot spots' shown as green circles:

- A Banjul Sewage Discharge Pipe
- B NAWEC emergency wastewater discharge point
- C Foam matresss industry
- D The Atlantic Seafood company
- E Kotu wastewater stabilisation ponds
- F Bakoteh dump site
- G GAMbega company
- H Banjul Brewery Ltd
- I Sankung Silla & Sons
- J Banjul Brewery Ltd. discharge point
- K GAMWATER
- L GGC groundnut industry
- M Nasser foam manufacturing
- N Mile II Dumpsite
- O Salam company
- P Kairaba laundry
- Q NAWEC power station
- R Jah cement
- S Toskani pharma Gambia Ltd.
- T Gambia Milling Ltd

Figure 5: Western region showing some of the potential 'hot spots' identified, the 18 proposed monitoring boreholes and the NAWEC extraction wells

2.4.3 Waste management

There are two official solid waste dumpsites in the GBA, Bakoteh dumpsite and Mile II dumpsite (Figure 5). The Bakoteh dumpsite receives solid waste from Kanifing Municipal Council (KMC) and parts of Kombo North and is situated in an old quarry that is surrounded by a residential area, a school and an orphanage. The Mile II dumpsite receives solid waste from Banjul city and is situated in a wetland and very close to the RVTH Sanatorium.

The municipalities do not have the capacity to collect all domestic waste for disposal and the majority of residents resort to open burning, dumping in old wells, burying or merely dumping on grounds around their households. The dumpsites are the only disposal facilities available, apart from the Medical Research Council's incinerator, and therefore a wide range of waste is deposited including domestic waste, commercial waste, industrial waste, construction waste and the majority of clinical waste. The waste in the dumpsites is occasionally burnt to reduce the quantity. Neither of the dumpsites are sanitary landfills and therefore there is a high risk of groundwater and nearby surface water contamination. (NEA, 2010)

Wastewater in The Gambia is also a critical source of pollution. Some parts of the urban area are connected to a municipal sewerage system, run by the National Water and Electricity Company Ltd. (NAWEC), through which sewage is either discharged untreated through a pipeline into the Atlantic Ocean (Banjul city), or is directed into wastewater stabilisation ponds (Kotu). The stabilisation ponds have a capacity of around 20,000 m^3/d. The stabilisation ponds do not only receive wastewater from the sewerage system but also from approximately 14 sludge tankers daily. There is no preliminary treatment of the wastewater before being discharged to the ponds. The ponds are not functioning as intended as the old pumps are constantly breaking down leading to the back up and overflow of sewerage. The sludge received from the sludge tankers often also contain plastics and other solids. (NEA, 2010)

Not all flush toilets in the urban areas are connected to the municipal sewerage system and many resort to private septic tanks. The risk of leakage to the groundwater from septic tanks is high as not all septic tanks are properly constructed. In low income areas and rural areas, outdoor pit latrines are commonly used. These pit latrines are often poorly constructed and are also a source of groundwater contamination. This is of particular concern during the rainy season when the groundwater table rises and the pits become hydraulically connected to the shallow aquifer. (NEA, 2010)

2.5 Purpose of water quality monitoring

The purpose of the water quality monitoring framework in The Gambia is to detect changes in water quality with time. Water quality monitoring data is not only valuable for basic information on the condition of the water resources in the country but also for planning and policy information, management and operational information and regulation and compliance information. The guiding principles behind the water quality monitoring framework are: (UNEP & WHO, 1998)

1. To detect any signs of deterioration of the surface water or groundwater quality
2. To identify any water bodies or resources that do not meet the desired water quality standards
3. To identify contaminated areas
4. To determine the extent and effect of waste discharges

5. To define regulations covering the quantity and quality of waste discharges
6. To evaluate the impact of the implementation of an Integrated Water Resources Management Programme

3. CURRENT STATE OF WATER QUALITY MONITORING

3.1 Past monitoring activities

The past water quality monitoring activities in The Gambia have not been carried out in a systematic manner. Monitoring has been done on a need to know basis on request from particular projects or organisations. Surface water quality monitoring has rarely been undertaken and has been mainly limited to salinity measurements. A few water quality samples were taken in some areas for a study on oyster farming. The parameters determined included dissolved oxygen (DO), salinity, total coliforms and faecal coliforms. NEA, every 2-3 years collects 10-15 surface water samples for testing by the Department of Water Resources (DWR) laboratory. However, surface water quality sampling has not been conducted in approximately the last 5 years.

Groundwater quality monitoring of the shallow sand aquifer is done regularly for NAWEC production boreholes in the Greater Banjul Area. The monitoring was conducted monthly for 10 years, but has recently been reduced to quarterly. Groundwater monitoring country wide is carried out on request. Groundwater analyses of the deep sandstone aquifer has previously been conducted in three deep boreholes across the country. The groundwater quality parameters generally monitored are listed in Table 1.

Table 1: Groundwater quality parameters analysed by DWR

Type of parameter	Parameter	Units
Physical	Temperature	^oC
	Turbidity (NTU)	NTU
	pH	-
	Electrical Conductivity	µS/cm
	Total Dissolved Solids	mg/l
	Salinity	‰
	Colour	-
	Odour	-
	Taste	-
	Suspended Solids	mg S.S./l
Chemical	Phosphate	mg PO_4^{3-}/l
	Nitrate	mg NO_3^--N/l
	Nitrite	mg NO^-_2-N/l
	Total Iron	mg $Fe^{2/3+}$/l
	Chloride	mg Cl^-/l
	Alkalinity	mg $CaCO_3$/l
	Free Carbon dioxide	mg CO_2/l
	Hardness	mg $CaCO_3$/l
	Calcium	mg Ca^{2+}/l
	Magnesium	mg Mg^{2+}/l
	Manganese	mg Mn^{2+}/l
	Fluoride	mg F^-/l
	Sulphate	mg SO_4^{2-}/l
	Ammonia	mg NH_4^+/l
Microbiological	Total Coliform	No./100ml
	Faecal Coliform	No./100ml
Observational	Sanitary Survey	Status of the observation site

Arsenic has been tested in a few shallow wells in the western part of The Gambia for a certain project, and arsenic was not detected. Monitoring was, however, not extensive or country wide.

3.1.1 Groundwater quality status

The water quality of numerous boreholes tested countrywide during the years 1994-2005 and in 2011 are summarized in Table 2. The table shows the number of samples tested and the average, minimum and maximum concentrations of each water quality parameter. The World Health Organisation (WHO) health guidelines are also indicated in the table where applicable, whereas aesthetic thresholds have been used for other parameters (WHO, 2011).

Table 2: Summary of groundwater quality from samples taken from boreholes analysed by DWR between 1994-2005 and 2011

Parameter	No. of samples	Minimum content	Maximum content	Median content	WHO drinking water guidelines (WHO, 2011)
pH	491	4.1	8.1	5.5	6.5-8.5
Temperature (°C)	469	18.8	39.3	30.1	Acceptable
EC (µS/cm)	489	3.7	15650.0	52.3	1300
TDS (mg/l)	394	<D.L	8850.0	25	1000*
Salinity (promille)	330	<D.L	9.2	0	NS
Turbidity (NTU)	20	0.3	2.8	0.7	<5*
Suspended Solids (mg/l)	20	<D.L	11.0	1	NS
Alkalinity (mg $CaCO_3$/l)	313	<D.L	7330.0	10.5	>20
Free CO2 (mg/l)	270	<D.L	706.0	86	NS
Total Hardness (mg $CaCO_3$/l)	336	<D.L	342.0	16.7	200
Calcium (mg Ca/l)	250	<D.L	82.1	4.8	200
Magnesium (mg/l)	249	<D.L	76.0	1.6	150
Chloride (mg/l)	257	<D.L	1250.0	8.5	250
Total Iron (mg Fe/l)	396	<D.L	500.1	0.03	0.3
Ammonia (mg N-NH3/l)	301	<D.L	243.0	0.03	NS
Nitrate (mg N-NO3/l)	391	<D.L	63.6	0.6	50
Nitrite (mg N-NO2/l)	265	<D.L	2.5	0.003	3
Phosphate (mg PO4/l)	247	<D.L	103.0	0.21	NS
Silica (mg SiO2/l)	22	9.0	30.0	13.8	NS
Manganese (mg/l)	113	<D.L	1.0	0.012	0.4
Chromium (mg Cr6+/l)	6	<D.L	<D.L	0	0.05
Copper (mg/l)	56	<D.L	6.0	0	2
Fluoride (mg/l)	232	<D.L	13.4	0.165	1.5
Potassium (mg/l)	60	<D.L	110.0	0.3	NS
Sodium (mg/l)	82	<D.L	650.0	4	200*
Sulphate (mg/l)	253	<D.L	160.0	1	250*
COD (mg/l)	3	<D.L	1623.0	1	NS
TC (/100ml)	172	0	70000.0	0	Absent
FC (/100ml)	408	0	50000.0	0	Absent

<D.L indicates measurements under the detection limit; *indicates guidelines that are not based on aesthetics rather than health; NS indicates no standard given by WHO.

The groundwater quality determined in numerous rural wells country wide are summarized in Table 3.

Table 3: Summary of groundwater quality from samples taken in rural wells by DWR between 1994-2000

Parameters	No. of samples	Minimum content	Maximum content	Median content	WHO drinking water guidelines (WHO, 2011)
pH	1049	3.6	10.5	5.5	6.5-8.5
Temperature (°C)	962	20.2	53.6	30.7	Acceptable
EC (uS/cm)	1050	10.6	23400.0	100.4	1300
TDS (mg/l)	792	7.0	1600.0	47.8	1000*
Salinity (promille)	547	<D.L	55.0	<D.L	NS
Alkalinity (mg $CaCO_3$/l)	114	<D.L	500.0	25.3	>20
Free CO2 (mg/l)	76	<D.L	4145.0	50.0	NS
Total Hardness (mg $CaCO_3$/l)	206	2.0	695.0	38.8	200
Calcium (mg Ca/l)	99	0.7	124.4	12.6	200
Magnesium (mg/l)	99	<D.L	185.8	3.8	150
Chloride (mg/l)	174	0.3	756.0	9.0	250
Total Iron (mg Fe/l)	807	<D.L	6.7	<D.L	0.3
Ammonia (mg N-NH3/l)	93	<D.L	16.0	0.2	NS
Nitrate (mg N-NO3/l)	659	<D.L	50.0	2.8	50
Nitrite (mg N-NO2/l)	67	<D.L	3.3	<D.L	3
Phosphate (mg PO4/l)	65	<D.L	91.2	0.3	NS
Silica (mg SiO2/l)	18	8.9	30.0	16.8	NS
Manganese (mg/l)	20	<D.L	1.0	<D.L	0.4
Chromium (mg Cr6+/l)	19	<D.L	0.1	<D.L	0.05
Fluoride (mg/l)	118	<D.L	1.2	0.3	1.5
Potassium (mg/l)	6	<D.L	1.8	1.0	NS
Sodium (mg/l)	8	<D.L	25.0	2.5	200*
Sulphate (mg/l)	63	<D.L	54.0	3.0	250
TC (/100ml)	234	<D.L	33200.0	<D.L	Absent
FC (/100ml)	873	<D.L	7200.0	5.0	Absent

<D.L indicates measurements under the detection limit; * indicates guidelines that are based on aesthetics rather than health; NS indicates no standard given by WHO

On average, the water of the boreholes and rural wells tested are of fairly good quality. The water quality values presented in Table 2 and Table 3 are related to groundwater in the SSA.

The pH values in the SSA have been recorded to be on the low side, ranging from 4.0 to 6.7 in some areas. In existing treatment works in the Greater Banjul Area this is raised by aeration for the stripping of free CO_2 gas or by lime dosing. High iron content has also been identified in a number of places, with concentrations typically ranging from 2.5 mg/l to 4 mg/l. In some areas, like Bansang, the groundwater has high iron and Total Suspended Solids (TSS) content. High iron content is also observed at Sibanor, Bullock, and Sintet in the Western Division, and Jali, Pakaliba, Dumbutu, Dongoroba, Bureng and Kwinella in the Lower Division.

The nitrate (NO_3) concentrations in groundwater are for the most part within the WHO guidelines of 50 mg/l. High concentrations of nitrate concentration, 45-50 mg/l, are mostly found in the Central River Region in a rural well located behind a market. The high concentrations are therefore likely related to pollution from the market. Fluoride content is generally well within WHO standards in the SSA groundwater. Only three of 232 SSA fluoride measurements were above the guideline, with concentrations 1.55, 1.6 and 13.4 mg/l. The highest concentration of 13.4 mg/l was measured close to Kotu power station and is therefore suspected to be related to a polluted discharge.

The electrical conductivity, and hence the total dissolved solids, have on average been measured to be well within the WHO standards in the range of 50 to 400 μS/cm at 25^{o}C. High electrical conductivities are normally observed in boreholes and wells close to the coast line and the saline section of the River Gambia. High electrical conductivity and TDS values were seen in for example rural wells in Kombo East, Jarra Central; and Upper and Lower Baddibu which are all located close to the saline section of the River Gambia. High conductivity and TDS values were also seen in the borehole close to Kotu power station. The groundwater in the well fields in the northern part of Greater Banjul Area shows electrical conductivity values below 100 μS/cm.

Some boreholes and rural wells showed high biological contamination with high levels of total and faecal coliforms. This is likely related to contamination by septic tanks or pit latrines in the vicinity or in the case of open wells, contamination can come from humans and animals at the well opening.

There are three DSA boreholes located in Banjul, Sankwia and Garowal (Figure 6). These three boreholes give an indication of the DSA across The Gambia, with Garowal located in Upper River Region, Sankwia located in Lower River Region, and Banjul located in Western Region. Water quality samples were taken from the free artesian flow at Banjul, while Sankwia and Garowal were sampled during pump-tests. Sampling has been carried out over 20 years for various projects and the results suggest that the groundwater chemistry in the DSA has remained fairly constant. (Howard Humphreys Ltd and Saihou Ceesay and Sons, 1987)

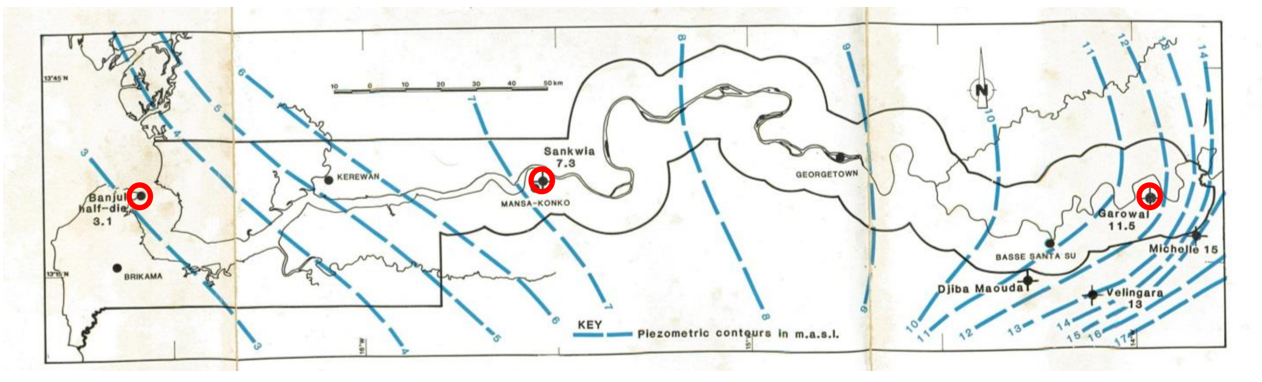


Figure 6: Piezometric map of the deep sandstone aquifer showing the location of the 3 deep boreholes, Banjul, Sankwia and Garowal, highlighted with a red circle. (Saihou Ceesay & Sons Ltd and Howard Humphreys Ltd, 1987)

Table 4: Water quality parameters of the deep sandstone aquifer groundwaters (Howard Humphreys Ltd and Saihou Ceesay and Sons, 1987)

Parameters	Garowal	Sankwia	Banjul	WHO drinking water guidelines
pH	7.0	8.0	7.5-8.0	6.5-8.5
Temperature (°C)	38	35	36	Acceptable
EC (uS/cm)	550	1780	3160	1300
TDS (mg/l)	322	955	1766	1000*
Calcium (mg Ca/l)	34	6	6	200
Magnesium (mg/l)	20	3	5	150
Chloride (mg/l)	17	355	660	250
Bicarbonate (mg HCO_3^-/l)	317	329	616	NS
Total Iron (mg Fe/l)	0.11	0.21	0.28	0.3
Nitrate (mg N-NO3/l)	0.1	0.2	0.1	50
Silica (mg SiO2/l)	17	16	31	NS
Manganese (mg/l)	0.03	0.03	0.03	0.4
Fluoride (mg/l)	0.4	1.8	5.3	1.5
Potassium (mg/l)	13	10	20	NS
Sodium (mg/l)	59	355	685	200*
Sulphate (mg/l)	28	42	101	250
Lead (mg/l)	0.03	0.03	0.03	0.01
Cadmium (mg/l)	0.005	0.005	0.005	0.003
Copper (mg/l)	0.03	0.03	0.03	2
Zinc (mg/l)	0.03	0.03	0.03	3
Boron (mg/l)	0.07	0.75	2.00	0.5

* indicates guidelines that are based on aesthetics rather than health; NS indicates no standard given by WHO

From Table 4, it can be seen that there is a tendency for the DSA groundwater quality to decrease in quality when moving from east to west in the country. The DSA groundwater shows an increasing mineralization from east to west shown by TDS and EC values. The eastern waters show higher concentrations of calcium and magnesium, while moving westwards across the country, concentrations of bicarbonate, sodium, chloride, boron, fluoride and iron increase. DSA groundwater in Sankwia and Banjul show EC, chloride fluoride and boron concentrations above the WHO drinking water guideline. While all DSA boreholes have lead and cadmium concentrations above the WHO guidelines. (Howard Humphreys Ltd and Saihou Ceesay and Sons, 1987)

3.1.2 Surface water quality status

The DWR conducts a few surface water quality analyses in a periodic manner depending on project needs (Table 5). The main interest of the sampling conducted was to determine the extent of the saline front and therefore analyses were mostly focussed on the physical parameters. As the surface water is not intended for drinking purposes, the water quality parameters are compared to the United States Environmental Protection Agency (USEPA) guideline values (USEPA, 2014) for the protection of freshwater aquatic life. The criteria maximum concentration (CMC) and criterion continuous concentration (CCC) indicate the highest concentration of a material in surface water that would not cause an unacceptable effect on an aquatic community when exposed briefly and when exposed indefinitely respectively (USEPA, 2014).

Table 5: A summary of the surface water quality from samples taken in the River Gambia by the Water Quality Laboratory between 1994-2000

Parameter	No. of samples	Minimum content	Maximum content	Median content	USEPA aquatic life criteria (USEPA, 2014)	
					CMC	CCC
pH	65	4.7	8.5	7.9	NS	6.5-9
Temperature (°C)	68	21.9	32.0	27.7	NS	NS
EC (uS/cm)	70	36.3	110000.0	58200.0	NS	NS
TDS (mg/l)	63	24.0	51100.0	29800.0	NS	NS
Salinity (promille)	21	<D.L	34.3	5.0	NS	NS
Turbidity (NTU)	47	5.0	260.0	25.0	NS	NS
Alkalinity (mg $CaCO_3$/l)	2	132.1	162.8	147.4	NS	≥20
Free CO2 (mg/l)	1	26.0	26.0	26.0	NS	NS
Total Hardness (mg $CaCO_3$/l)	11	620.0	6915.2	6200.0	NS	NS
Calcium (mg Ca/l)	6	385.0	600.0	540.0	NS	NS
Magnesium (mg/l)	6	440.0	1400.0	1358.5	NS	NS
Chloride (mg/l)	18	13273.0	48200.0	18359.5	8600	2300
Total Iron (mg Fe/l)	26	<D.L	0.8	<D.L	NS	10
Ammonia (mg N-NH3/l)	13	<D.L	9.4	0.6	17 (1h avg.)	1.9 (30d rolling avg.)
Nitrate (mg N-NO3/l)	44	0.1	15.0	0.9	NS	NS
Nitrite (mg N-NO2/l)	11	<D.L	<D.L	<D.L	NS	NS
Phosphate (mg PO4/l)	20	<D.L	1.3	0.4	NS	NS
Silica (mg SiO2/l)	1	5.0	5.0	5.0	NS	NS
Manganese (mg/l)	1	0.4	0.4	0.4	NS	NS
Chromium (mg Cr6+/l)	1	<D.L	<D.L	<D.L	0.16	0.11
Dissolved Oxygen (mg/l)	40	2.0	15.0	6.8	5.5 (30d mean for warm water)	
BOD (mg/l)	45	<D.L	8.2	2.0	NS	NS
COD (mg/l)	4	130.0	770.0	455.0	NS	NS
TC (/100ml)	20	<D.L	1500.0	36.5	70 (for shellfish harvesting)	
FC (/100ml)	57	<D.L	1609.0	38.0	15 (for shellfish harvesting)	

<D.L indicates measurements under the detection limit; NS indicates no standard given by USEPA

Surface water samples taken from Kombo East and Greater Banjul in Western Region, the areas closest to the Atlantic Ocean, show salinities of approximately 25-35 ‰ indicating saline water. Samples taken in North Bank Region, Lower River Region and Central River Region are for the most part brackish with salinities ranging from 0.8-25 ‰. Samples taken in the eastern part of the Central River Region vary from freshwater to brackish water depending on the season, as during the dry season the saline front extends further up the river than during the rainy season. The high salinities are also supported by the high chloride content and electrical conductivity measured in the samples. Only one sample was taken in the Upper River Region and salinity was not measured. The electrical conductivity of the sample was only 36.3 µS/cm which is equivalent to that of rainwater.

The Biochemical Oxygen Demand (BOD) is a good measure of pollution in surface waters. The average BOD value, 2.0 mg/l, from the samples show waters of good quality as per the USEPA guideline of 5 mg/l for surface waters intended for abstraction of drinking water (USEPA, 2001). Based on the samples taken, the coliform content of the river is fairly low, with averages under 40/100 ml for both total and faecal coliforms. Good quality surface waters should maintain numbers of 5000/100 ml and 1000/100 ml for total and faecal coliforms respectively according to the USEPA guideline (USEPA, 2001). Based on the major cations and anions measured water quality must be rated to be fairly good.

3.2 Groundwater monitoring network

3.2.1 Existing and impending observations sites

As part of the NWSRP/NIRAS consultancy, 53 existing boreholes were inspected and evaluated in terms of functionality and suitability for the future monitoring network. Of the 53 boreholes, 28 are owned by NAWEC and are used for the production of drinking water. The NAWEC boreholes were previously analysed by the DWR laboratory but are currently not being monitored. Four of NAWEC boreholes were found to be backfilled with waste and one of the boreholes could not be traced. (NIRAS, 2013a)

Twelve of the 53 boreholes were constructed by the Department of Livestock Services (DLS) to provide water for livestock farming. Five of these boreholes were found to be vandalized. Twelve boreholes fitted with piezometers were also identified. These boreholes belonged to the Village Water Supply Systems (VWSS) and were constructed in order to monitor the seasonal groundwater level fluctuation both in the phreatic and shallow sand aquifer. The DWR also have an additional borehole that can be used for monitoring. (NIRAS, 2013a)

As part of the NWSRP/NIRAS consultancy, 20 new boreholes are to be constructed in 2014 for monitoring of water level country wide and their location was based on groundwater flow patterns (Table 6) (NIRAS, 2013a). Annex 3 presents a map of the proposed existing and new monitoring boreholes respectively.

Table 6: The location of the proposed 20 new boreholes

No.	Site name	Division
1	Tannene	West Coast Region
2	Somita	West Coast Region
3	Mayork	West Coast Region
4	Kwinella	Lower River Region
5	Karantaba	Lower River Region
6	Pakaliba	Lower River Region
7	Denton Boiram	Central River Region
8	Yoro Beri Kunda	Central River Region
9	Santanto Bubu	Central River Region
10	Kerr Modi Hali	Central River Region
11	Kerr Sait Mariam	Central River Region
12	Tabanani	Central River Region
13	Ndungu Kebbeh	North Bank Region
14	Gunjur	North Bank Region
15	Farafanni	North Bank Region
16	Ballingara	North Bank Region
17	Yorobawol	Upper River Region
18	Brifu	Upper River Region
19	Mansajang	Upper River Region
20	Kantel Kunda	Upper River Region

3.3 Surface water monitoring network

3.3.1 Existing and impending observations sites

As part of the NWSRP/NIRAS consultancy study (NIRAS, 2013b), an evaluation of the state and suitability of the existing surface water monitoring sites was carried out, in order to identify sites for inclusion in the future monitoring operations. On the River Gambia, eight main monitoring stations were located. Only 2 were operational (newly renovated), the remaining 6 were non-operational either due to vandalism or destruction caused by collision with ferries or river barges. On the tributaries to the River Gambia, five monitoring sites were located. One of the sites had been renovated, one was not in operation and two were identified as good sites but were not fitted with monitoring equipment. (NIRAS, 2013b)

A summary of the existing stations, both functioning and non-functioning, consists of the following: (NIRAS, 2013b)

- 11 water level stations: Banjul, Balingho, Pakaliba, Kaur, Chamen, Kuntaur, Jahally, Bansang, Sami Tenda, Basse and Fatoto

- 11 salinity stations, based on manual discrete sampling: Banjul, Kemoto, Tendaba, Balingho, Japineh, Bambali, Sanbang, Kaur, Kudang Tenda, Kuntaur and Sapu.

4. PROPOSED WATER QUALITY MONITORING FRAMEWORK

The quality of water is dependent on physical, chemical, biological and radioactive parameters. A monitoring programme should ideally cover all aspects of water quality, but more often than not it is a compromise between sufficient coverage of water quality parameters and monitoring costs. The chemical quality alone, consist of a vast number of parameters that can contaminate water sources and affect humans and ecosystems. These chemicals can be naturally occurring, from industrial sources, from human dwellings and from agricultural activities. (UNICEF, 2008) The monitoring programme is to include groundwater, both the shallow sand aquifer (SSA) and the deep sand aquifer (DSA), and surface waters of The Gambia. The DSA is currently not being abstracted but this could change in the future as the capacity of the SSA is not likely to meet the demands of the growing economy in the long run.

The overall framework of the monitoring programme is divided into two phases, the first phase being a baseline survey to provide sufficient background knowledge of the water quality, thus ensuring that all parameters of potential concern are taken into account and that background concentrations are known for regulatory compliance. On the basis of the baseline survey, the long term monitoring can be defined.

4.1 Water quality parameters

4.1.1 Groundwater

It is recommended that a baseline study be carried out with an extensive coverage of water quality parameters and should include both the SSA and DSA. A list of the baseline parameters recommended are presented in Table 7. The parameters marked with an asterisk indicate the water quality parameters that have not previously been tested by DWR. These additional water quality parameters for the baseline study could be outsourced or samples could be conserved and testing contracted to specialized laboratory outside of The Gambia, so as to avoid unnecessary investment in equipment, if the parameters are found not to be of concern in The Gambia.

The regular testing for heavy metals and total pesticides is however recommended in the long term regardless of the results of the baseline study. This is due to the fact that the development of The Gambia will inevitably lead to the growth of the industrial and agricultural sectors, which in turn would require the monitoring of the related impacts. The acquisition of equipment or the use of specialized contracted laboratories is therefore necessary. The use of specialized contracted laboratories is also common practice in Europe for complicated and/or expensive methods such as those for pesticides, some heavy metals, petroleum products, cyanotoxins etc. Specialized contracted laboratories tend to be cheaper, faster and more reliable.

Table 7: Groundwater quality parameters to be included in the baseline monitoring survey

Type of parameter	Parameter	Units
Physical	Temperature	^oC
	Turbidity (NTU)	NTU
	pH	-
	Electrical Conductivity	µS/cm
	Total Dissolved Solids	mg/l
	Salinity	‰
	Colour	-
	Odour	-
	Taste	-
	Suspended Solids	mg S.S./l
	Total Organic Carbon (TOC)*	mg/l
Chemical	Phosphate	mg PO_4^{3-}/l
	Nitrate	mg NO_3^--N/l
	Nitrite	mg NO^-_2/l
	Total Iron	mg $Fe^{2/3+}$/l
	Chloride	mg Cl^-/l
	Alkalinity	mg $CaCO_3$/l
	Free Carbon dioxide	mg CO_2/l
	Hardness	mg $CaCO_3$/l
	Calcium	mg Ca^{2+}/l
	Magnesium	mg Mg^{2+}/l
	Manganese	mg Mn^{2+}/l
	Fluoride	mg F^-/l
	Sulphate	mg SO_4^{2-}/l
	Ammonia	mg NH_4^+/l
	Arsenic*	mg As/l
	Cyanide*	mg CN^-/l
	Mercury*	mg Hg^{2+}/l
	Cadmium*	mg Cd^{2+}/l
	Lead*	mg Pb^{2+}/l
	2,4-D*$^+$	µg/l
	Atrazine*$^+$	µg/l
	Alachlor*$^+$	µg/l
	Cyclodienes*$^+$	µg/l
	DDE/DDT*$^+$	µg/l
	Diuron*$^+$	µg/l
	Glyphosphate*$^+$	µg/l
	Metolachlor*$^+$	µg/l
	Organo Phosphate/Carbamate*$^+$	µg/l
	Pyrethroids*$^+$	µg/l
	Adsorbable organic halides (AOX)*	µg Cl^-/l
Biological	Total Coliform	No./100ml
	Faecal Coliform	No./100ml
Radiological	Gross alpha activity*	Bq/l
	Gross beta activity*	Bq/l
Observational	Sanitary Survey	Status of the observation site

*Indicates parameters for which the DWR water quality laboratory does not have the necessary equipment and/or reagents.
+Indicates the pesticide types that can be tested with the ELISA test kit (Biosense Laboratories AS, n.d.) already in use in Gambia

Adsorbable organic halides (AOX) refers to the sum of chlorine, bromine and iodine concentrations and is a representative parameter for biotoxicity and potential hazard. Monitoring AOX can give a good indication of chloro-organic pollution, typically from industries or landfills. (Noma et al., 2001)

The measurement of a number of pesticides will need to be proposed in the baseline study. The pesticide families to be monitored are based on the primary pesticides approved in the Sahelian region and also the pesticides that can be tested for using the ELISA kit (Biosense Laboratories AS, n.d.). It is however recommended to use specialized contracted laboratories for pesticide testing for the future monitoring programme to save on equipment and training costs.

The addition of heavy metals and radiological parameters to the list of water quality parameters has also been proposed for the baseline study. The monitoring of heavy metals is necessary to determine any naturally high concentrations that could be of concern and also to determine background level concentrations which can then be used for regulatory compliance of pollution source such as industries and waste sites. Radioactivity is usually due to the presence of naturally occurring elements in the uranium and thorium decay series, but can also occur due to manmade radioactive materials (UNICEF, 2008). Radioactivity of natural occurrence in The Gambia has yet to be investigated. Also, although radioactivity from human activities is not suspected in The Gambia, groundwater in The Gambia is also influenced by activities in neighbouring countries judged by groundwater flow patterns. An initial screening for radioactivity is therefore recommended for gross alpha and beta activity, where alpha emitters are normally naturally occurring and beta emitters are primarily linked to nuclear industry products (UNICEF, 2008). Should screening indicate radioactivity above screening guideline values, the radionuclides should be identified and individual concentrations measured (UNICEF, 2008).

The water quality monitoring framework to be adopted should be based on the information obtained in the baseline survey, and should also take into account any recent changes in land use. The results of the baseline survey will likely allow for a reduction in the numbers of water quality parameters measured. Some parameters may be found to be absent in the whole of The Gambia and could therefore be eliminated from the monitoring program (or carried out intermittently). Such parameters could include gross alpha and beta activity, and arsenic (unless relevant for certain industrial activities). Some parameters may also only be found to be present in certain areas and monitoring of these chemicals can then be limited to the relevant observation sites. Such parameters could include for example limiting the monitoring of pesticides to agricultural areas and fluoride to the DSA, if not detected in the SSA. The monitoring of total organic carbon (TOC) for example can likely also be limited to groundwater sampling close to waste sites.

4.1.2 Surface water

Although surface waters are not readily used for consumption in The Gambia, it is recommended to carry out a baseline study on this source too. A comprehensive understanding of the current state of the surface waters will thus provide a basis for regulatory compliance. Changes in water quality due to pollution from human activities like agriculture and industry will therefore be able to be monitored, sourced and controlled.

The water quality parameters recommended for the baseline study of surface waters are similar to that of groundwater. For surface waters however, BOD is an important parameter for indicating pollution. Monitoring for nitrates, phosphates and total pesticides are also recommended due to the vast agricultural activities in the country. The release of nutrients into surface waters from agriculture or waste discharge often results in eutrophication. It is therefore advisable to test for chlorophyll a and secchi depth in the baseline study, which can give an indication of the extent of phytoplankton in the waters. This will give an idea of the correlation between secchi depth and chlorophyll a concentrations. This correlation will allow for the use of secchi depth, a simple and cheap measurement, to provide an indication of chlorophyll a content and therefore the degree of eutrophication, in the monitoring programme. The monitoring of DO in surface water is proposed to be conducted in the early morning hours where feasible as DO concentration is most critical before sunrise, i.e. before the onset of photosynthesis.

From a study of surface waters in Senegal it was found that of the phytoplankton community 32% (25 species) of the total species richness were from the cyanobacteria taxonomic group. Cyanobacteria also accounted for 54% of the total phytoplankton biomass. (Berger et al., 2006) As a number of potentially toxin producing cyanobacterial species were identified in Senegal (Berger et al., 2006; Berger et. al, 2005), it is advisable to check for cyanotoxins in the baseline study. From the species identified in Senegal, it is proposed to test for microcystin, cylindrospermopsin and anatoxin in the initial baseline study.

Other than cyanotoxins, it is proposed to do a more general biological test for toxicity. This is a good qualitative indicator of the general quality of the water as it is related to the overall harmful effect of pollution on aquatic life rather than determining the concentration of certain chemical compounds. This is therefore a useful screening parameter. It is suggested to use the HACH LUMIStox equipment which determines the inhibitory effect of water samples on luminescent bacteria. The lowest ineffective dilution (LID) can be determined which indicates the lowest dilution factor at which the inhibitory effect is less than 20%. (Hach Lange, 2010-2012)

The testing of heavy metals is also recommended for regulatory compliance, as any differentiation from the baseline values could be indicative of pollution sources.

Table 8: Surface water quality parameters to be included in the baseline monitoring survey

Type of parameter	Parameter	Units
Physical	Temperature	^oC
	Turbidity (NTU)	NTU
	pH	-
	Electrical Conductivity	□S/cm
	Total Dissolved Solids	mg/l
	Salinity	‰
	Suspended Solids	mg S.S./l
	BOD	mg/l
Chemical	Phosphate	mg PO_4^{3-}/l
	Nitrate	mg NO_3^--N/l
	Nitrite	mg NO^-_2/l
	Total Iron	mg $Fe^{2/3+}$/l
	Chloride	mg Cl^-/l
	Alkalinity	mg $CaCO_3$/l
	Free Carbon dioxide	mg CO_2/l
	Hardness	mg $CaCO_3$/l
	Calcium	mg Ca^{2+}/l
	Magnesium	mg Mg^{2+}/l
	Manganese	mg Mn^{2+}/l
	Fluoride	mg F^-/l
	Sulphate	mg SO_4^{2-}/l
	Ammonia	mg NH_4^+/l
	Arsenic*	mg As/l
	Cyanide*	mg CN^-/l
	Mercury*	mg Hg^{2+}/l
	Cadmium*	mg Cd^{2+}/l
	Lead*	mg Pb^{2+}/l
	2,4-D*$^+$	µg/l
	Atrazine*$^+$	µg/l
	Alachlor*$^+$	µg/l
	Cyclodienes*$^+$	µg/l
	DDE/DDT*$^+$	µg/l
	Diuron*$^+$	µg/l
	Glyphosphate*$^+$	µg/l
	Metolachlor*$^+$	µg/l
	Organo Phosphate/Carbamate*$^+$	µg/l
	Pyrethroids*$^+$	µg/l
Microbiological	Total Coliform	No./100ml
	Faecal Coliform	No./100ml
	Lowest Ineffective Dilution (LID)*	Dilution factor
	Chlorophyll a*	µg/l
	Microcystin*	µg/l
	Anatoxin*	µg/l
	Cylindrospermopsin*	µg/l

*Indicates parameters whereby the DWR water quality laboratory does not have the necessary equipment and/or reagents.

As for groundwater monitoring, depending on the results of the baseline study, the subsequent monitoring framework can be set up.

4.2 Number and location of monitoring sites

4.2.1 Groundwater

The location of the groundwater monitoring sites is based on the location of the existing and proposed observation boreholes, the direction of groundwater flow and presence of human and industrial activities. For practical reasons and to curb costs, it is proposed to select groundwater monitoring sites from the existing NAWEC production boreholes and the boreholes proposed for continuous groundwater level monitoring under the responsibility of DWR.

The water quality is of greatest concern in the Western Region due to high population densities and industrial activities. Also, the majority of drinking water produced is abstracted from the shallow aquifers of the western region (NEA, 2010). As seen from the groundwater contours in **Error! eference source not found.** and Annex 4, the groundwater flows radially out to the Atlantic Ocean and the Gambia River delta from the centre of the Western Region. It can also be observed in Annex 4 that the main drinking water production well fields are located in the northern part of the region. It is proposed to monitor the water quality upstream of the production boreholes and in between production boreholes and human or industrial activities where possible. This will allow potential deterioration of water quality to be captured before drinking water abstraction. Some of the monitoring sites recommended monitor upstream and downstream of potential 'hot spots' which allows the monitoring of changes in water quality due to contamination from these 'hot spots'. This is vital information for regulatory compliance.

Due to the sheer number of observation and production boreholes, it is important to consider the available resources of the country. Therefore the monitoring framework highlights ten first priority groundwater monitoring boreholes, followed by an additional 10 second priority monitoring boreholes. When sufficient resources are available, it is proposed to expand the monitoring program to include all observation and production boreholes. On **Error! Reference source not found.**, the irst priority monitoring sites are highlighted by black circles, while the second priority sites are highlighted by purple triangles.

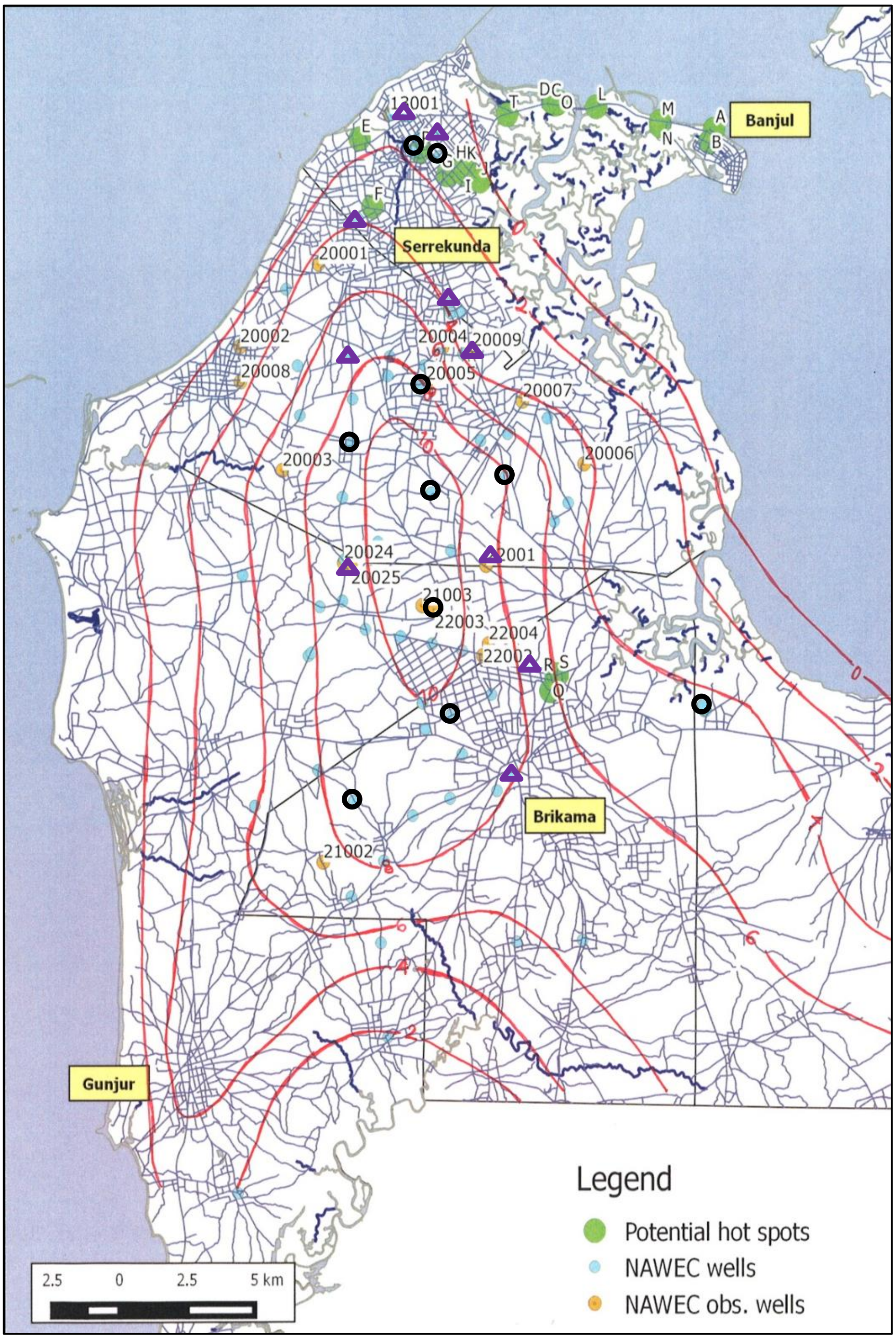


Figure 7: Hydrogeological map showing contours for groundwater level in the western region of The Gambia (manually abstracted from Saihou Ceesay & Sons Ltd and Howard Humphreys Ltd, 1987), location of potential 'hot spots' and the location of observation boreholes and NAWEC production boreholes. The black circles indicate first priority boreholes, while the purple triangle indicate second priority boreholes for monitoring.

It is also proposed to employ the 20 new monitoring boreholes that are to be drilled for monitoring groundwater quality country wide, as they will be well distributed throughout the rest of The Gambia (Annex 3). These boreholes are not only important for the baseline study where the current groundwater quality country wide will be determined, but also for monitoring the effect of agricultural practices, primarily the application of fertilizers and pesticides, on the groundwater quality.

The three existing boreholes that reach into the DSA in Banjul, Garowal and Sankwia (Figure 6) are also recommended to be included in the monitoring programme. The construction of additional DSA boreholes is not necessary at this stage, as the DSA is currently not exploited and therefore the three existing boreholes are deemed sufficient for monitoring effects on the environment and possible future use.

4.2.2 Surface water

Monitoring of the surface water has two main objectives, which is the monitoring of the extent of the saline intrusion and monitoring of water quality in the freshwater section of the River Gambia.

It is proposed to continuously monitor salinity at 12 stations along the river from the mouth at Banjul to Kuntaur station situated approximately 250 km upstream (Figure 8), and at one station on a coastal river. This will provide information on the location and movement of the saline front which is important in terms of irrigation. The proposed monitoring sites were chosen based on the existing monitoring stations and include: (NIRAS, 2013b)

- Stations along the main River Gambia: Banjul, Kemoto, Tendaba, Balingho, Japineh, Sanbang, Pakaliba, Kaur, Chamen, Kuntaur, Jahally and Bansang
- Station on Allaheim, a coastal river, near or upstream of Kartong

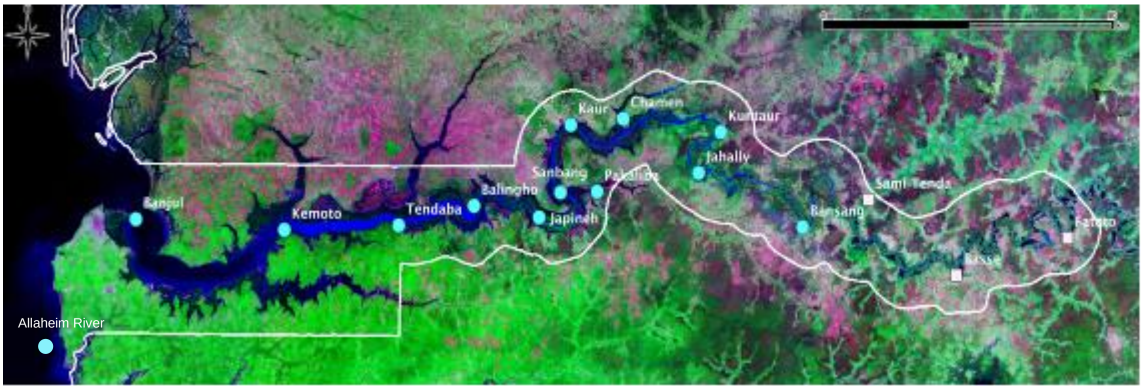


Figure 8: Proposed monitoring network for salinity monitoring (and water level monitoring). The blue dots indicate salinity and water level monitoring stations while the pink squares indicate water level monitoring stations. (NIRAS, 2013b)

In order to establish surface water quality baseline data, it is suggested to monitor the upstream fresh water section of the Gambia River and its tributaries, as well as some of the Atlantic Ocean streams that drain part of the Kombos, which are highly populated and industrial areas. The Atlantic Ocean streams will allow monitoring of the impact of discharges or pollution sources from human activities and settlements. The monitoring sites will include the following (Figure 9): (NIRAS, 2013b)

- Sites on the Gambia River: Kaur, Kuntaur, Jahally, Bansang, Basse and Fatoto
- Sites on tributaries: Pakaliba, Chamen, Sami Tenda, Dampha Kunda and Sudowol
- Sites on the Atlantic seaboard: Kotu Bridge, Brufut Madiana and Darsilami

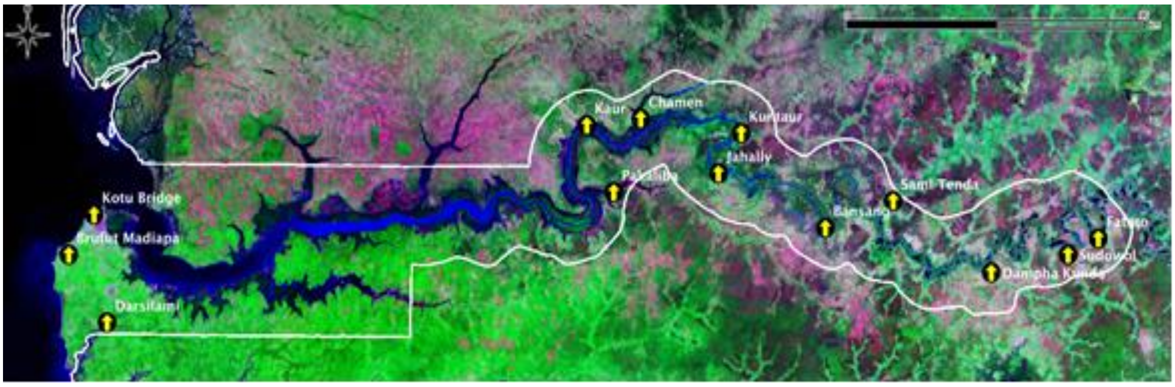


Figure 9: Proposed surface water quality sampling network for the monitoring of water quality parameters listed in Table 8 (NIRAS, 2013b)

4.3 Definition of water quality parameters and frequency of monitoring

The frequency of monitoring needs to take into account the seasonal changes in The Gambia and feasibility of the monitoring in terms of resources. The frequency is also dependent on the sampling area in terms of human activity and population density. Frequency should increase in proportion to the quantity of water abstracted, the population served and therefore the degree of risk involved with water quality deterioration.

4.3.1 Groundwater

The baseline survey of the groundwater quality is recommended to be conducted once before the start of the rainy season, in May, and just after the first rains, in June, country wide. It is also suggested to be conducted at the end of the wet season/start of the dry season in October. The groundwater in the Western Region is proposed to be sampled on a monthly basis for one year. This is due to the high population density, the large volume of water abstracted for drinking water production, the lack of adequate waste management practices, and the presence of industrial activities (European Communities, 1979).

Monitoring frequency of the SSA thereafter is dependent on the results of the baseline survey. As long as the DSA is not exploited, a monitoring of the DSA boreholes once every 2 years is deemed sufficient. This to re-evaluated if the DSA is to be exploited.

4.3.2 Surface water

The monitoring of the saline intrusion in the lower section of the River Gambia is recommended to be carried out by automatic, electronically based stations and therefore salinity monitoring can be continuous. (NIRAS, 2013b) It is important to highlight the need for heightened security around these sites, as the evaluation of existing sites indicated the prevalence of vandalism. Therefore the installation of instruments comes with a risk of theft.

The baseline survey of the freshwater upstream section of the River Gambia and its tributaries, as well as three coastal streams on the Atlantic seaboard should involve monthly monitoring of the water quality for a year. Monthly monitoring of the coastal streams is proposed to provide an adequate baseline for regulatory compliance for the protection of ecosystems due to their proximity to industries and settlements. The greatest threat to the freshwater sections of the River Gambia and its tributaries are related to agriculture and the potential inflow of contaminants from upstream (international sections) of the basin. As the freshwater sections of the River Gambia and its tributaries are not used for drinking water purposes and are not flanked by areas of high population density, the subsequent monitoring of the water quality is recommended to be carried out every 4 years, whereby the same monthly water quality monitoring programme as per the baseline survey is to be conducted. (European Communities, 1991) The Atlantic Ocean streams are located such as to monitor the effect of discharge from settlements and industries on the environment. Changes in water quality are suspected to be more frequent in these areas and monitoring, succeeding the baseline survey, is thus recommended to be carried out twice yearly. It is recommended to sample once during the wet season (preferably after the first rains) and once during the dry season (preferably towards the end – if the streams are not completely dried up).

4.4 Water quality sampling procedures

It is proposed that groundwater sampling is conducted as discrete grab samples, and that surface water sampling is conducted as grab samples for freshwater samples and continuous monitoring in the saline/brackish water monitoring of the Gambia River and coastal streams. Sampling should be conducted carefully to ensure that the samples are representative of the water of interest. Sampling of groundwater boreholes, should be taken after the borehole have been purged, whereby three times the volume of the boreholes should be pumped out to remove stagnant water, ensuring that the samples are representative of the conditions of the free flowing water at the time. (Department of Water Affairs and Forestry, 2006) For sampling of surface water, it is recommended to collect grab samples from the middle of the channel at mid-depth where possible. When resources allow, it is recommended to upgrade to depth-integrated grab samples. (UN/ECE TF-LQM&A, 2002)

Standard sampling procedures are given in detail in different international and national standards. It is proposed to follow the International Organisation for Standardization (ISO) 5667-1-17 series that gives a detailed account of sampling procedures in terms of the design of sampling programmes, sampling techniques, and preservation and handling of samples. (UN/ECE TF-LQM&A, 2002)

It is important to carry out quality assurance of the monitoring program to ensure that the laboratory results produced are reliable. The DWR water quality laboratory are currently using GEMS/Water Programme for internal quality assurance. It is recommended to continue the use of this program and ensure that the following steps are undertaken (UNEP & WHO, 1998):

- Develop a calibration curve for each variable. Where a calibration curve already exists, validate the existing curve by analysing two standard solutions that sufficiently cover the working range of the curve
- For each variable, measure one method blank (reagent water) per every 20 samples analysed
- For each variable, analyse one field blank (reagent water bottled in the laboratory but taken to the sampling site and undergone the same sampling techniques as the samples collected) for every set of samples
- For each variable, analyse one duplicate of a randomly chosen sample from each set of up to 20 samples
- For each variable, as a recovery check, analyse one specimen that has been spiked with a known concentration of the variable of interest.

For laboratory accreditation, it is recommended that the DWR water quality laboratory participate in an external quality assurance program as well. This involves examining the accuracy of the analysis results of a sample analysed in the DWR laboratory with those of the same sample analysed by another laboratory using the same analytical methods and procedures. (UNEP & WHO, 1998)

5. CONCLUSION

Water quality monitoring is a vital part of water resource management by providing information on which rational decisions can be based. The monitoring programme is to be employed in order to identify actual and future threats to water quality, provide adequate information for the development of plans and policies for water resource management, as well as information for evaluating the success and efficiency of management actions.

A successful monitoring programme requires preliminary survey work to provide a baseline of the existing water quality conditions. This background knowledge then provides the basis for subsequent monitoring. It is however recognized that resources in The Gambia are limited and therefore the water quality monitoring framework proposed can be built up gradually. Priority should be given to groundwater quality monitoring in the GBA, as groundwater in this area provides drinking water for the majority of the Gambian population. Moreover, groundwater in the GBA is more prone to contamination due to high population densities and industrial activity. Monitoring can thereafter be expanded to cover groundwater countrywide, followed by the monitoring of surface water primarily affected by agricultural practices.

The monitoring framework encompasses a number of groundwater monitoring boreholes in the western region, based on the water flow pattern so as to monitor water quality upstream of the drinking water production boreholes. The remaining groundwater monitoring boreholes consist of 20 boreholes distributed evenly countrywide to allow for sufficient coverage. The surface water monitoring sites include sites along the River Gambia, both in the saline/brackish section and the freshwater section. Surface water quality monitoring is also proposed in three coastal rivers in the Western region.

The monitoring framework proposed commences with a baseline survey that characterizes the existing condition of the water resources in terms of physical, chemical, biological and radiological water quality. This is conducted over a year, whereby groundwater in the Western region is to be monitored on a monthly basis, while groundwater countrywide is to be monitored three times during the year, that is before the rainy season, after the first rains of rainy season and at the end of the rainy season/start of the dry season. Subsequent groundwater monitoring frequency is dependent on the results of the baseline study, but is likely to be reduced to quarterly or twice yearly sampling.

The baseline monitoring of the freshwater section of the Gambia River and the coastal rivers in the Western region also entails monitoring on a monthly basis for one year. Subsequent monitoring frequency is again based on the results of the baseline survey. However, unless the baseline survey highlights particular concerns, monitoring is proposed to be reduced to monthly sampling for one year every 4 years in the Gambia River, and twice yearly in the coastal rivers. The saline or brackish section of the Gambia River is to be monitored continuously for salinity using automatic electronically based stations.

The results of the baseline study not only defines the frequency of monitoring but also the water quality parameters to be monitored. The baseline study involves an extensive list of water quality parameters that are likely to be reduced significantly. Some parameters may be found to be absent or present at insignificant concentrations and can therefore be eliminated from the monitoring programme, while others may be monitored less frequently or limited to certain areas where they could be of concern. Water quality sampling techniques, preservation and handling and analysis are recommended to be conducted in line with the ISO 5667-1-17 series, to ensure reliable and comparable results. Laboratory accreditation through internal and external quality assurance programmes is also highly recommended.

It is important to re-evaluate the water quality monitoring framework every so often, to ensure that it is still providing the information needed to ensure sustainable use and protection of the nation's water resources.

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ANNEX 1: Simplified Mesozoic – Cenozoic Succession of the Gambia

The table shows a simplified summary of the geological succession and lithology of the onshore region of the Gambia River basin since the middle of the Cretaceous period. (SLI, 2005)

Period	**Series**	**Stage**	**Lithology**
Quaternary	Holocene Pleistocene Pliocene	 Continental Terminal	Aeolian sands, silts and alluvial clays Alternating fine-medium grained sands with ochre silts and clays, laterites and occasional limestone
Tertiary	Miocene Unconformity …………….. Oligocene Unconformity Eocene	 ……………. ……………	Grey-green plastic shale and marly fine sands with subordinate limestone. ………………………………………………. Marly limestone; limited extent ……………………………………………… Green-grey plastic shale and marly limestone with bands of flint near base
Cretaceous	Palaeocene Unconformity …………….. Upper Cretaceous (Senonian)	 …………… Maastrichtian …………… Campanian	Chalky limestone and white marly limestone with intercalations of dark grey marls; sandy faces in extreme west and east ……………………………………………… Fine-coarse grained sandstones, with subordinate grey black shale, phosphoric nodules and lignite bands ………………………………………………. Grey clays and marls intercalated with fine calcareous sandstones, dolomitic limestones and lignite bands

ANNEX 2: List of pesticides approved for use in The Gambia

Pesticides approved by the sahelian pesticides committee (spc) (NEA, 2014)

A Conference of Heads of State of CILSS member countries adopted in 1992 a Resolution relating to pesticides registration in the sub-region. This was followed by a convention, on common Regulations for Pesticide Registration in the CILSS zone.

The Gambia ratified the convention in November 1997.

The objectives of these Regulations are to ensure an effective phytosanitary control and a safe application of environmentally safe agrochemicals in the sub-region.

The Convention established the Sahelian Pesticide Committee (SPC), a body mandated to approve or reject the entry of pesticides into the Sahel. It is a unique registration body, and it is responsible for implementing the common Regulation. The SPC meets twice a year to deliberate on applications for registration of pesticides submitted by agrochemical firms. To date, the Committee has examined over 200 registration dossiers; about thirty pesticides formulations have been given provisional clearance, and five fully registered.

The Gambia is represented on the SPC by the Registrar of Pesticides and Chemicals of the NEA, and by the Head of the Agricultural Pest Management Unit of the Department of Agricultural Services, two members of the Hazardous Chemicals and Pesticides Control and Management Board; this multi- sectoral Board is the highest authority for the management and control of hazardous chemicals, including pesticides, in The Gambia.

Below is the list of pesticides that have been registered or provisionally cleared for importation and use in the CILSS member states.

Trade Name	Active Ingredient	Manufacturer	Status	Area of Use
Dursban 450ULV	Chlorpyrifos Ethyl 450g/l	DOW elanco	Reg.*	Insecticide
Dursban 5%	Chlorpyrifos Ethyl 50g/kg	DOW elanco	Reg.	Insecticide
Dursban 5G	Chlorpyrifos Ethyl 50g/kg	DOW elanco	Reg.	Insecticide
Dursban 24ULV	Chlorpyrifos Ethyl 240g/l	DOW elanco	Reg.	Insecticide
Dursban 4E	Chlorpyrifos Ethyl 480g/l	DOW elanco	Reg.	Insecticide
Dimilin OF6	Diflubenzuron 60g/l	Solvay Duphar	PC**	Insecticide
Karate 5EC	Lambda-Cyhalothrin50g/l	Zeneca	PC	Insecticide
Karate 2.5EC	Lambda-Cyhalothrin 25g/l	Zeneca	PC	Insecticide
Karate 5 WG	Lambda-Cyhalothrin 50g/kg	Zeneca	PC	Insecticide
Super Fusilade	P-butyl fluazifop 125g/l	Zeneca	PC	Herbicide
Cyhalon 10EC	Cyhalothrin100g/l	Zeneca	PC	Insecticide

Garlon4	Triclopyr 480g/l	Dow Elanco	PC	Herbicide
Phostoxin	Aluminium Phosphide 56%	Detia	PC	Insecticide Fumigant
Nurelle D 30/300 EC	Chorpyrifos ethyl 300g/l and Chorpyrifos 30g/l	Dow Elanco	PC	Insecticide
Nurelle D 10/100EC	Chorpyrifos ethyl 100 g/l and Cypermethrin 10g/l	Dow Elanco	PC	Insecticide
Reldan 50EC	Chorpyrifos methyl 50g/l	Dow Elanco	PC	Insecticide
Reldan 500ULV	Chorpyrifos methyl 500g/l	Dow Elanco	PC	Insecticide
Reldan 170ULV	Chorpyrifos methyl 170g/l	Dow Elanco	PC	Insecticide
Furadan 4	Carbofuran480g/l	FMC	`PC	Insecticide Nermaticide
Furadan 5G	Carbofuran50g/l	FMC	PC	Insecticide Nermaticide
Polytrin C330Ec	Profenofos300g/l and cypermethrin 30g/l	Ciba Geigy	PC	Insecticide
Tracker 16.5 ULV	Tralomethrin 66g/l	DU Pont de Nemours	PC	Insecticide
Unden75 WP	Propoxur 750g/kg	Bayer AG	PC	Insecticide
Celphos	Aluminium phosphide 560g/kg	Calliope	PC	Insecticide
Primagram500Ec	Metolachlor 250g/l andAtrazine 250g/l	Ciba Geigy	PC	Herbicide
Cotodon Plus500 Ec	Terbutryn 167g/l and Metolachlor 333g/l	Ciba Geigy	PC	Herbicide
Rifit Extra 500Ec	Pretilachlor375g/l and Dimethamethrin 125g/l	Ciba Geigy	PC	Herbicide
Polytrin C 180Ec	Profenofos150g/l and cypermethrin 30g/l	Ciba Geigy	PC	Insecticide
Marshal 20UL	Carbofuran 200g/l	FMC	PC	Insecticide
Marshal 35DS	Carbofuran 350g/kg	FMC	PC	Insecticide

*Reg. indicates registered; **PC indicates provisionally cleared

N/N for further clarification, please contact the Registrar of Pesticides and Chemicals at the National Environment Agency, 5 Fitzgerald street Banjul Tel: 228056/ 224867/224868.

Updated list of Pesticides Registered with the Sahelien Pesticides Committee from June 1994 to June 2001

Trade Name	Class	Manufacturer	Active Ingredient	Registration Number	Area of Use
Dimilin of 6	II	Uniroyal Chemical	Diflubenzuron (60g/l)	0001/I/03-94/APV-SAHEL 0001/I/10-97/APV-SAHEL 0006/I/12-00/HOM-SAHEL	Insecticides against locusts
Karate 5EC	II	Zeneca	Lambada-cyhalothrine(50g/l)	0002/I/03-94/APV- SAHEL 0002/I/10-97/ APV- SAHEL	Insecticides against: cotton, fruits vegetables, sorghum, Soya beans niebe
Karate 2.5EC	II	Zeneca	Lambada-cyhalothrine(25g/l)	0003/I/03-94/APV- SAHEL 0003/I/10-97/ APV- SAHEL	Insecticides against: cotton, fruits vegetables, sorghum, Soya beans niebe
Karate 5 WG	II	Zeneca	Lambada-cyhalothrine(50g/kg)	0004/I/03-94/APV- SAHEL 0004/I/10-97/ APV- SAHEL	Insecticides against: cotton,
Fusilade Super125EC	II	Zeneca	Fluazifop-p-Butyl (125g/l	0005/H03-94/APV- SAHEL 0005/H/10-97/APV- SAHEL	Herbicide contre les graminees du cotonier, de l' arachide et des fruits et legumes
Cyhalone 10 EC	**II**	Zeneca	Cyhalonthrine (100g/l)	0006/I/03-94/APV- SAHEL 0006/I/10-97/ APV- SAHEL	Insecticides against: cotton, fruits vegetables, sorghum, Soya beans niebe
Dursban 450ULV	II	DOW AgroSciences	Chlorpyrifos Ethyl 450g/l	0007/I/10-94/APV- SAHEL 0001/I/07-97/ APV- SAHEL	Insecticides contre les locustes, et les sauteriaux fourmis et les termites
Dursban 5% DP	III	DOW AgroSciences	Chlorpyrifos Ethyl 50g/kg	0008/I/10-94/APV- SAHEL 0002/I/07-97/ APV- SAHEL	Insecticides contre les sauteriaux, en traitement foliare
Dursban 5G	III	DOW AgroSciences	Chlorpyrifos Ethyl 50g/kg	0009/I/10-94/APV- SAHEL 0003/I/07-97/ APV- SAHEL	Insecticides contre les termites, les noctuelles, tampins, lesvers blance sur mais et sorgho
Dursban 24 ULV	II	DOW AgroSciences	Chlorpyrifos Ethyl 240g/l	0010/I/10-94/APV- SAHEL 0004/I/07-97/ APV- SAHEL	Insecticides contre les sauteriaux, et le criquet pelerin
Dursban 4E	II	DOW AgroSciences	Chlorpyrifos Ethyl 480g/l	0011/I/10-94/APV- SAHEL 0005/I/07-97/ APV- SAHEL	Insecticides contre les ravageurs des agrumes, du cafeire, du cotonnier, et des cultures maraicheres
Garlon	II	DOW AgroSciences	Triclopyr 480g/l	0012/I/10-94/APV- SAHEL 0012/I/07-97/ APV- SAHEL	Herbicide cerbroussaillant specifique et arboricide, lutte contre le striga,atles dicotyledones sur canne sucre
Phostoxin TB	x	Detia Degesch	Phosphure d` aluminium (56%)	0013/1/10-94/APV-SAHEL 0013/1/11-99/APV-SAHEL	INSECTICIDES. fumigant against store pest and rodents
Nural D 30/300EC	II	DOW AgroSciences	Chlorpyrifos Ethyl 300g/l and cypermethrin 30g/l	0014/1/06-95/ APV-SAHEL	Insecticides contre les ravageurs du cotonnier

Nural D 10/100EC	II	DOW AgroSciences	Chlorpyrifos Ethyl 100g/l and cypermethrin 10g/l	0015/1/06-95/ APV-SAHEL	Insecticides contre les ravageurs du cotonnier
Reldan 50 EC	U	DOW AgroSciences	Chlorpyrifos methyl 500g/l	0016/1/06-95/ APV-SAHEL	Insecticides contre les sauteriaux les contharides, les pucerons, et les insecticide des denrees stockees
Reldan 500 ULV	U	DOW AgroSciences	Chlorpyrifos methyl 500g/l	0017/1/06-95/ APV-SAHEL	Insecticides contre les sauteriaux les contharides,
Reldan 170 ULV	U	DOW AgroSciences	Chlorpyrifos methyl 170g/l	0018/1/06-95/ APV-SAHEL	Insecticides contre les sauteriaux les contharides, les pucerons, et les insecticide des denrees stockees
Furadan 4F	la	FMC	Carbofuran (480g/l)	0019/1/12-95/ APV-SAHEL 0019/1/06-99/ APV-SAHEL	Insecticides-nematicide contre les freurs de tige, les cochenilles, les termites de la canne a sucre, les nematodes et charancons du bananier
Furadan 5G	II	FMC	Carbofuran (50g/kg)	0020/1/12-95/ APV-SAHEL 0020/1/06-99/ APV-SAHEL	Against nematodes and soil organisms
Polytrin C 330 EC	II	Novartis	Profenofos 300g/l) – cypermethrin 30g/l	0021/1/12-95/ APV-SAHEL 0021/1/06-99/ APV-SAHEL	Insecticides against lepidopteres, les insects piqueurs-suceurs et les acariens du cotonnier
Tracker 16,5 ULV	III	Du pont de nemours	Tralomethrine 66g/l	0022/1/12-95/ APV-SAHEL 0022/1/05-00/ APV-SAHEL	Insecticides contre les ravageurs des agrumes, du cafeire, du cotonnier, et des cultures maraicheres
Unden 75 WP	II	Bayer AG	Propoxur 750g/kg	0023/1/12-95/ APV-SAHEL 0023/1/12-00/ APV-SAHEL	Insecticides contre les ravageurs des agrumes, du cafeire, du cotonnier, et des cultures maraicheres
celphos	x	Calliope	Phosphure d` aluminium (560%)	0024/1/12-94/APV-SAHEL 0024/1/11-99/APV-SAHEL	INSECTICIDES. fumigant against store pest and rodents
Rifit Extra 500EC	III	Navartis	Pretilachlor 375g/l & dimethametryne 125g/l	0027/1/10-96/APV-SAHEL 0027/1/06-99/APV-SAHEL	Herbicide against leave miner
Polytrin C 180 EC	III	Novartis	Profenofos 150g/l) – cypermethrin 30g/l	0029/1/10-96/ APV-SAHEL 0029/1/06-99/ APV-SAHEL	Insecticides against cotton insect
Marshal 35 DS	II	FMC	Carbosulfan 350g/gk	0030/1/10-96/ APV-SAHEL 0030/1/11-99/ APV-SAHEL	Inscticide autrise contre les insect des semences et du sol
Marshal 20 UL	II	FMC	Carbosulfan 200g/l	0031/1/10-96/ APV-SAHEL 0031/1/11-99/ APV-SAHEL	Inscticide autrise contre les sautheriaux et locustes
Asulox 40SL	U	Rhone Poulenc	Asulame 400 g/l	0032/H/11-98/ APV-SAHEL	Herbicide contre les graminees annuelles et perennes de la canne a sucre
Ronstar 25 EC	III	Rhone Poulenc	Oxadiazon 250g/l	0033/H/11-98/ APV-SAHEL	Herbicide contre les adventices annuelles du riz
Fuji –one 40EC	III	Nihon nohyako	Isoprothiolane 400g/l	0034/F/11-98/ APV-SAHEL	Fongicides against- pyriculariose du riz
Vydate 10 G	II	Dupont de nemoures	Oxamyl 10 g/kg	0035/I,N/11-98/ APV-SAHEL	Insecticides-nematicide contre les freurs de tige, les cochenilles, les termites de la canne a sucre, les nematodes et charancons du bananier
Calthio DS** ***Contain POP chemicals	**II**	**Calliope**	**Thirame (250g/kg) &** ***lindane 200g/l*** ***(why lindane?)***	**0036/l,F/11-98/ APV-SAHEL**	**Insecticides fungicide pour traitements des semences du mis de I arachide, du riz, du niebe, du sorgho et du cotonnier**

Cypercal 50 EC	III	Calliope	Cypermethrine (50 g/l)	0037/l/11-98/ APV-SAHEL	Insecticides contre les principaux lepidopteres phyllophages des cultures maraicheres
Cypercal D 36/400 EC	II	Calliope	Cypermethrine (36 g/l)& dimethoate (400g/l)	0038/l/11-98/ APV-SAHEL	Insecticides contre les ravageurs du cotonnier ainsi que les pucerons et les aleurodes
Avaunt 150SC	**III**	**Asteria**	Indoxacarb 150 g/l	0039/l/11-98/ APV-SAHEL	Insecticides contre les principaux, ravageurs phyllophages principaux du cotonnier
Diazonon 20 ULV	II	Marubeni	Diazonon 200g/l	0040/l/06-99/ APV-SAHEL	Insecticide contre les foreurs de tiges du riz, canne a sucre, sorgho, mis; contre les pucerons Et les chenilles de l'arachide et du haricot; contre les locustes et les sauteriaux
Diazonon 90 ULV	II	Marubeni	Diazonon 900g/l	0041/l/06-99/ APV-SAHEL	Insecticide contre les foreurs de tiges du riz, canne a sucre, sorgho, mis; contre les pucerons les locustes et les sauteriaux
Diazonon 40 EC	II	Marubeni	Diazonon 400g/l	0042/l/06-99/ APV-SAHEL	Insecticide contre les foreurs de tiges du riz, canne a sucre, sorgho, mis; contre les pucerons Et les chenilles de l'arachide et du haricot; contre les locustes et les sauteriaux
Diazonon 60 EC	II	Marubeni	Diazonon 600g/l	0043/l/06-99/ APV-SAHEL	Insecticide contre les foreurs de tiges du riz, canne a sucre, sorgho, mis; contre les pucerons Et les chenilles de l'arachide et du haricot; contre les locustes et les sauteriaux
Stomp 500EC	III	Cyanamid	Pendimethaline 500g/l	0044/H/06-99/ APV-SAHEL	Herbicide de prelevee contre les mauvaises herbes du cotonnier
Nomolt 5% ULV	III	Cyanamid	Teflubenzuron 50g/l	0045/H/06-99/ APV-SAHEL	Insecticide/aracticide against locustes and sauteriaux
Marshal 25 EC	Ib	FMC Europe	Carbosulfan 250g/l	0046/1/06-99/ APV-SAHEL	Insecticide contre les pucerons et les thrips du cotton
Marshal 2% DP	III	FMC Europe	Carbosulfan 20g/kg	0047/1/06-99/ APV-SAHEL	Insecticide contre les locustes et plusieurs geners de sauterelles
Cypercal P 30/300 EC	II	Calliope	Cypermethrin 30g/l & Profenofos 300 g/l	0048/1/06-99/ APV-SAHEL	Insecticide/aracticide phyllophages principaux carpophages et cotonnier
Kalach 360SL	III	Calliope	Glyphosate 360g/l	0049/H/06-99/ APV-SAHEL	Herbicide non selective
Percal M DP	III	Calliope	permethrin 4g/l & malathion16g/l	0050/l/06-99/ APV-SAHEL	Insecticides against principales especes de coleopteres et de lepidopteres ravageurs des denrees stockees
Primagram 500SC	III	Novartis	Metolachlore 250g/l & artazine 250g/l	0025/l/10-96/ APV-SAHEL 0025/l/06-99/ APV-SAHEL	Herbicide against maize and ssorgho
Cotodon plus 500EC	III	Novartis	Terbutryne 167g/l Metolachlore 333g/l	0026/H/10-96/ APV-SAHEL 0026/H/06-99/ APV-SAHEL	Herbicide against l'arachide and cotton
Benlate 50WP	U	Dupont de Nemours	Benomyl 500g/l	0051/F/06-99/ APV-SAHEL	Fungicide systemique contre un grand nombre de maladies (cercosporiose, fusariose, septoriose et verticiliose) des cultures maraicheres, fruitiers et des grandesm cultures

Elsan 50 EC	II	Tomen	Phenthoate 500g/l	0052/l/06-99/ APV-SAHEL	Insecticide/ovicide contre les insectes (lepidopteres, hemipteres et coleopteres) du riz,du mis,des cultures maraicheres, du niebe, des arbres fruitiers et du cotonnier
Londox 60 DF	III	Dupont de Nemours	Bensulfuran methyl 600g/l	0053/H/06-99/ APV-SAHEL	Herbicide selective du riz irrigue recommande contre les cyperacees et aussi efface contre les dicotyledones et possedant un effet complementarie
Apron plus 50 DS	II	Novartis	Metalaxyl 100g/kg, carboxin60g/kg, furathiocab340g/kg	0054/l,F/6-99/ APV-SAHEL	Insecticide fungicide autorise contre les insect du sol, des legumineuses alimentaires, du coton et les maladies fongique des plantules.
Gasepex combi 500S	III	Novartis	Ametryne 250g/l, atrazine250g/l	0055/H/6-99/ APV-SAHEL	Herbicide selective autorise contre les adventice de la cane a sucre
Adnois 6.25 UL	III	Rhone Poulenc	Fipronil 6.25g/l	0056/l/6-99/ APV-SAHEL	Insecticide autorise pour lutter contre les larveset adultes des acridiens en traitements de couverture totale
Adnois 25 UL*	III	Rhone Poulenc	Fipronil 25g/l	0057/l11-99/ APV-SAHEL	Insecticide autorise pour lutter contre les larveset adultes des acridiens en traitements de couverture totale
Adnois 20 UL*	III	Rhone Poulenc	Fipronil 20g/l	0058/l/11-99/ APV-SAHEL	Insecticide autorise pour lutter contre les larveset adultes des acridiens en traitements de couverture totale
Adnois 15 UL*	III	Rhone Poulenc	Fipronil 15g/l	0059/l/11-99/ APV-SAHEL	Insecticide autorise pour lutter contre les larveset adultes des acridiens en traitements de couverture totale
Adnois 12.5 UL*	III	Rhone Poulenc	Fipronil 12.5g/l	0060/l/11-99/ APV-SAHEL	Insecticide autorise pour lutter contre les larveset adultes des acridiens en traitements de couverture totale
Adnois 10 UL*	III	Rhone Poulenc	Fipronil 10g/l	0061/l/11-99/ APV-SAHEL	Insecticide autorise pour lutter contre les larveset adultes des acridiens en traitements de couverture totale
Adnois 7.5 UL *	III	Rhone Poulenc	Fipronil 7.5g/l	0062/l/11-99/ APV-SAHEL	Insecticide autorise pour lutter contre les larveset adultes des acridiens en traitements de couverture totale
Adnois 5 UL *	III	Rhone Poulenc	Fipronil 5g/l	0064/l/11-99/ APV-SAHEL	Insecticide autorise pour lutter contre les larveset adultes des acridiens en traitements de couverture totale
Adnois 4UL *	III	Rhone Poulenc	Fipronil 4g/l	0065/l/11-99/ APV-SAHEL	Insecticide autorise pour lutter contre les larveset adultes des acridiens en traitements de couverture totale
Adnois 2 UL *	III	Rhone Poulenc	Fipronil 2g/l	0066/l/11-99/ APV-SAHEL	Insecticide autorise pour lutter contre les larveset adultes des acridiens en traitements de couverture totale
Actril DS	II	Rhone Poulenc	2.4-D (600g/l) + ioxynil (100g/l)	0067/H/11-99/ APV-SAHEL	Herbicide autorise pour lutter contre les dicotyledones de la conne a sucre
Sherdiphos 420EC	Ib	Rhone Poulenc	Cypermethrin 30g/l, dimethoat 240g/l + triazophos 150g/l	0068/l,A/11-99/ APV-SAHEL	Insecticides/acaricide autorise pour lutter contre les insect el les acariens di cotonnier
Fastac R 415 EC	II	Cyanamid	Alphacypermethrine 15g/l+dimethoate 400g/l	0069/l/11-99/ APV-SAHEL	Insecticides/autorise piquers suceurs contre les insect el les chenilles ducotonnier
Fastac R 418 EC	II	Cyanamid	Alphacypermethrine 18g/l+dimethoate 400g/l	0070/l/11-99/ APV-SAHEL	Insecticides/autorise piquers suceurs contre les insect el les chenilles ducotonnier

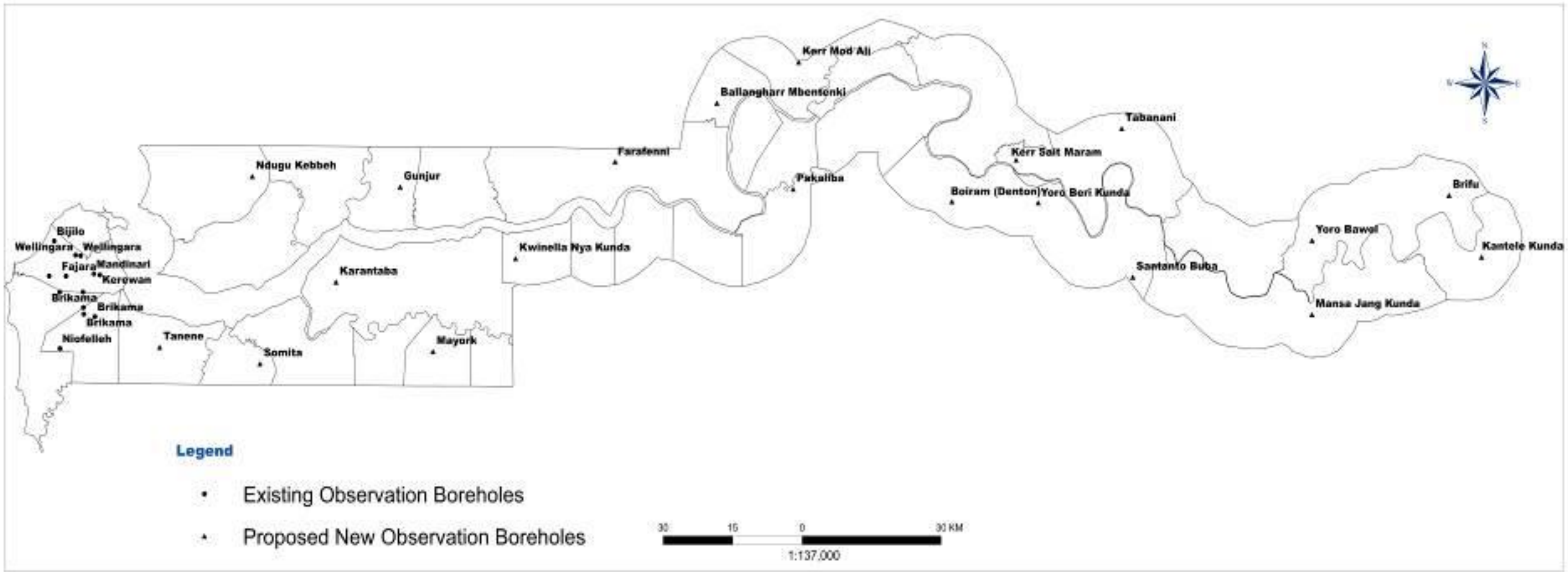
Fastac R 318 EC	II	Cyanamid	Alphacypermethrine 18g/l+dimethoate 300g/l	0071/l/11-99/ APV-SAHEL	Insecticides/autorise piquers suceurs contre les insect el les chenilles ducotonnier
Fastac A 265 EC	Ib	Cyanamid	Alphacypermethrine 15g/l+dimethoate 250g/l	0073/l/11-99/ APV-SAHEL	Insecticides/autorise piquers suceurs contre les insect el les chenilles ducotonnier
Fastac R 315 EC	II	Cyanamid	Alphacypermethrine 15g/l+dimethoate 300g/l	0074/l/11-99/ APV-SAHEL	Insecticides/autorise piquers suceurs contre les insect el les chenilles ducotonnier
Adnois 6 UL *	III	Rhone Poulenc	Fipronil 6g/l	0063/l/11-99/ APV-SAHEL	Insecticide autorise pour lutter contre les larveset adultes des acridiens en traitements de couverture totale
Fastac R 315 EC	II	Cyanamid	Alphacypermethrine 15g/l+dimethoate 300g/l	0075/l/11-99/ APV-SAHEL	Insecticides/autorise piquers suceurs contre les insect el les chenilles ducotonnier
Fastac R 165 EC	II	Cyanamid	Alphacypermethrine 15g/l+dimethoate 150g/l	0076/l/11-99/ APV-SAHEL	Insecticides/autorise piquers suceurs contre les insect el les chenilles ducotonnier
Fastac R 215 EC	Ib	Cyanamid	Alphacypermethrine 15g/l+dimethoate 200g/l	0077/l/11-99/ APV-SAHEL	Insecticides/autorise piquers suceurs contre les insect el les chenilles ducotonnier
Bellater extra fluide	II	Cyanamid	Atrazine 250g/l + cyanazine 250	0078/H/11-99/ APV-SAHEL	Herbicide de per levee selectif autorise d`utilisation pour lutter contre les adventices du mais
Velpar 75DF	III	Dupont Nemours	Hexazinone 750g/kg	0079/H/11-99/ APV-SAHEL	Herbicide autorise contre les adventices de la canne a sucre
Apron R Star 42 WS	III	Novartis	Thiamethoxam 200g/kg difenoconazole 20g/kg + metalaxyl-m 200g/kg	0080/l,F/05-00/ APV-SAHEL	Insecticides/ fungicides
Polo 500 SC	III	Novartis	Diafenthiuron 500g/l	0081/l,A/05-00/ APV-SAHEL	Insecticides/acaricides
Phaser 350 EC	Ib	aventis	endosulfan	0082/l/05-00/ APV-SAHEL	Insecticides
Atoll 500 SC	II	aventis	Atrazine 500g/l + isoxaflutole 38g/l	0083/H/05-00/ APV-SAHEL	Herbicides
Topstar 400 SC	III	aventis	Oxadiargyl 400g/l	0084/H/05-00/ APV-SAHEL	Herbicides
Action 800SC	U	STEPC	Diuron 800g/l	0085/H/05-00/ APV-SAHEL	Herbicides
Conquest plus 388 EC	Ib	Aventis	Acetamipride 16g/l, cypermethrin72g/l + triazophos 300g/l	0086/l/05-00/ APV-SAHEL	Insecticides
Touchdown 480SC	II	zeneca	Glyphosate-trimesium 480g/l	0087/H/05-00/ APV-SAHEL	Herbicides
Polytrine C 230 EC	III	Novartis	Cypermethrin 30g/l Profenofos 200 g/l	0088/l/05-00/ APV-SAHEL	insecticices
Cotogard 500SC	III	Novartis	Fluometuron 250g/l /Prometryne 250g/l	0089/l/05-00/ APV-SAHEL	Herbicide
Trebon 10 EC	II	Africa Agro Service	Ethofenprox 100g/l	0090/l/05-00/ APV-SAHEL	Insecticide
Trebon 20EC	II	Africa Agro Service	Ethofenprox 200g/l	0091/l/05-00/ APV-SAHEL	Insecticide
Ofunack 40EC		Africa Agro Service	Pyridaphenthion 400 g/l	0092/l/05-00/ APV-SAHEL	Insecticide
Ofunack 25 ULV	II	Africa Agro Service	Pyridaphenthion 250 g/l	0093/l/05-00/ APV-SAHEL	Insecticide

Solfac 050 EW	III	Bayer	Cyfluthrin 50g/l	0094/l/05-00/ APV-SAHEL	Insecticide
Atravic 500 SC	III	Asteria	Atrazine 500g/l	0095/H/05-00/ APV-SAHEL	Herbicide
Gramoxone Super** ***Contain POP chemicals	**II**	ZENECA	**Paraquat 200g/l**	**0096/H/05-00/ APV-SAHEL**	**Herbicide**
Actalm Super	U	ALM International	Pyrimiphos-mrthyl 17g/l - cyfluthrine	0097/l/05-00/ APV-SAHEL	insecticide
Agrazin 500SC	U	STEPC	Atrazin 500 g/l	0098/H/12-00/ APV-SAHEL	Herbicide
Sumicombi 30EC	II	Somitomo corporation	Fenitrothion 250g/l-fenivalerate 50g/l	0099/l/12-00/ APV-SAHEL	insecticide
Sumicombi-alpha 25ULV	II	Somitomo corporation	Fenitrothion 245g/l – esfenivalerate 5g/l	0100/l/12-00/ APV-SAHEL	insecticide
Sumithion 3D	U	Somitomo corporation	Fenitrothion 30g/kg	0101/l/12-00/ APV-SAHEL	insecticide
Green muscle	III	Calliopre	Metarhizium flavoviride 5.10 spores/g	0152/l/12-00/ APV-SAHEL	Microinsecticides (Biological)
Sumithion 5D	U	Somitomo corporation	Fenitrothion 50g/kg	0102/l/12-00/ APV-SAHEL	insecticide
Sumithion 50EC	II	Somitomo corporation	Fenitrothion 500g/l	0103/l/12-00/ APV-SAHEL	insecticide
Sumithion L-20	II	Somitomo corporation	Fenitrothion 200g/l	0104/l/12-00/ APV-SAHEL	insecticide
Sumithion L-50	II	Somitomo corporation	Fenitrothion 500g/l	0105/l/12-00/ APV-SAHEL	insecticide
Sumithion L-100	II	Somitomo corporation	Fenitrothion 1000g/l	0106/l/12-00/ APV-SAHEL	insecticide
Cyanox L-50	II	Somitomo corporation	Cyanophos 500g/l	0107/l/12-00/ APV-SAHEL	insecticide
Unden 2DP	III	Bayer	Propoxur 20g/kg	0108/l/12-00/ APV-SAHEL	insecticide
Alsystin 050UL	III	Bayer	Triflumuron 50g/l	0109/l/12-00/ APV-SAHEL	insecticide
Applaud 40SC	III	Somitomo corporation	Buprofezine 400g/l	0110/l/12-00/ APV-SAHEL	insecticide
Caiman 350EC	Ib	STEPC	Endosulfan 350g/l	0111/l/12-00/ APV-SAHEL	insecticide
Hostathion	II	Avenis	Triazophos 420g/l	0112/l/12-00/ APV-SAHEL	insecticide
Phaster 500EC	Ib	Avenis	Endosulfan 500g/l	0113/l/12-00/ APV-SAHEL	insecticide
Conquest 88EC	II	Avenis	Acetamipride 16g/l + cypermethrin 75g/l	0114/l/12-00/ APV-SAHEL	insecticide
Adonis 8EC	III	Avenis	Fipronil 8g/l	0115/l/12-00/ APV-SAHEL	insecticide

Fury D 412EC	II	FMC	Zeta-cypermethrin 12g/l dimethoate 400g/l	0116/l/12-00/ APV-SAHEL	insecticide
Fury P 162EC	II	FMC	Zeta-cypermethrin 12g/l profenfos 150g/l	0117/l,A/12-00/ APV-SAHEL	insecticide
Fury D 212EC	II	FMC	Zeta-cypermethrin 12g/l 200g/l	0118/l,A/12-00/ APV-SAHEL	insecticide
Endocoton 350EC	Ib	Makhteshim	Endosulfan 350g/l	0119/l/12-00/ APV-SAHEL	Insecticide
Endocoton 500EC	Ib	Makhteshim	Endosulfan 500g/l	0120/l/12-00/ APV-SAHEL	insecticide
Curacron	III	Novartis	Profenofos 500g/l	0121/l/12-00/ APV-SAHEL	insecticide
Gylphogan 480SL	III	Agan	Glyphosate 480g/l	0122/H/12-00/ APV-SAHEL	Herbicide
Queletox 640UL	II	Bayer	Fenithion 640g/l	0123/AV/12-00/ APV-SAHEL	Avicide contre les mange-mill (quelea quelea) uniquement dans les dortoirs
Cypercal P 186EC	II	Calliope	Cypermethrin 36g/l + profenofos 150g/l	0124/l,A/12-00/ APV-SAHEL	Insecticides/acaricides
Cypercal P 230EC	II	Calliope	Cypermethrin 30g/l + profenofos 200g/l	0125/l,A/12-00/ APV-SAHEL	Insecticides/acaricides
Cypercal P 236EC	II	Calliope	Cypermethrin 36g/l + profenofos 200g/l	0126/l,A/12-00/ APV-SAHEL	Insecticides/acaricides
Cypercal P 336EC	II	Calliope	Cypermethrin 36g/l + profenofos 300g/l	0127/l,A/12-00/ APV-SAHEL	Insecticides/acaricides
Dursban –B 18/150 EC	Ib	Dow Agro Sciences	Cyfuthrine 18g/l + chlorpyrifos150g/l	0128/l/06-00/ APV-SAHEL	insecticide
Dursban –B 18/200 EC	Ib	Dow Agro Sciences	Cyfuthrine 18g/l + chlorpyrifos200g/l	0129/l/06-00/ APV-SAHEL	insecticide
Lorsban –B 7/150 EC	II	Dow Agro Sciences	b- Cyfuthrine 7g/l + chlorpyrifos150g/l	0130/l/06-00/ APV-SAHEL	insecticide
Lorsban –B 7/200 EC	II	Dow Agro Sciences	b- Cyfuthrine 7g/l + chlorpyrifos200g/l	0131/l/06-00/ APV-SAHEL	insecticide
Stomp 500EC	III	BASF	Pendimethaline 500g/l	0132/H/06-00/ APV-SAHEL	Herbicide
Tersen 420EC	II	Senchim AG	Cypermethrin 30g/l dimethoate 240g/l triazophos150g/l	0133/l,A/06-00/ APV-SAHEL	insecticide
Dual 230 SC	II	Senchim AG	Cypermethrin 30g/l + profenofos 200g/l	0134/l/06-00/ APV-SAHEL	insecticide
Tenor 500SC	II	Senchim AG	profenofos 500g/l	0135/l/06-00/ APV-SAHEL	Insecticide

Cytoate 436EC	II	Senchim AG	Cypermethrin 36g/l + dimethoate 400g/l	0136/l,A/06-00/ APV-SAHEL	insecticide
Thiofonex 500EC	II	Senchim AG	Endosulfan 500g/l	0137/l,A/06-00/ APV-SAHEL	Insecticide
Cyclofos 236 EC	II	Senchim AG	Cypermethrin 36g/l chlorpyrifo 200g/l	0138/l/06-00/ APV-SAHEL	Insecticide
Cotoforce 500SC	IV	Senchim AG	Fluometuron 250g/l + prometrne250g/l	0139/H/06-00/ APV-SAHEL	Herbicide
Spectral 450DP** ***Contain POP chemicals	***II***	***Senchim AG***	**Thirame 250g/l + *Lindan***	0140/l,F/06-00/ APV-SAHEL	insecticide
Dual 186EC	II	Senchim AG	Cypermethrin 36g/l + profenofos 150g/l	0141/l/06-00/ APV-SAHEL	insecticide
Thiofanex 350EC	II	Senchim AG	Endosulfan 350g/l	0142/l,A/06-00/ APV-SAHEL	insecticide
Ateafor 500SC	IV	Senchim AG	Atrazin 500g/l	0143/H/06-00/ APV-SAHEL	Herbicide
Duo 171EC	II	Senchim AG	Cypermethrin high-cis 21g/l + profenofos 150g/l	0144/l/06-00/ APV-SAHEL	insecticide
Garil	II	Dow AgroScience	Triclopyr 72g/l + propanil 360g/l	0145/H/06-00/ APV-SAHEL	Herbicide
Gallant Super	III	Dow AgroScience	Haloxyfop-R methyl 104g/l	0146/H/06-00/ APV-SAHEL	Herbicide
Nurelle D 36/150EC	II	Dow AgroScience	Cypermethrin 36g/l chlorpyrifo ethyl 150g/l	0147/l/06-00/ APV-SAHEL	insecticide
Nurelle D 36/150EC	II	Dow AgroScience	Cypermethrin 36g/l chlorpyrifo ethyl 200g/l	0148/l/06-00/ APV-SAHEL	insecticide
Alazine	III	Agan Chemicals	Alachlore 250g/l + atrazine250g/l	0149/H/06-00/ APV-SAHEL	Herbicide
Alazine	III	Agan Chemicals	Alachlore 350g/l + atrazine200g/l	0150/H/06-00/ APV-SAHEL	Herbicide
Deltaphos 210EC	Ib	Aventis	Deltamethrin 10g/l + triazophos 200g/l	0151/l/06-00/ APV-SAHEL	insecticide

ANNEX 3: Location map of new groundwater monitoring network



ANNEX 4: Hydrogeological map of the Western Region of The Gambia

The map shows the groundwater flow contours in The Gambia, the location of individual boreholes in the deep and shallow aquifers and well fields. (Saihou Ceesay & Sons Ltd and Howard Humphreys Ltd, 1987)