CSIR WATER RESEARCH INSTITUTE

(CSIR WRI)

Annual Report 2011

CSIR
WATER RESEARCH INSTITUTE

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QUALITY RESEARCH

SUSTAINABLE WATER FOR DEVELOPMENT

CSIR WATER RESEARCH INSTITUTE

ACCRA, GHANA

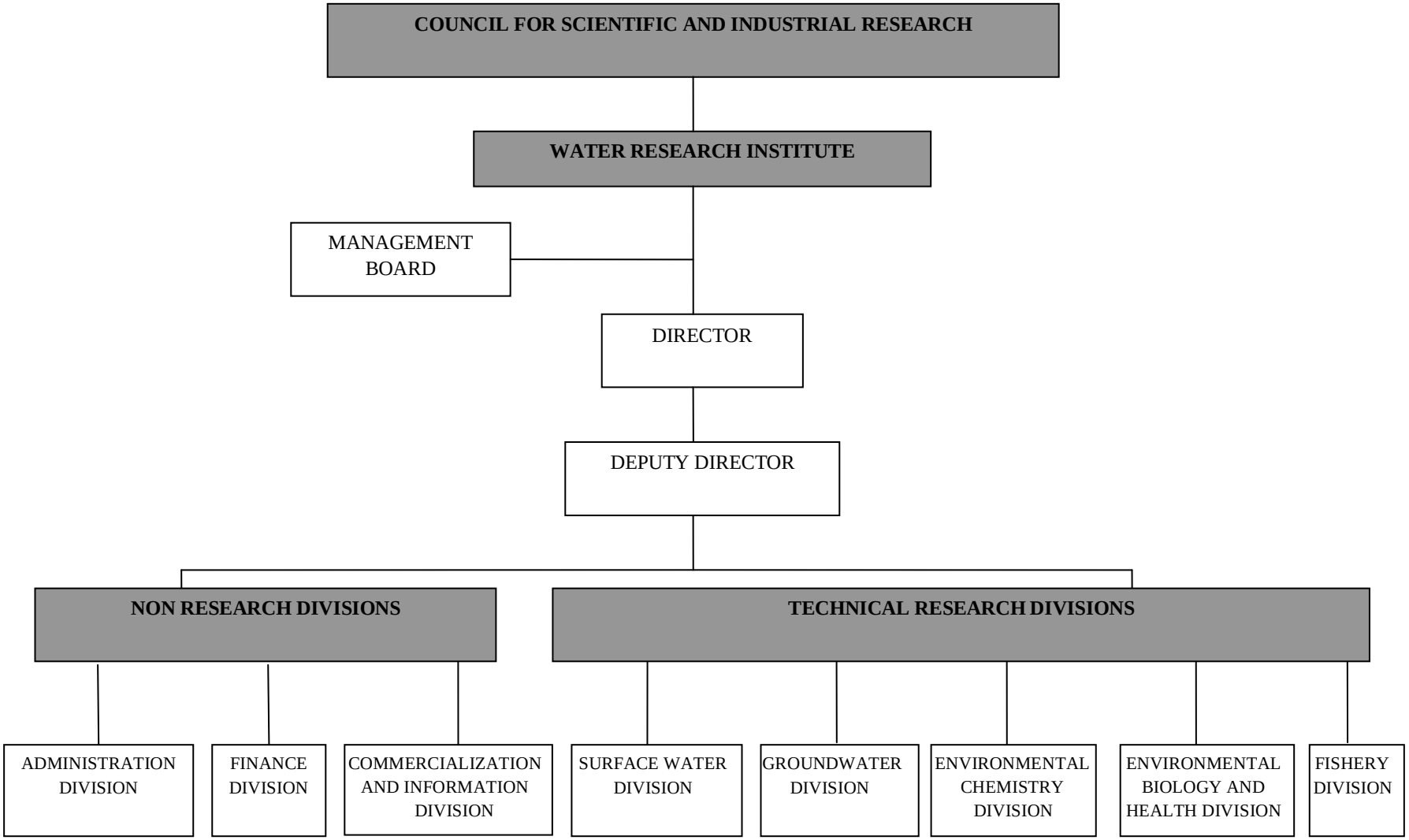
ACRONYMS

AAS	-	Atomic Absorption Spectrophotometer
AEO	-	Agricultural Extension Officers
AGRA	-	Alliance for Green Revolution in Africa
AIWMS	-	Agro-forestry and Integrated Water Management Specialists
AMA	-	Accra Metropolitan Assembly
ARDEC	-	Aquaculture Research and Development Centre
ARR	-	Acute Risk Ratio
ASFA	-	Aquatic Sciences and Fisheries Abstract
ASTI	-	Agricultural Science Technology and Innovations
BDC	-	Basin Development Challenges
BMZ	-	German Federal Ministry for Economic Cooperation and Development
BOD	-	Biochemical Oxygen Demand
CIDA	-	Canadian International Development Agency
COD	-	Chemical Oxygen Demand
CPUE	-	Catch Per Unit Effort
CPWF	-	Challenge Programme on Water and Food
CSIR	-	Council for Scientific and Industrial Research
CWSA	-	Community Water and Sanitation Agency
DANIDA	-	Danish International Development Agency
DO	-	Dissolved Oxygen
EIA	-	Environmental Impact Assessment
EPA	-	Environmental Protection Agency
FAO	-	Food and Agriculture Organization
FC	-	Forestry Commission
FCR	-	Food Conversion Ratio
FDB	-	Food and Drug Board
GAA	-	Ghana Aquaculture Association
GCLME	-	Guinea Current Large Marine Ecosystem
GEF	-	Global Environment Facility of the World Bank
GGL	-	Goldfields Ghana Limited
GIDA	-	Ghana Irrigation Development Authority
GIS	-	Geographic Information System
GMA	-	Ghana Meteorological Agency
GOPDC	-	Ghana Oil Palm Development Company
GTZ	-	Deutsche Gesellschaft für Technische Zusammenarbeit
GWCL	-	Ghana Water Company Limited
GWD	-	Ghana Wildlife Division
HDLV	-	High Density Low Volume
HSD	-	Hydrological Services Department
IAB	-	Institute of Aquatic Biology
ICATWS	-	International Conference on Appropriate Technology for Water and Sanitation
IGF	-	Internally Generated Funds
IHP	-	International Hydrological Programme
IOC	-	Intergovernmental Oceanographic Commission
ISSER	-	Institute of Statistical, Social and Economic Research
IUCN	-	International Union for Conservation of Nature

IWMI	-	International Water Management Institute
IWRM	-	Integrated Water Resources Management
IWT	-	Institute of Water Technology
IMC	-	Internal Management Committee
KCCR	-	Kumasi Centre for Collaborative Research
KNUST	-	Kwame Nkrumah University of Science and Technology
MC	-	Minerals Commission
MEST	-	Ministry of Environment, Science and Technology
MoFA	-	Ministry of Food and Agriculture
MWRWH	-	Ministry of Water Resources Works and Housing
NAP	-	National Action Plan
NGO	-	Non-Governmental Organizations
NMIMR	-	Noguchi Memorial Institute for Medical Research
NTDs	-	Neglected Tropical Diseases
RLWRDS	-	Research Library and Water Resources Documentation System
ROI	-	Return on Investment
SDRCP	-	Sustainable Development of Research Capacity Programme
SNAS	-	School of Nuclear and Allied Sciences
SSA	-	Sub-Saharan Africa
SWAT	-	Soil and Water Assessment Tool
TDA	-	Transboundary Diagnostic Analysis
TDS	-	Total Dissolved Solids
TWQR	-	Target Water Quality Range
UDS	-	University for Development Studies
UNEP	-	United Nations Environment Programme
UNESCO	-	United Nations Education, Scientific and Cultural Organisation
UNIDO	-	United Nations Industrial Development Organisation
UNU/INRA	-	United Nation University – Institute for Natural Resource in Africa
VBA	-	Volta Basin Authority
VLTC	-	Volta Lake Transport Company
VRA	-	Volta River Authority
WARDA	-	West Africa Rice Development Agency
WATSAN	-	Water and Sanitation
WHO	-	World Health Organisation
WRC	-	Water Resources Commission
WRI	-	Water Research Institute
WRRI	-	Water Resources Research Institute
WRIS	-	Water Resources Information Services
WSF	-	Water Storage Facility
ZEF	-	Centre for Development Research of the University of Bonn, Germany

TABLE OF CONTENTS

Organizational Chart



EXECUTIVE SUMMARY

This report contains an overview of research and commercialization activities undertaken by the Water Research Institute of the Council for Scientific and Industrial Research (CSIR WRI) in 2011. The Water Research Institute (WRI) is one of the 13 institutes of the Council for Scientific and Industrial Research (CSIR). The overall goal of the CSIR WRI is to conduct research into all aspects of water resources (both living and non-living) in order to provide scientific and technical information and services as well as strategies for the sustainable development, utilization and management of such resources for the socio-economic advancement of the country.

The 2011 Annual Report consists of four (4) chapters namely Introduction, Research and Development Activities, Administration and Finance. The report has been compiled based on the research and development activities, commercialization of research and development activities through consultancy and advisory services, and administrative matters such as staff strength, appointments, promotions, national service recruitment, as well as financial and accounting matters during the year 2011.

The Institute undertook a total of 30 research projects during the year. These included: managing water at the urban-rural interface: the key to climate change resilient cities; groundwater in Sub-Saharan Africa: implication for food security and livelihood; monitoring groundwater resources occurrences and their quality within the Pra and Tano basins; water quality assessment of sachet water sold in the Tamale Metropolis; biting activity and disease transmission potential of Black Fly in River Densu Basin; and water quality impacts of cage and pen aquaculture on the Volta Lake.

A total of 20 technical reports, 13 conference papers, 24 consultancy reports and 24 journal papers were authored by scientists of the Institute in collaboration with scholars worldwide.

1.0 INTRODUCTION

1.1 Establishment

The Water Research Institute (WRI) is one of the 13 research institutes of the Council for Scientific and Industrial Research (CSIR). It is a public institution established in 1996 by the CSIR Act 521. It was created by the merger of the Institute of Aquatic Biology (IAB) and the Water Resources Research Institute (WRRI) of the CSIR which were created in 1965 and 1982, respectively.

1.2 Vision

To become a centre of excellence in the provision of scientific research into water and related resources for sustainable socio-economic growth

1.3 Mission

To conduct research into all aspects of water resources (both living and non-living) in order to provide scientific and technical information and services as well as strategies for the sustainable development, utilization and management of such resources for the socio-economic advancement of the country

1.4 Values

Our core values include dedication to duty, commitment, loyalty to quality assurance and customer satisfaction

1.5 Key Objectives

The key objectives of the Institute are:

- To generate, develop and transfer appropriate technologies, information and services for sustainable development, utilization and management of surface water resources;
- To generate, process and disseminate information on the availability of groundwater, rate and volumes to be abstracted for various uses as well as the reliability and sustainability of its recharge;
- To generate, process and disseminate water and waste water quality information to end users;
- To enhance public health status through sound environmental management and water pollution control strategies;
- To increase local fish production through participatory research and technology transfer in aquaculture and sustainable management strategies in inland and coastal waters of Ghana; and
- To undertake commercialisation of research and development activities through consultancy and advisory services and the provision of water resources information, documentation and technical support services.

1.6 Divisions

The mandate of the Institute is realized through the research and development activities of five (5) Technical Divisions and three (3) Non-technical Divisions. The Technical Divisions are:

- Environmental Biology and Health
- Environmental Chemistry
- Fishery
- Groundwater

- Surface Water

The Non-technical Divisions are:
- Administration
- Commercialization and Information
- Finance

1.7 Branches

- Main office in Accra
- Branch office at Tamale in the Northern Region
- Aquaculture Research and Development Centre (ARDEC) at Akosombo in the Eastern Region (Figure 1)

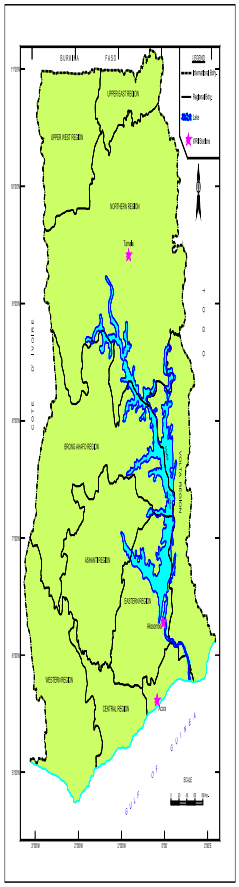


Figure 1: Location map of branches of CSIR Water Research Institute

An overview of the major activities of the Institute during the year 2011 is herein presented. We shall be grateful to receive any comments and suggestions you may wish to make on any aspects of our activities or report. Kindly send them to the following address:

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2.0 RESEARCH AND DEVELOPMENT ACTIVITIES

2.1 ENVIRONMENTAL BIOLOGY AND HEALTH DIVISION

The objective of the Environmental Biology and Health Division is to enhance public health status through sound environmental management and water pollution control strategies. The Division has expertise in areas of microbiology, parasitology, entomology, aquatic invertebrates, molecular biology and public health. Its approach to research, consultancy, advisory services, technology transfer, water-related public health and environmental issues is multidisciplinary. Activities of the Division include:

- enhancement of public health status through sound environmental and water pollution control strategies;
- microbiological quality analyses of water and other samples;
- research into water-related/borne parasitic diseases of public health importance;
- research into water-related vectors of diseases of public health importance to develop innovations in control and prevention;
- environmental impact assessment and watershed management;
- identification and management of invasive plants in Ghana;
- molecular epidemiology, understanding the mechanism and genetics of drug resistance and the development of molecular biology diagnostic tools;
- production of health education and supply of biological specimens as teaching materials;
- consultancy in the establishment of science and medical laboratories; and
- training of scientists, technologists, technicians and students.

2.1.1 Biting Activity and Disease Transmission Potential of Black Fly in River Densu Basin

(Project Staff: Dr. Alex A. Opoku – Senior Research Scientist)

The objective of this study was to assess the levels of bites and parasite infectivity in black flies in the Densu Basin. During the period under review, adult flies were captured by two vector collectors alternating at an hourly interval. The flies were captured from 7 am to 6 pm for 5 consecutive days using human bait method. Captured flies were kept alive until dissection. The physiological age was determined by separating nulliparous from parous. Each fly was also examined for *Onchocerca volvulus* by tearing apart the thorax and head of the fly.

A total of 355 flies were caught in June and 375 flies in July and dissected. Out of the 355 flies dissected in June, 96 % were parous and 0.5 % infected with the *O. volvulus* parasite. Out of the 375 flies dissected in July, 76 % were parous, 0.34 % infected and 0.17 % infective (i.e. with parasite in the head). A paired t-test treatment of parity showed that the proportion of parous flies carrying the parasite in July was significantly different from the flies caught carrying parasite in June ($P<0.05$). A paired t-test treatment of the parity rates also showed that there were significantly more parous flies than nulliparous ones ($P<0.05$) in both June and July. Despite a significantly high proportion of parous flies, the number of flies infective was significantly low ($P<0.01$). The number of infective larvae per infected fly at Asuoyaa ranged from 0 – 1. However, in natural conditions, the number of infective larvae per infected fly ranged from 2 – 8 in the Onchocerciasis Control Programme (OCP) area (WHO 1985). Parasite load of the flies at Asuoyaa was low and this indicated that a large proportion of parous flies

might have shed their infective *O. vovulus* larvae during previous meal or the larvae were developing either in the abdomen or thorax. The study could therefore be used as a basis for OCP.

2.1.2 Investigations on the Importance of Faecal Coliform Attachment to Algae and Suspended Solids in Natural Wastewater Treatment Systems

(Project Staff: Mr. Ebenezer D. O. Ansa – Research Scientist, Mr. M. A. Acheampong, F. K. Nkrumah and A. S. Boakye-Yiadom)

The Institute, in collaboration with Department of Chemical Engineering, Kumasi Polytechnic, initiated and completed this project in the reporting year to assess the importance of algae and suspended solids as surfaces for bacteria attachment in natural wastewater treatment systems. The specific objectives were to assess the methods of bacteria detachment using plate counts and investigate the importance of algae and suspended solids as surfaces for bacteria attachment in natural wastewater treatment systems.

During the reporting period, algae grown by natural colonization using pre-settled domestic wastewater were concentrated by centrifugation. *Escherichia coli* (*E. coli*) suspended in normal saline was added to processed algal and kaolin suspensions and monitored over time using chromocult coliform agar. Detachment procedures were conducted to assess attached *E. coli* after three and five days of incubation at 37^{o}C. Paired samples t-test was used to assess attached *E. coli*. Similar experiments were conducted using only wastewater and wastewater with parozone. Various methods of detaching faecal coliforms involving the use of Sonication (different equipment types), Vortex-mixing, combination of Vortex-mixing and Sonication, Syringe-needle, and Parozone were investigated.

Detachment tests performed after three days and five days of incubation in algae-*E. coli* incubations did not reveal significant increase in *E. coli* numbers ($p = 0.081$ for three days, and $p = 0.097$ for five days). However, in the case of *E. coli*-kaolin suspension, *E. coli* counts before and after detachment tests for both three and five days of incubation showed comparable results ($p > 0.05$).

It was concluded from the study that the use of syringe fitted with a needle could be an effective means of detaching attached faecal coliforms. This emerged as the best method of detachment among a host of others tested. The use of 0.11g/l parozone was also effective in preventing attachment of *E. coli* to each other or to suspended matter. Algae helped in sedimenting faecal coliforms to the bottom of reactors within 24 hours. The mechanism by which this occured did not involve a process of permanent attachment to algal surfaces. Faecal coliforms did not attach to algae after 24 and 48 hours of incubation (Figure 2). Hence, the study threw more light on the importance of algae in reducing the numbers of pathogenic bacteria in treatment systems and added to the knowledge of how faecal coliforms could be removed from domestic waste water.

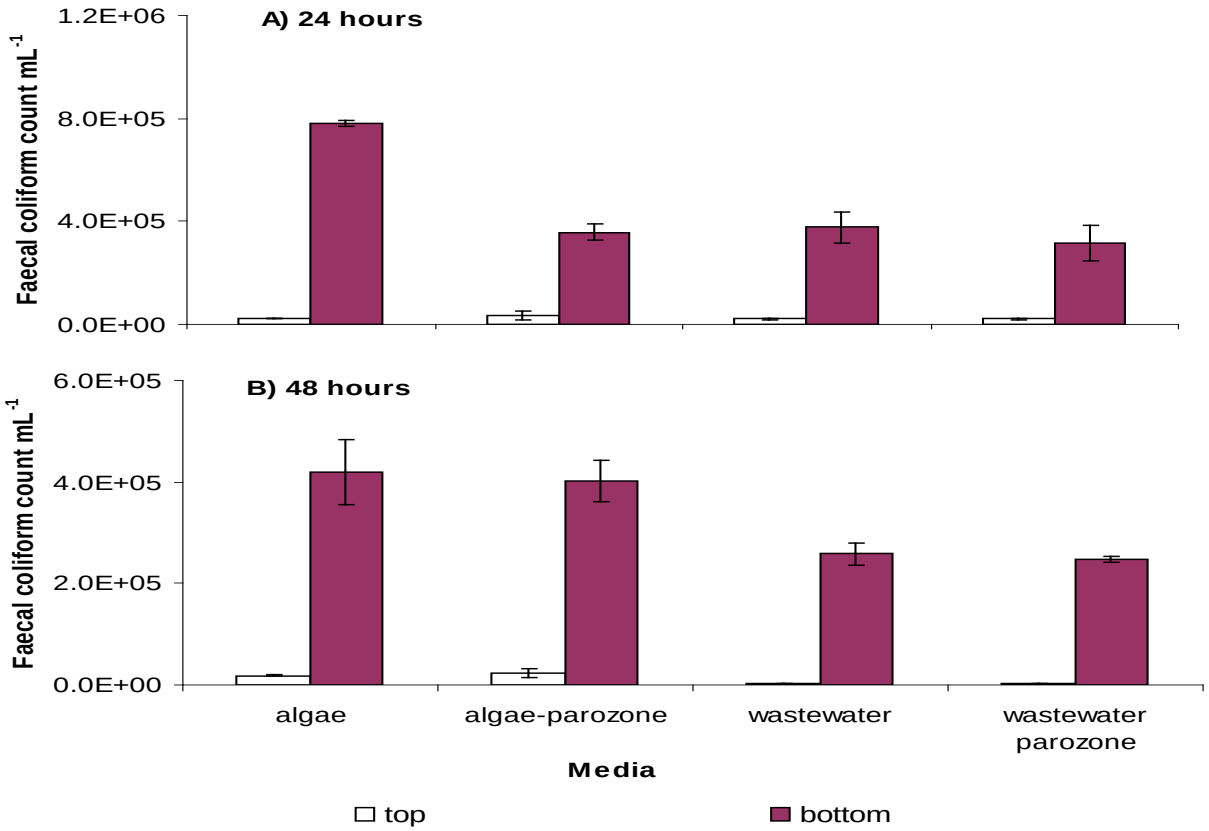


Figure 2: Sedimenting faecal coliforms to the bottom of reactors within 24 and 48 hours

2.1.3 Physico-chemical and Bacteriological Quality of Water Storage Facility and the Awonsu Stream – Newmont Ghana

(Project Staff: Dr. R. Asmah – Research Scientist, Dr. J. A. Ampofo – Principal Research Scientist and Mrs. R. A. Banu – Research Scientist)

This project started and ended in the reporting year. The objective was to determine the possibility of pollution of the Tano River by the dislodge of water from the water storage facility (WSF) of Newmont Ghana Gold Ltd (NGGL).

Activities carried out included selection of seven (7) sampling locations for monitoring, collection of water samples for bacteriological analysis and conducting interviews. Parameters analyzed included total coliforms, faecal coliforms, *M. enterococcus, E. coli* and total heterotrophic bacteria.

The lowest and highest faecal coliform (FC) counts of 76 and 3702 per 100 ml were recorded at the WSF and the Tano upstream locations, respectively. The Awonsu upstream had the highest mean *E. coli* count per 100 ml. The counts of *E. coli* at all sampling sites were affected by the washing down of faecal matter via surface runoff from the surroundings (Table 1). The levels of *E. coli* and *Enterococcus faecal* at the various sampling sites are shown in Figures 3 and 4. The higher levels of bacteria recorded in the Tano River and Awonsu streams as compared to that of the WSF indicated that the water discharged from the WSF was not the source of pollution of the water bodies.

Table 1: Overall mean bacteriological counts (Counts/100 ml)

Location	TC	FC	*E coli*	*E. faecalis*	THB
WSF	1970	76	38	6	684
WSF-D	2910	243	128	10	2697
ECD 2	4418	325	100	8	1382
Awonsu Upstream (KSW 14)	4795	2358	1673	264	2792
Awonsu Downstream (KSW-15)	6626	2565	838	429	896
Tano Upstream (NSW 10)	6079	3702	1073	206	4170
Tano Downstream (KSW 1)	4999	690	266	169	3841
EPA Maximum Permissible value	**400**		**10**		

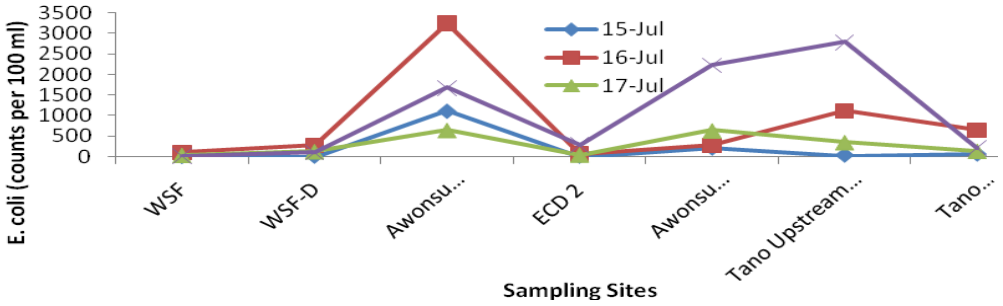


Figure 3: Variations in *E. coli* counts over days

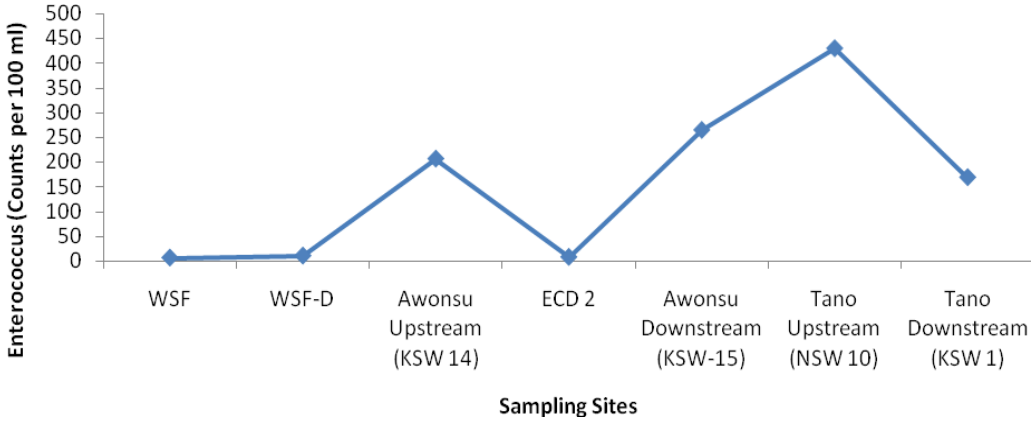


Figure 4: Mean counts of *Enterococcus faecal* at the sampling sites

2.1.4 Independent Assessment of Drinking Water Quality in Accra-Tema Metropolis

(Project Staff: Dr. J. A. Ampofo – Principal Research Scientist, Mr. Anthony Y. Karikari – Research Scientist and Mrs. Regina A. Banu – Research Scientist)

Drinking of tap water may be associated with health risks for susceptible individuals due to deterioration of microbiological quality in the distribution system. The deterioration in water quality occurs either because of regrowth of micro-organisms in biofilms which are formed on interior surfaces of water pipes or because of back siphonage of contaminated water. It was against this background that this study was conducted to assess the quality of water produced and supplied by the Ghana Water Company Ltd. (GWCL) in their distribution systems in various locations in Accra - Tema Metropolitan Area.

Activitites carried out included selection of monitoring sites and collection of water samples for bacteriological analyses. Parameters analysed were total coliform, faecal coliform, total heterotrophic bacteria and *E.coli*.

The study showed that water quality at the treatment plants (Kpong treatment plant and Weija treatment plant) were bacteriologically safe to be used as drinking water sources as they conformed to Ghana Standards GS 175-1 of zero total coliform, faecal coliform and *E.coli* counts per 100 ml of water tested. However, water sampled from the Accra Booster Station (Oponglo) was contaminated with coliform bacteria and this could be due to inadequate rechlorination at the booster station. Only eleven (11) out of the thirty-one (31) consumer taps sampled were suitable for drinking. In all, Twenty one (21) out of the thirty seven (37) sampled points were contaminated especially with total coliforms (Table 2). Dansoman Police Station was found to have the highest levels of total coliforms and this could be attributetd to illegal connections and burst pipelines within the area.

The following recommendations were given to remedy the situation:

- To reduce introduction of bacterial contaminants into the distribution systems, GWCL should make sure that there is a constant flow of water in the pipelines
- Connections to GWCL water supply lines should be done by accredited professionals to reduce introduction of contaminants
- Distribution lines should be properly protected in marshy areas
- Sanitation around distribution lines should be checked regularly
- Regular monitoring of the water quality in the distribution systems should be carried out.
- Rechlorination should be done frequently at booster stations to check any bacterial regrowth and free chlorine residuals should be checked daily at representative points throughout the systems
- The public must be encouraged to inform the appropriate offices of leakages in pipe lines in their vicinity and GWCL must provide a toll free line to facilitate easy communication

Table 2: Bacteriological analysis of water from Accra East

Sample Identification	Total Coliform (TC) (cfu/100 ml)	Faecal Coliform (FC) (cfu/100 ml)	*E. coli* (cfu/100 ml)	Total Heterotrophic Bacteria (cfu/100 ml)
Kpong Plant	0	0	0	<1
Ashaiman Booster St.	0	0	0	<1
Tema Gen. Hospital	4	0	0	2
SOS Tema	0	0	0	50
Tema GWCL Offices	2	0	0	5
Com. 1 Police St	0	0	0	3
Tema Mkt	0	0	0	<1
Danpong Pharmacy	4	1	0	24
Coca Cola Area	0	0	0	<1
Papaye	0	0	0	<1
Accra Boaster St (Oponglo)	10	0	0	13
Kanda TV3 Area	0	0	0	<1
Flair Catering Services	272	0	0	37
La Hospital	10	1	0	332
PURC Office	104	0	0	19
Osu (Haveli Area)	651	176	44	1408
Airpt Area (CSIR Flat)	0	0	0	11
Airpt Area Inter. Bnk	7	0	0	5
Assoc. Int. Sch. Area	0	0	0	<1
Legon Hosp.	11	0	0	13
Legon Quarters	10	0	0	2
IPS	280	0	0	74
Haatso Sprmkt area	224	0	0	43
North Lg Hosp.	376	0	0	960
CSIR WRI Office	252	0	0	25
Weija (Canadian)	0	0	0	<1
Weija (Candy)	0	0	0	<1
Weija (Bamag)	0	0	0	<1
Dansoman GWCL	0	0	0	<1
Dansoman Police St	676	0	0	28
Dansoman Mkt	60	0	0	13
Dansoman Glefe	0	0	0	22
Mamprobi P'clinic	120	0	0	32
Korle-Bu Hosp.	37	0	0	16
Bowers Sch Bishop.	0	0	0	<1
Princess Louis Hosp.	4	0	0	7
Adabraka Polyclinic	558	0	0	77
WHO Guidelines	**0**	**0**	**0**	**-**
Ghana Std. (GS 175)	**0**	**0**	**0**	**500**

2.1.5 Leachate Quality Assessment at Sabah Landfill Site in Accra West

(Project Staff: Mr. Anthony Y. Karikari – Senior Research Scientist, Dr. Joseph A. Ampofo – Principal Research Scienctist, Mrs. Regina A. Banu – Research Scientist and Mr. Mark Akrong – Research Scientist)

Landfilling is one of the least expensive methods for disposal of solid waste. About 90 % of municipal solid waste (MSW) is disposed in open dumps and landfills. If not managed properly, the leachate could cause major environmental challenges. It was against this background that this study was initiated and completed in the reporting year to assess the quality of the leachate at Sabah landfill site near Weija in Accra West for possible treatment.

Leachate samples were collected at selected sites and analyzed for the presence of total coliform, faecal coliform, *Escherichia coli*, Bacillus, *Vibro spp* and *Salmonella*. Mould, yeast and helminth eggs were also considered in the analyses. All bacteria samples were analysed using the membrane filtration (MF) technique, except *Clostridium* which was analysed by pour plate technique using nutrient agar. Yeast and Mould enumeration was also done by the pour plate technique using Oxytetracyline Glucose Yeast Extract media. The concentration method by Schwartzbrod (1998) with the aid of WHO bench aid for the diagnosis of intestinal parasite (WHO, 1994) was used in the quantification of the helminth eggs.

The results of all samples analysed showed that the levels of almost all the selected parameters exceeded the EPA recommended levels (Table 3). This could pose health risks to the surrounding communities and the nearby Densu River if not managed well. To help mitigate the situation, the following recommendations were given:

- A waste management and treatment policy should be put in place by appropriate authorities and leachates must be pre-treated before disposal.
- The leachate must be contained.
- Legislations against siting of waste dumps near water bodies must be reviewed and enforced.
- Settlements around or close to landfill sites must be avoided and be backed by law.
- Research on all waste dump sites must be conducted regularly to acertain the environmental and health impacts.

Table 3: Microbiological characteristics of leachate from Sabah landfill site in Accra West

Microorganisms	**Sampling locations**				**Maximum Permissible levels for irrigation**	**EPA guideline values**
	Site 1	**Site II**	**Site III**	**Site IV**		
Total Coliform (cfu/100ml)	26 x 10^6	6 x 10^5	244 x 10^5	18.6x 10^2	<1000	<400
Faecal Coliform (cfu/100ml)	33 x 10^5	1 x 10^4	26 x 10^4	38.4 x 10	<10	10
E. coli (cfu/100ml)	22.4 x 10^5	0	1 x 10^5	36.9 x10^2	<10	<10
Salmonella spp. (cfu/100ml)	41 x 10^3	0	9 x 10^3	10.4 x 10	<10	<10
Yeast (cfu/ml)	15	0	14	0	0	0
Clostridium spp. (cfu/100ml)	**0**	**0**	**0**	0	<10	<10
Vibrio spp. (cfu/100ml)	12.0 x 10	0	23.3x10^2	14	<10	<10
Bacillus spp. (cfu/1ml)	5	0	8	4	<10	<10
Mould (cfu/ml)	20.4 x 10	12	50	13	<10	<10
Helminth Egg (L_{-}^{-1})	0	0	0	0	-	<1

2.1.6 Assessment of the Efficiency of Effluent Treatment by Beverage Industries in Ghana

(Project Staff: Dr. Joseph A. Ampofo – Principal Research Scientist)

The Institute, in collaboration with the Environmental Science Programme, University of Ghana, started and ended this research project in the reporting year. The primary objective was to assess the efficiency of treatment of effluents at the Blue Skies Holdings Ghana, Nsawam and Cocoa Processing Company Ltd, Tema. The specific objectives were to determine the bacteriological characteristics of effluent discharged into the environment from the Blue Skies Holdings Ghana and Cocoa Processing Company Ltd.; determine whether the effluent discharged from these two industries comply with EPA effluent quality recommended limits; assess the effluent treatment systems of the two industries and administer questionnaires to find out whether other beverage industries within the study areas treat their effluents prior to discharge.

During the year under review, effluent samples from the industries were collected at two hours intervals for six months. The effluent samples were collected before entry to treatment plant, before secondary treatment and after final treatment. The samples were each analyzed for the presence of coliform bacteria using the membrane filtration (MF) method to ascertain the levels of total coliform and *E. coli*. A survey was also conducted by means of questionnaires to find out whether effluents were treated prior to discharge and to assess the knowledge of Environmental Officers on the treatment of effluent.

The study showed that the average count for total coliform, *E. coli* and total heterotrophic bacteria at Blue Skies were 1200 cfu ml^{-2}, 70 cfu ml^{-2} and 1510 cfu ml^{-2} respectively. Total coliform most often decreased as it went through the treatment system of Blue Skies. Average coliform values were above the EPA approved discharge value of 400 cfu ml^{-2}. The average *E. coli* value of 70 cfu ml^{-2} was above the EPA permissible discharge level of 10 cfu ml^{-2} (Figure 5).

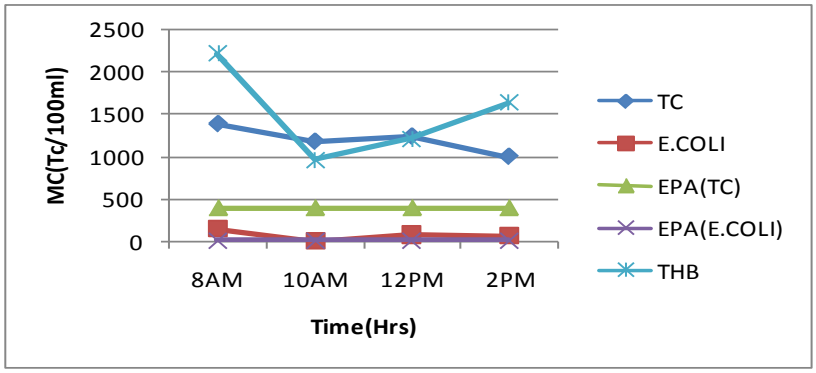


Figure 5: Variation of microbes over a period of time at Blue Skies Holdings Ghana, Nsawam

It was found from the survey that 45.5 % of the beverage industries do not treat their effluent whiles 54.5 % had some form of treatment (Figure 6). All industries with some form of effluent treatment had environmental officers knowledgeable about effluent treatment but only twenty percent of them had knowledge on design criteria (capacity and load) of their treatment plant.

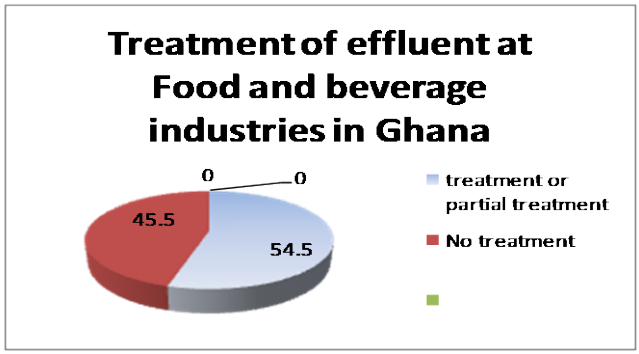


Figure 6: Treatment and non-treatment of effluent at food and beverage industries (FBI's) in Ghana

Based on the findings of this study, it was recommended that a more effective treatment system should be constructed at Blue Skies Holdings Ghana, Nsawam and the primary treatment system at Cocoa Processing Company Ltd. should be expanded with additional aerators. There should also be frequent collection of scum and butter at the Sump and Collection Tank. This would further reduce the level of the organic pollution to meet EPA standards.

2.2 ENVIRONMENTAL CHEMISTRY DIVISION

The long-term general objective of the Environmental Chemistry Division is to generate, process and disseminate water and wastewater quality information to end-users. Specific objectives are to:

- perform quality and quantity assessments of industrial, agricultural and domestic discharges in both urban and rural areas and identify their impact on aquatic ecosystems;
- collect, process and disseminate comprehensive high quality and reliable environmental data on surface and groundwater with regard to their chemical constituents; and
- monitor pollution in coastal waters and lagoons of Ghana.

Currently, the major research programmes of the Division are:

- Water quality monitoring;
- Industrial wastewater studies;
- Environmental impact studies; and
- Development of strategies for water pollution control.

2.2.1 Water Quality Impacts of Cage and Pen Aquaculture on the Volta Lake

(Project Staff: Dr. Ruby Asmah – Research Scientist, Mr. Anthony Y. Karikari – Senior Research Scientist, Dr. Edward K. Abban – Principal Research Scientist, Dr. Joseph K. Ofori – Senior Research Scientist and Mr. Lionel A. K. Awity – Research Scientist)

This collaborative study with the Fisheries Commission started in 2009 and ended in the reporting year. The objectives were to take an inventory of cage and pen fish culture activities on the Volta Lake and to determine their impacts on water quality. During the year under review, physico-chemical data collected was analysed and report on water quality prepared.

The study showed that volumes of fish farm cages ranged from 57.1 m^3 to 6500 m^3. About 60% of the farmers used extruded feed which is known to have less negative impact on water quality. Fingerlings for stocking were produced from the indigenous *Oreochromis niloticus* obtained from the lake to minimize gene pollution in case of fish escape.

The physico-chemical analysis showed that the water quality remained unchanged with regard to parameters such as pH, turbidity, conductivity, transparency and DO. Trace metals concentrations in the water were also low and did not present any threat to biota. Major ions concentrations were within ranges suitable for aquatic ecosystem use. Nutrient concentrations, although were low in most areas with the fish cages, were found to be higher downstream of the lake (Stations S8 to S12) (Table 4). The source of the nutrients enrichment could not be readily attributed to wastes from the fish cages as communities around these areas did also discharge domestic waste/effluents into the lake.

Table 4: Nutrients characteristics of the Volta Lake

Sampling station	NO_2-N (mg/l)	NO_3-N (mg/l)	NH_4-N (mg/l)	PO_4-P (mg/l)
S1	0.006	0.010	0.001	0.001
S2	0.006	0.010	0.001	0.086
S3	0.011	0.008	0.001	0.06
S4	0.006	0.008	0.001	0.021
S5	0.011	0.018	0.001	0.001
S6	0.005	0.016	<0.001	0.038
S7	0.005	0.01	<0.001	<0.001
S8	0.096	0.411	0.311	<0.001
S9	0.115	0.411	0.281	<0.001
S10	0.103	0.412	0.40	0.014
S11	0.101	0.41	0.244	0.034
S12	0.012	0.006	<0.001	0.42
S13	0.005	0.002	<0.001	0.075
S14	0.012	0.01	0.001	0.078
Mean	**0.035**	**0.124**	**0.104**	**0.075**
Min	**0.005**	**0.002**	**<0.001**	**<0.001**
Max	**0.115**	**0.412**	**0.40**	**0.420**
STD	**0.045**	**0.188**	**0.156**	**0.118**

Although there were no clearly detectable negative impacts of cage aquaculture on water quality within the study area of the Volta Lake, it was recommended that:

- there should be continuous monitoring of water quality of the lake for early detection of any adverse impacts;
- the potential for cumulative ecosystem effects of clusters of farms should be considered in approval of sites for farms; and
- the carrying capacity of the lake should be determined to ensure that the right number of cage fish farms, production capacities and right practices are maintained.

2.2.2 Surface Water Quality Monitoring and Assessment of the Volta, Southwestern and Coastal River Systems

(Project Staff: Dr. O. D. Ansa-Asare – Principal Research Scientist, Mr. Humphrey F. Darko – Research Scientist and Mr. Sampson Abu)

The Institute, in collaboration with the European Union (EU), started this project in 2010 and completed in the reporting year. The objective was to develop an efficient and effective management system for the sustainable development of Ghana's water resources to ensure full socio-economic benefits for present and future generations.

The scope of work included collection of water samples, laboratory analysis, data interpretation and preparation and submission of quarterly and annual reports. During the reporting year, three field visits were made to 40 stations in the Volta, Southwestern and Coastal river systems to collect water, sediment and fish samples for analysis.

The results showed that the Volta River System was less polluted when compared to the Southwestern and Coastal river systems. The Water Quality Index (WQI) classification of the water samples indicated that most of the water bodies were in Class II, the "fairly good quality" state, but with seasonal variations in water quality (Figure 7). Twifo-Praso (R. Pra), Hiawa (R. Ankobra) Dunkwa-On-Offin (R. Offin) and Lake Bosomtwe were the only stations that had WQI values less than 50, indicating poor water quality. It was recommended that measures should be taken to reduce pollution in the river basins to improve the quality of the water bodies.

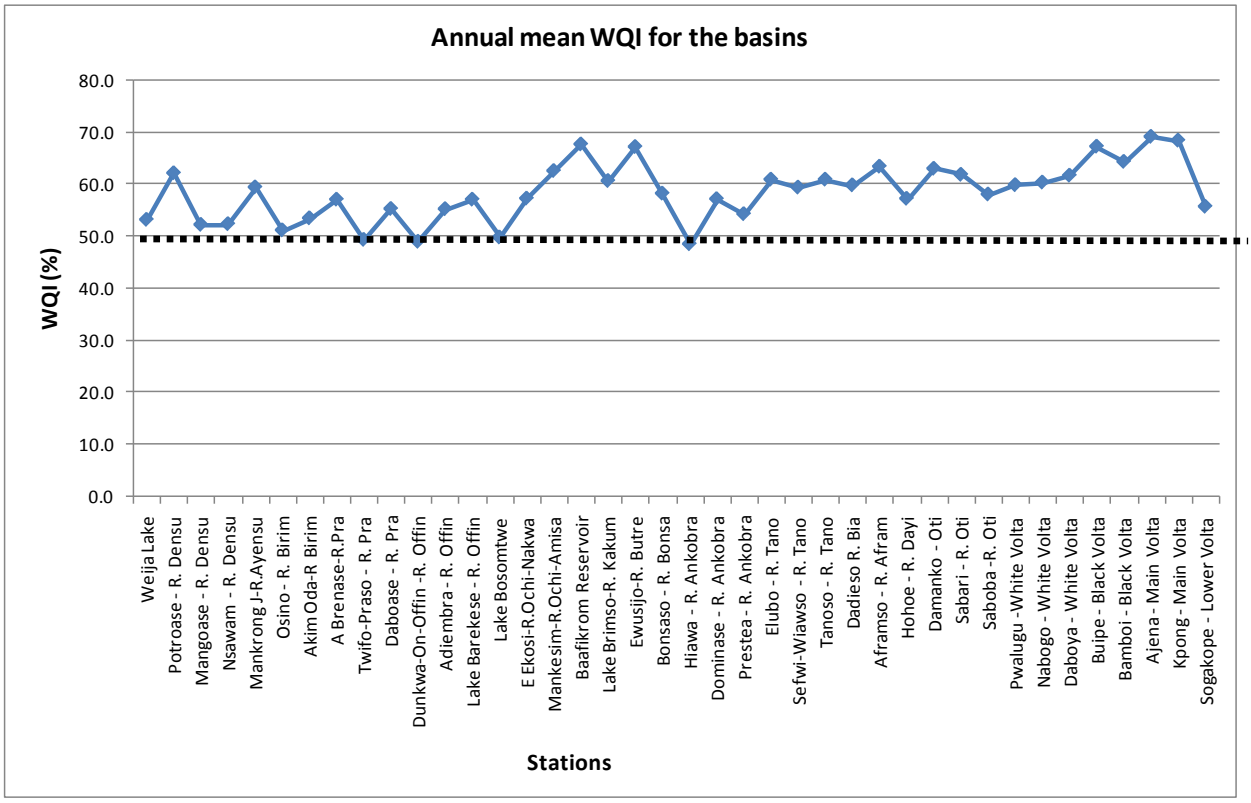


Figure 7: Annual mean Water Quality Index (WQI) of the basins

2.2.3 Water Quality Assessment of Sachet Water Sold in the Tamale Metropolis

(Project Staffs: Mr. Samuel Obiri – Research Scientist and Ms. Zita Naamengnyle - Principal Technical Officer)

This project was initiated and completed in the reporting year to determine the quality of sachet water being sold in Tamale metropolis of the Republic of Ghana. The specific objectives were to assess the physico-chemical parameters; concentration of heavy metals such as manganese, zinc, iron and lead; and isolate and count the number of total and faecal coliform colonies in sachet water sold in Tamale metropolis.

Random sampling techniques were adopted in selecting 19 sachet water brands popularly sold in Tamale metropolis. In all, 608 sachet water samples were selected and analysed. The physico-chemical results of the study showed that with the exception of Samaraba sachet water brand which had low pH, all the sachet water sampled were within the acceptable WHO limit (Table 5). It was observed from the microbial analysis that most of the sachet water being sold in Tamale metropolis had levels of total and faecal coliforms which could pose health hazards to residents who consume them (Table 6). The result of heavy metal analysis is shown in Table 7. It was recommended that further research is needed to generate data on sachet water quality status for policy formulation.

Table 5: Overall mean values of pH, conductivity, TDS and colour of sachet water from Tamale metropolis

ID	TDS (mg/l)	EC (µS/cm)	pH (pH units)	Turbidity (NTU)	Colour
Cool	80.1	132	7.11	2	2.5
Halal	87.4	149	7.14	4	2.5
Luck Spring	79.7	135	7.25	1	2.5
Batachuo	84.5	143	7.18	3	2.5
Jojay	73.3	122	7.31	2	2.5
Brasma	85.6	146	7.12	1	2.5
Almal	75.8	127	7.35	3	2.5
V.I.P	77.9	131	7.41	1	2.5
Uniplus	68.4	134	7.27	2	2.5
KTC	72.9	121	7.13	5	2.5
Ricky's	75.3	126	7.20	1	2.5
Zamzam	79.6	133	7.24	2	2.5
Ko sung	76.5	128	7.30	8	10
MILLA	79.3	133	7.23	1	2.5
Aqua-ba	88.6	148	7.17	2	2.5
Good	79.2	132	7.20	3	2.5
Samaraba	82.2	137	5.85	4	2.5
MJ	86.2	145	7.34	2	2.5
TASINIM	76.1	127	7.26	2	2.5
Nakargu	77.1	129	7.49	4	2.5
WHO Guideline Value			6.5 – 8.5	5	

Table 6: Overall mean results of total and faecal coliforms in sachet water from Tamale metropolis

ID	Total coliform (cfu/100 ml)	Feacal coliform (cfu/100 ml)
Be safe	620	12
Nyale lim	190	2
Lover	30	6
Samaraba	35	16
Voltic	104	12
Brasma	1020	86
Almal	25	0
V.I.P	60	0
Uniplus	45	10
KTC	19,400	1,500
Ricky's	590	32
Zamzam	22	2
Ko sung	15	0
MILLA	0	0
Aqua-ba	670	66
Good	90	4
Samaraba	230	37
MJ	0	0
TASINIM	0	0
Nakargu	0	0

Table 7: Overall mean results of iron, lead, manganese and zinc in sachet water from Tamale metropolis

ID	Fe (mg/l)	Mn (mg/l)	Pb (mg/l)	Zn (mg/l)
Cool	0.108	0.081	<0.001	<0.001
1. Halal	0.172	0.069	<0.001	<0.001
2. Luck Spring	0.261	0.096	<0.001	<0.001
3. Batachuo	0.161	0.074	<0.001	<0.001
4. Jojay	0.069	0.076	<0.001	<0.001
5. Brasma	0.151	0.076	<0.001	<0.001
6. Almal	0.183	0.122	<0.001	<0.001
7. V.I.P	0.076	0.112	<0.001	<0.001
8. Uniplus	0.186	0.122	<0.001	<0.001
9. KTC	0.114	0.024	<0.001	<0.001
10. Ricky's	0.062	0.010	<0.001	<0.001
11. Zamzam	0.099	0.005	<0.001	<0.001
12. Ko sung	0.212	0.018	<0.001	<0.001
13. MILLA	0.099	<0.002	<0.001	<0.001
14. Aqua-ba	0.084	0.001	<0.001	<0.001
15. Good	0.064	0.002	<0.001	<0.001
16. Samaraba	0.126	0.025	0.010	<0.001
17. MJ	0.093	0.012	<0.001	<0.001
18. TASINIM	0.072	0.038	<0.001	<0.001
19. Nakargu	0.142	0.021	0.005	<0.001

2.2.4 Water Quality Studies in Relation to Cage Fish Culture in Busa and Sing Reservoirs in Upper West Region

(Project Staff: Dr. K. Kwarfo-Apegyah – Research Scientist, Mr. Michael Kumi – Research Scientist, Mr. Mark Osa Akrong – Research Scientist, Miss Millicent Ewurama Adu-Boakye – Principal Technical Officer and Mr. Salifu Abdul Latif – Principal Technical Officer)

This study started in the reporting year and is expected to end in 2013. The objectives were to:

- monitor the physical, chemical and biological water quality parameters that influence fish production;
- identify the source of pollutants that are hazardous to fish production in the reservoirs; and
- make recommendations to control the pollution of the reservoirs to ensure sustainable and profitable cage fish production.

During the reporting period, water samples were collected from the up, mid and down stream of Busa and Sing reservoirs in Upper West Region and analysed physico-chemically and bacteriologically. Trace metals such as lead and zinc were also analysed.

The bacteriolological analysis showed that faecal coliform (FC) levels ranged from 1 – 6 cfu/100 ml, *E. coli* ranged from 0 – 3 cfu/100 ml, *Salmonella sp.* ranged from 0 – 1 cfu/100 ml and Total Heterotrophic bacteria ranged from 134 – 704 cfu/100 ml (Table 8). The results obtained showed that all parameters analysed were within the water quality range of Ghana Water Resource Commission for aquaculture purposes (Table 9). Hence, the reservoirs could be used for fish production to ensure food security and generate income for local folks.

Table 8: Results of bacteriological analysis of Busa and Sing reservoirs in Upper West Region

Sample ID.	Total Coliform (cfu/100 ml)	Faecal Coliform (cfu/100 ml)	*E. coli* (cfu/100 ml)	*Salmonella* spp. (cfu/100 ml)	Total Heterotrophic Bacteria (cfu/100 ml)
Busa Upstream	175	1	1	0	300
Busa Mid stream	60	2	1	0	134
Busa Down stream	1020	4	2	1	356
Sing Upstream	20	3	0	0	316
Sing Mid stream	175	3	1	0	384
Sing Down stream	255	6	3	1	704
WHO Recommended Values	-	<1000	-	-	-

Table 9: Results obtained from physicochemical analysis of Busa and Sing reservoirs in Upper West Region

	Sing Reservoir				Busa Reservoir				WRC
Parameter	**S1**	**S2**	**S3**	**Average**	**B1**	**B2**	**B3**	**Ave**	**TWQR**
EC(µS/cm)	110.9	107.5	106.9	108.4	63.5	86.1	61.7	70.4	
TDS	66.3	64.5	64.3	65.03	38	51.5	37.1	42.2	< 2
pH	7.16	7.08	7.12	7.12	7.13	7.15	7.12	7.13	6.5-9.0
Turbidity(NTU)	15	14	13	14	6	21	5	10.67	
Colour (Hz)	7.5	7.5	7.5	7.5	5	10	2.5	5.8	
NO_3-N	0.33	3.68	0.23	1.41	0.96	0.26	0.33	0.52	< 300
SO_4	< 0.01	< 0.01	7.1	7.1	0.3	< 0.01	< 0.01	0.3	
PO_4	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	0.1
SiO_4	20.5	9.7	14.6	14.9	9.3	16.6	14.8	13.6	
F	< 0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	
Na	< 0.1	0.6	<0.1	0.6	<0.1	0.6	<0.1	0.6	
K	4	4.1	8	5.4	2.6	5.8	2.3	3.6	
Total Alkalinity	18	18	16	17.3	28	24	24	25.3	20-100
HCO_3	27	26.9	20.3	24.7	37.2	19.3	31.3	29.3	
T/Hard	34	34	26	31.3	46	44	40	43.3	
Ca Hard	14	20	20	18	32.1	34.1	26.1	30.8	
Mg Hard	20	14	6	13.3	13.9	10	14	12.6	
Ca	5.5	8	9	7.5	12.6	16.6	10.3	13.2	
Mg	4.8	3.3	2.5	3.5	3.4	4.4	3.4	3.7	
Cl	9	8	16	11	9	48	9	22	
Fe	0.739	0.605	0.61	0.65	0.429	0.643	0.43	0.501	
Mn	0.077	0.068	0.058	0.068	0.027	0.23	0.016	0.091	
Cu	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	
Cd	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	
Zn	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	
Pb	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	
TSS	12 000	19 000	8 000	13000	3 000	9 000	5 000	5667	
DO	2.4	2.4	2.5	2.4	2.5	2.4	2.3	2.4	
BOD	1.8	1.8	2.1	1.9	2	1	1.5	1.5	
Temp of H_2O (℃)	34	33	34.5	33.8	32.5	32.5	33.5	32.8	28-30
Temp of Air(℃)	28	27	28	27.7	28.5	29.5	27.5	28.5	

Units are in mg/l, unless otherwise stated

2.2.5 Three Districts Water Supply Project

(Project Staff: Mr. Humphrey F. Darko – Research Scientist, Dr. O. D. Ansa-Asare – Principal Research Scientist, Dr. J. A. Ampofo – Principal Research Scientist and Mr. Mohammed Bello)

This on-going study was initiated in 2008 to assess the quality and suitability of treated water for potable use in the Dangme East, Dangme West and North Tongu districts.

The scope of work included collection of water samples, laboratory analysis, data interpretation and preparation and submission of reports. In the reporting year, water samples were collected from the Raw Water Tank, Slow Sand Filtration Tank and the Clear Water (Chlorinated) Tank at the project site at Aveyime where the Treatment Plant is located. Additional water samples were also collected along the distribution lines from standpipes in the different communities and a booster station reservoir at Dawa and analyzed.

All physico-chemical parameters measured, such as pH (6.75 – 7.89 pH units) were within the WHO (2006) drinking water guideline range. However, the bacteriological quality of most of the water samples decreased from April to November during the year, making their sources not suitable for domestic purposes such as drinking.

2.3 FISHERY DIVISION

The Fishery Division has a mandate to engage in research to generate scientific information whose application would enhance sustainable management and development of Ghana's fish, fisheries and aquaculture resources. The Division's goal is to increase local fish production to support livelihoods through increasing yield from existing fisheries and development of sustainable aquaculture and culture based fisheries practices.

Currently, the Division's major research and development programmes are aquaculture development, environmental impact assessment and monitoring of fish population in relation to socio-economic development activities, fisheries enhancement and culture-based fisheries.

2.3.1 Water Quality Assessment of Water Research Institute's Fish Ponds in Tamale

(Project Staff: Mr. *Etornyo Agbeko – Research Scientist and Dr. Kwadwo Kwarfo-Apegyah – Research Scientist)*

Pond conditions affect the behaviour, spawning, fingerling production, survival and growth of fish. Water quality status of ponds used for fingerling production is vital to increase the survival of fingerlings. It was against this background that this project was initiated and finalized in the reporting year to monitor water quality parameters in concrete ponds for fingerling production and generate baseline data of water quality parameters for management of concrete ponds in northern Ghana.

Water samples were taken twice monthly in the mornings from three (3) ponds used for *Oreochromis niloticus* fingerling production on the premises of the CSIR-Water Research Institute (WRI) in Tamale. The water samples were analyzed monthly through standard methodologies and water quality data compiled monthly.

The pH ranged from 7.71 – 9.38 pH units. Other parameters such as conductivity was fairly stable with values of 199.52 µS cm^{-1} and 186.00 µS cm^{-1} in March and August, respectively. Mean temperature was higher in March (31.6 °C) compared to August (27.8 °C). The average number of fingerlings produced per month increased from 250 in March to 500 in August when temperature was low, representing 100% increase in production. Fluctuations in water temperature in the concrete ponds therefore influenced the production of fingerlings. It was recommended that routine water quality monitoring and a modern fish hatchery are required for optimum fingerling production.

2.3.2 Growth Parameters and Economics of Tilapia Cage Culture Using Two Commercial Diets

(Project Staff: Mr. Emmanuel Tetteh-Doku Mensah – Research Scientist and Dr. Felix K. Attipoe – Research Scientist)

This study which started and ended in the reporting year was aimed at generating information on growth parameters and profitability of using commercial feeds in tilapia cage culture. Two commercial feeds, *Nicoluzzi* and *Rannan,* were tested on the growth of *O. niloticus* in a 66.67 m^3 cages on the Volta Lake. The fish was stocked at a rate of 60 fish per cubic metre with an average size of 171 ± 23.1 g. The fishes were fed trice a day at an initial rate of 5% of body weight with the respective floating pelletized feed types and adjusted to 3% and 2.5% towards the end of the culture period. Each treatment feed was duplicated and proximate analysis carried

out (Table 10). Growth rate of fishes and water quality were monitored and growth parameters, yields and profitability analysis conducted.

Table 10: Proximate composition of experimental diets analyses

Parameter	Diet I		Diet II	
	Manufacturer	Analyzed	Manufacturer	Analyzed
Moisture (%)	12.5	9	9.5	8.6
Crude protein (%)	32	33.68	33	32.79
Ash (%)	13	10.62	7.7	8.16
Crude fibre (%)	4.5	2.3	5	5.1
Fat (%)	6.5	-	6	-

All water quality parameters measured did not differ significantly (at $p > 0.05$) from each treatment and were all within the optimal rage for tilapia growth. The highest growth rate was observed in fishes fed with Test Diet I (420.23 ± 20.44 g), with a mean relative weight gain of 59.11 ± 1.00 % as compared to fishes fed with Test Diet II (408.62 ± 54.31 g, 59.04 ± 0.92%). The high gross and net yield recorded for fishes fed with Test Diet I could be due to their good growth performance, relatively high survival rate which in turn gave high profit index of 1.87 (Tables 11 and 12). The total feed of Test Diet II used was high and this reflected in the total cost of feed fed, coupled with the high price of feed per kilo. Hence, the economic viability of an aquaculture operation depends on the feed. It was recommended that:

- the price per kilo, crude protein and performance of any aquaculture feed should be evaluated before use; and
- alternative source of cheap and cost-effective feeds must be investigated and its production encouraged in Ghana.

Table 11: Yield characteristics of the two test diets

Yield characteristics	Diet I	Diet II
Stocking density	4000	4000
Stocking rate (fish/m³)	60	60
Biomass stocked (kg)	686.88 ± 16.52[a]	670.48 ± 104.09[a]
Biomass harvested (kg)	1306.8 ± 22.63[a]	1271.41 ± 91.97[a]
Gross yield (kg)	1464.54 ± 30.88[a]	1306.77 ± 173.67[a]
Net yield (kg)	619.92 ± 6.11[a]	600.93 ± 12.11[a]
Total recovery	3491 ± 243.24[a]	3175 ± 32.53[a]
Survival (%)	87.28 ± 6.08[a]	79.38 ± 0.81[a]
Mortality rate (%)	12.73 ± 6.08	20.63 ± 0.81

[*]mean ± standard deviation, [a] = no significant difference

Table 12: Comparison of the cost-benefit analysis of the two test diets

Economic parameters	Diet I	Diet II
Prize of fingerling (GH¢)	0.5	0.5
Cost of fingerlings (GH¢)	2000	2000
Prize of feed/kg (GH¢)	1.88	1.9
Total feed fed (kg)	1920.99 ± 20.72	2046.97 ± 49.43
Total cost of feed (GH¢)	3611.46 ± 38.95	3889.24 ± 93.91
Value of fish crop (GH¢)	6852.36 ± 710.88	6749.97 ± 102.23
Profit (GH¢)	1138.51 ± 63.29	963.12 ± 616.96
Profit index	1.87 ± 0.01	1.76 ± 0.19
Economy of weight gain (kg)	2.76 ± 0.01	3.06 ± 0.06

[*]mean ± standard deviation

2.3.3 CPW&FV3 Project on Integrated Management of Small Reservoirs for Multiple Uses: Report on Survey of Fishermen Operating in the Boura and Binaba Reservoirs in Burkina Faso and Ghana

(Project Staff: Dr Joseph K. Ofori – Senior Research Scientist, Dr. E. K. Abban, Dr. Margaret Attipoe, Mr. Daniel Akungyuuri, Mr. Solomon O. Amoah, Mr. George Husunu and Mr. Martin Dakpame)

This project focused on integrated management options at local scale for small reservoirs in a multiple use context. It began in 2010 and it is expected to end in 2013. The aim was to enhance fish production in the Binaba and Boura reservoirs in Ghana and Burkina Faso, respectively.

During the year under review, surveys of the fishermen and their operations to obtain baseline information both on household and fisheries operations at the two sites were conducted. The potential to increase fish production from the reservoirs was also verified.

The surveys showed that fishing in the Boura reservoir is carried out between December and July each year followed by four months break from August to November to allow for fish spawning and recruitment. Permit fees of CFA 8000 for outsiders and CFA 500 for locals were charged by the local authorities before access to fish from the reservoir is granted to fishermen. A total of 34 males, aged from 21 to 57 years, resident fishermen operated on the Boura reservoir. All except one were married with 3 people dependent on others in the household. Children constituted the highest proportion of the household (47.6 %) followed by dependent males (20.4 %) and elderly females (32.0 %). Fifty three percent (53 %) of the fishermen own canoes for fishing while the others who do not own one co-use canoes of their neighbours. Three main fishing gears deployed for fishing were gill nets, cast nets and hook and line. Most fishermen use mainly cast nets (74 %) for fishing. The use of hook and line and gillnets constituted 57 % and 46.4 %, respectively. Typical species caught were *Oreochromis niloticus, Heterotis niloticus, Tilapia zillii, Clarias gariepinus, Hemichromis bimaculatus, Lates niloticus and Brycinus nurse*. It was estimated that about 4 – 5 kg of fish was used weekly by household whilst income from fish sales averaged CFA 40,000 on monthly basis. Prices of fish varied as follows:

Species	Price CFA/kg
Nile perch (*Lates niloticus)*	1500
Tilapia (*O. niloticus*)	1000
African catfish (*C. garipinus*)	600
Sardines (*Brycinus* spp.)	300

Fish catches records showed a decline from over 3 big bowls (>30 kg) per catch since 2004 to less than 1 bucket (6 – 10 kg) per catch presently. The decline in fish catches could be attributed to factors such as proliferation of floating and submerged aquatic weeds which obstruct fishing, decline in rainfall patterns which has reduced water inflow, presence of crocodiles and increased number of cattle that water from the reservoir leading to muddling of the immediate shoreline, thus destroying spawning grounds. Also, fish management strategies were not practiced to ensure sustainable fishing in Boura.

On the other hand, fishing in the Binaba reservoir was carried out between August and May each year with about two months break to allow for reproduction and recruitment of the young fish. Fifteen male fishermen, aged from 25 to 51 years were interviewed in Binaba. All, except one, were married with an average of 3 people dependants in the household. Children constituted 47.6 % followed by dependent males (35.7 %) and elderly females (16.7 %) of the household. Fishermen use gillnets (100 %), basket traps, hooks and line (80 %) and cast nets (80 %) for

fishing. Forty-seven percent (47 %) of the fishermen own canoes while the others either rent or co-use canoes from their friends. Typical species caught were *Heterotis niloticus, Oreochromis niloticus, Tilapia zillii, Hemichromis bimaculatus, Clarias gariepinus* and *Brycinus nurse*. However, fish management strategies to ensure sustainable fishing were not practiced and general information provided by the fishermen on the fishing status of the reservoir pointed to declining fish catches over the years. The outcome of the study could be used to determine the fishing pressure exerted on the fishery of the reservoirs and thereby evolve management programme that will result in increase fish production. The overall significance is to enable the enhancement of fish production through aquaculture (cage culture) to ensure food security and increase protein for the communities.

2.3.4 African Catfish, *Clarias gariepinus*, Hatchery Seed Production for Supply to Farmers and Research for Increased Farmed Fish Production in Ghana

(Project Staff: Dr. Joseph N. Padi – Research Scientist, Mr. Francis A. Anani – Research Scientist and Mrs. Patience Atsakpo)

Ghana has an annual fish supply deficit in excess of 400,000 metric tons and there is limited scope for increasing fish supply from natural water bodies because of overfishing and habitat degradation. Aquaculture or fish farming is an alternative to capture fisheries and one of the promising indigenous fishes that could potentially boost fish production in the country is the African mud catfish, *Clarias gariepinus*, due to its hardiness, fast growth and lack of inter-muscular bones which render the flesh of the fish relatively easy to eat. It was against this background that this study was initiated in 2010 to evaluate nursery performance of catfish fry in two 0.2 ha earthen ponds to generate data to assess the suitability of large ponds for catfish fingerling production; and to assess palm kernel oil application rates that will eliminate the predatory aquatic insect, *Notonecta* spp., from catfish nursery ponds to enhance catfish fingerling production. It is expected to be finalized in 2013.

In the year under review, eighteen (18) female catfish brood stock weighing 0.2 – 1.1 kg were injected on two occasions with pituitary collected from the brain of eighteen (18) male catfish. The eggs were stripped (harvested) from the injected females and fertilized with milt (sperm) collected from eight (8) male fishes. Eggs were incubated under a flow through system inside eight (8) rectangular netting materials (hapas) suspended in a fibre glass tank. Fry were siphoned off after hatching and maintained in plastic bowls on live brine shrimp (*Artermia* spp) with frequent exchange of water to maintain oxygen levels above 3 mg/l. Fry were nursed in two 0.2 ha earthen ponds for 57 days. Ponds were fertilized with chicken manure to generate plankton and fish were also fed with a 40 % crude protein diet which was formulated mainly from fishmeal, soya bean, corn and wheat bran. Dissolved oxygen and water temperature were maintained within 6.18 – 7.56 mg/l and 24.1 – 25.4 ^{o}C, respectively, in the bowls in which fry was held at the hatchery. In addition, aquatic insects, *Notonecta* spp., were collected from the ponds using a hapa material. The effects of two different applications (0.25 g and 0.5 g) of palm kernel oil on the surface of water in which *Notonecta* spp. were held was evaluated to assess survival of this aquatic insect. A control experiment was also run where no oil was applied to the surface of water in which insects and fry were held and the effect of the oil on fry survival was assessed. The experiment was conducted in twelve (12) ten litre (10 L) white plastic aquaria for a period of two days (48 hrs).

It was observed from the study that pituitary injection of female mud catfish induced ovulation and eggs were successfully harvested manually from 100 % of the females. The quantity of eggs (fecundity) harvested from individual females ranged from 42,000 – 97,000. Hatching rates from

individual females ranged from 12.2 % – 98 % with a mean of 54.0 $\pm$ 29.0 % and fry output in the hatchery was estimated at 66,000. Abnormalities observed among fingerlings that were harvested from the ponds indicated that inbreeding thresholds that negatively impact on survival have been reached. For example, 4 % of the fingerlings did not have any pectoral fins, 6 % (13) – 5 % (11) of the fingerlings either had no left or right pectoral fin, and albinism (absence of skin pigment) was observed among the fingerlings harvested.

Survival of fingerlings in the two ponds was marginal and this was exacerbated by accidental invasion of the ponds by tilapia fingerlings and predation from tadpoles and frogs. Survival of fingerlings in the two nursery ponds ranged from 0.3 – 1.6 % (134 – 239 fingerlings) after 57 days. This level of survival was several orders of magnitude lower than the survival (10 % or 5,753 fingerlings) achieved in a single pond in 2010. Nevertheless, the observed catfish fingerling fell within the survival range of 0 – 28.7 % reported by Obuya, *et al*. (1995) and de Graaf, *et al*. (1995) in unprotected earthen ponds.

Palm kernel oil application rate of 0.50 g (0.56 ml) successfully killed 100 % of the aquatic insects (*Notonecta* spp.) and catfish fry survival decreased by only 12 % compared to the control treatment after 48 hours. In contrast, 0.25 g (0.28 ml) of palm kernel oil killed 93 % of the insects within the same period and fry survival was reduced by 29 % compared to controls. The lowest fry survival (53 %) was observed in the treatment in which oil was not applied to the surface of the water in which both fry and insects were held.

It was concluded from the study that low survival of catfish fry observed in nursery ponds is a universal phenomenon particularly in unprotected ponds. Therefore, investment in the development of protective systems that are cost effective in eliminating predators such as frogs and birds from catfish ponds is critical for improved catfish fingerling production. Also, palm oil application rate of 0.5 g has the potential to eliminate the predatory aquatic insect, *Notonecta* spp., from earthen ponds to enhance survival of catfish fry.
The following recommendations were outlined:

- New catfish brood stock need to be sourced from the wild to improve catfish germplasm at ARDEC to minimize inbreeding.
- A new hatchery for catfish production is needed at ARDEC to create space for increased fingerling output.
- A protective system that prevents frogs and birds from invading catfish nursery ponds need to be developed for increased catfish fingerling production at ARDEC.

2.3.5 Improving Reproductive Performance of the African Bonytongue Fish, *Heterotis niloticus*, for Increased Fingerling Production for Aquaculture

(Project Staff: Dr. Joseph N. Padi – Research Scientist and Mrs. Patience Atsakpo)

The African bonytongue, *Heterotis niloticus*, is an indigenous freshwater fish that exhibits rapid growth with high consumer acceptability. To ensure expansion of bonytongue culture, this study was initiated in 2010 to generate baseline data to aid economical use of pond space for bonytongue reproduction given that bonytongue is less tolerant of other fish species during pond-based reproduction. The specific objectives were to assess the effects of increased bonytongue brood stock stocking rate (density) on reproductive performance in ponds; and investigate whether multiple use of the same nest occurs in the bonytongue to enable maximization of brood stock densities in reproduction ponds. It is expected to end in 2013.

In the reporting year, bonytongue brood stock with body weight ranging from 1.1 – 2.3 kg were stocked in pond 'A' at a density of 30 fish/pond (150 fish/ha). The experiment was repeated with a higher brood stock density of 100 fish/pond (500 fish/ha) in pond 'B'. The fishes were maintained on 33 % crude protein commercial feed and were fed twice daily at a rate of 2 % of fish body weight. Ponds were examined on a daily basis for reproduction evidenced by the presence of fry in nests. Fingerlings were harvested from the ponds and total fingerling output was estimated using sub-sampling techniques. In addition, nineteen (19) bonytongue nests on the periphery of pond 'B' used for assessment of the effects of varied bonytongue stocking rate on reproduction were pegged randomly with stakes to aid identification of individual nests. Daily examination of all the 19 nests was conducted for the presence of swim-up fry.

Eight (8) and fifty-nine (59) reproductions were observed in the ponds stocked with 30 fish/pond and 100 fish/pond, respectively. Monthly variations in bonytongue reproductive performance were observed in the two ponds with the highest reproduction in September 2011 (Figure 8).

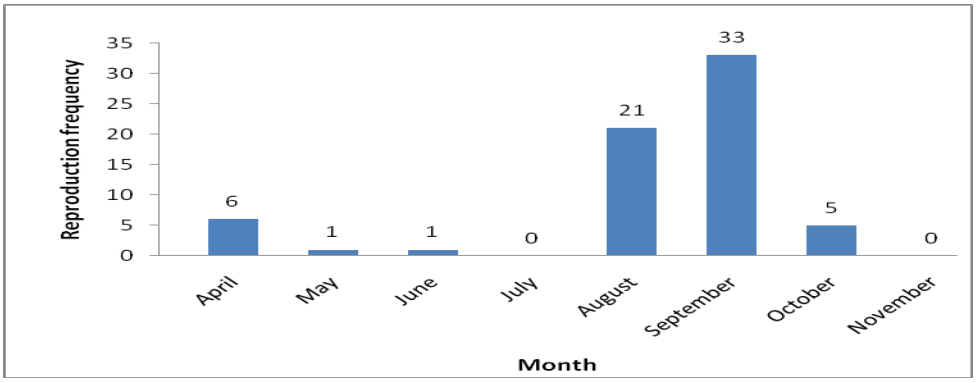


Figure 8: Reproduction frequency of the African Bonytongue (*Heterotis niloticus*) in 0.2 ha (2000 m^2) earthen ponds from April to November 2011 at ARDEC, Akosombo

The average frequency of reproduction/pond was approximately 34 reproductions and the number of bonytongue fingerlings produced from the two trials was 4,010. Multiple reproduction was observed in seven (7) out of the nineteen (19) nests constructed by bonytongue in the earthen 0.2 ha pond used in this study. Bonytongue reproduced two (2) times in one (1) nest and three (3) times in six (6) different nests. No reproduction was observed in two (2) of the 19 nest used.

It was concluded from the study that increasing bonytongue brood stock density within the range of 30 – 100 fish/ha has the potential to improve reproduction thereby enhancing fingerling production. The observed multiple use of the same nest by bonytongue indicated that brood stock densities in ponds could increase above the levels used in this study without adversely impacting on fingerling production in this species. Therefore, research is needed to further improve on reproduction of the bonytongue to maximize the use of pond space in seed production of this species. Preliminary trials at ARDEC demonstrated that survival can be enhanced in hapas under protection from frogs and birds.

2.3.6 Cichlid Fish Populations from the Kpong Headpond

(Project Staff: Mr. Theodore Quarcoopome – Research Scientist)

This study was undertaken to assess the characteristics of Cichlid populations from the Kpong Headpond to provide requisite information to support sustainable utilization and management of the fishes for sustainable fisheries, food security and socio-economic development.

During the reviewed year, samples of Cichlid fishes were obtained monthly from both inshore and open waters using sets of monofilament and multifilament gill nets of different mesh sizes as well as assorted gears for experimental and artisanal catches. All fishes sampled were identified individually with the keys of Leveque, *et al.* (1992). Each specimen was measured for body weight, total length and standard length to the nearest 0.1 g, 0.1 cm and 0.1 mm, respectively. Parameters such as species composition, relative importance, length frequency, length-weight relationships (LWR), condition factor (CF) and sex ratio which represent aspects of the population characteristics of Cichlids in the Kpong Headpond were also estimated from the data analysis. The length-weight relationships for each species and sex were computed based on the equation $W = aL^b$ (Ricker, 1975). The condition factor (CF) for each species and sex was calculated as $CF = 100 \text{ X } W/L^3$ (Ricker, 1975). The sex ratio for each species was computed monthly based on the null hypothesis of 1:1 ratio of male to female and tested for statistical significance at 95 % confidence interval (CI) by the chi-square method.

Eight species including *Astatotilapia guntheri, Hemichromis bimaculatus, Hemichromis fasciatus, Oreochromis niloticus, Sarotherodon galileus, Steatochromis irvinei, Tilapia guineensis* and *Tilapia zillii* belonging to the genera *Chromidotilapia, Hemichromis, Orechromis, Sarotherodon, Steatocranus* and *Tilapia* were identified. The highest standard length (SL) of 280.0 mm was recorded for *O. niloticus* while the least (49.0 mm) was recorded for *H. bimaculatus*. A summary of the descriptive statistics of the species identified including sample size and total weight is shown in Table 13.

Table 13: Summary of descriptive statistics of Cichlid species from Kpong Headpond

Species	*A. guntheri*	*H. bimaculatus*	*H. fasciatus*	*O. niloticus*	*S. galileus*	*S. irvinei*	*T. guineensis*	*T. zillii*
Mean SL*	63.72	60.9	84.68	167.0	117.82	115.3	130.2	142.36
Min SL	50.0	49.0	60.0	75.0	50.0	75.0	49.0	68.0
Max SL	102.0	78.0	185.0	280.0	260.0	139.0	190.0	195.0
Stdev SL	13.68	5.81	21.25	85.25	48.237	21.16	34.078	34.755
Mode SL	55.0	55.0	75.0		135.0		125.0	150.0
Mean Wt*	71.69	9.61	22.36	306.48	107.79	48.46	108.06	128.61
Min Wt	5.2	4.7	6.4	14.7	6.5	13.30	4.5	8.4
Max Wt	96.8	233.7	212.1	891.8	635.9	71.30	310	271.3
Stdev Wt	14.56	14.82	26.37	397.66	137.36	21.0	67.448	73.899
Total Wt	751.9	2268.0	2325.2	1225.9	3772.50	387.70	6915.7	1800.50
Sample Size	52	237	105	4	35	8	64	14

*Standard length, SL, were measured in mm while Weight, Wt, were measured in g

The most important species in terms of numbers was *H. bimculatus* (45.66 %) while *T. guineensis* was the most important in terms of weight (35.70 %). The least encountered species was *O. niloticus* (0.77 %). The percentage composition of the other species is shown in Table 14.

Table 14: Percentage composition of Cichlid species from Kpong Headpond in terms of weight and number

Species	Number	% Number	Weight	% Weight
A. guntheri	52	10.02	751.9	3.86
H. bimaculatus	237	45.66	2268.0	11.65
H. fasciatus	105	20.23	2325.2	11.94
O. niloticus	4	0.77	1225.9	6.30
S. galileus	35	6.74	3712.5	19.07
S. irvinei	8	1.54	387.70	1.99
T. guineensis	64	12.33	6915.7	35.53
T. zillii	14	2.70	1800.5	9.25
Total	519	100.0	19,467.1	100.0

The estimated 'b' value for the length-weight relationships for Cichlid species ranged between 2.008 and 4.920 while the correlation (r) values ranged from 0.819 to 0.999. With the exception of *H. bimaculatus* and *A. guntheri* which had slightly lower correlation values, all the Cichlid species showed strong correlation between length and weight. The 'b' values for male and female of all species gave indications of negative allometric growth with the exception of male *S. galileus*, male and female *T. zillii*, *S. irvinei* and *O. niloticus* as shown in Table 15. The condition factor (CF) for males ranged from 2.9988±0.4489 for *H. fasciatus* to 4.5783±0.6982 for *S. galileus*. For females, the CF ranged from 3.1247±0.4718 for *H. fasciatus* to 4.7318±0.8228 for *S. galileus* (Table 16). Females of five species namely *H. bimaculatus*, *H. fasciatus*, *S. galileus*, *S. irvinei* and *T. guineensis* were in better condition than the males whilst in the other three remaining species, males were in better condition than females. Chi-square analyses showed that for each species the computed monthly sex ratio was less than the critical value. This means that the observed differences in monthly sex ratio for all Cichlid species were not significant at 95 % confidence interval and the hypothesis of 1:1 male to female is to be accepted. Hence, any observed differences in sex ratio was due to chance.

It was recommended that regular biological, population, community and genetic monitoring of the Cichlid species be undertaken to inform management interventions to ensure the survival of the species and the viability of fisheries in the Kpong Headpond. The commercially important species, *O. niloticus*, seemed to be disappearing from the Headpond and may require management and conservation intervention as indicated by the percentage contribution to total sample number and weight.

Table 15: Length-weight relationships of Cichlid species from Kpong Headpond

Species	n	Length range (cm)	a	b	r
Pooled *A. guntheri*	52	5.0 – 10.2	-3.382	2.450	0.926
Male *A. guntheri*	5	7.2 – 8.8	-3.193	2.366	0.922
Female *A. guntheri*	24	5.0 – 10.2	-2.970	2.213	0.852
Pooled *H. bimaculatus*	237	4.9 – 7.8	-3.232	2.330	0.837
Male *H. bimaculatus*	62	5.0 – 7.5	-2.986	2.195	0.886
Female *H. bimaculatus*	103	5.0 – 7.8	-3.2559	2.340	0.819
Pooled *H. fasciatus*	105	6.0 – 18.5	-4.4173	2.940	0.969
Male *H. fasciatus*	25	6.0 – 11.5	-4.5216	2.993	0.962
Female *H. fasciatus*	54	6.2 – 18.5	-3.6992	2.545	0.961
Pooled *O. niloticus*	4	7.5 – 28.0	-4.674	3.120	0.999
Male *O. niloticus*	1	7.5			
Female *O. niloticus*	3	14.3 – 28.0	-4.410	2.008	0.999
Pooled *S. galileus*	35	5.0 – 26.0	-4.387	3.020	0.990
Male *S. galileus*	12	6.0 – 25.0	-4.821	3.225	0.992
Female *S. galileus*	15	5.0 – 26.0	-4.017	2.825	0.994
Pooled *S. irvinei*	8	7.5 – 13.9	-4.1349	2.808	0.986
Male *S. irvinei*	3	11.2 – 13.5	-5.9123	3.6496	0.998
Female *S. irvinei*	3	7.5 – 11.5	-4.9065	3.2091	0.995
Pooled *T. guineensis*	64	4.9 – 19.0	-4.274	2.950	0.991
Male *T. guineensis*	29	4.9 – 16.8	-4.209	2.914	0.987
Female *T. guineensis*	25	6.8 – 19.0	-4.182	2.904	0.996
Pooled *T. zillii*	14	6.8 – 19.5	-4.674	3.117	0.978
Male *T. zillii*	5	14.6 – 18.3	-7.4275	4.920	0.976
Female *T. zillii*	7	6.8 – 19.5	-5.3104	3.430	0.990

Table 16: Mean condition factor of Cichlid species from Kpong Headpond

Species	Pooled	Male	Female
A. guntheri	4.422±0.9935	4.5491±0.9819	4.4015±1.0655
H. bimaculatus	3.807±0.6136	3.8883±0.5368	3.9548±0.6818
H. fasciatus	3.0087±0.4781	2.9988±0.4489	3.1247±0.4718
O. niloticus	3.9183±0.2919	4.1115	4.0386±0.0338
S. galileus	4.5989±0.813	4.5783±0.6982	4.7318±0.8228
S. irvinei	2.9716±0.3047	2.83±0.1932	3.22±0.2721
T. guineensis	4.1629±0.5751	4.1508±0.6785	4.2078±0.5321
T. zillii	3.8465±0.7456	3.8912±0.7746	3.8017±0.7745

2.4 GROUNDWATER DIVISION

The long-term objective of the Groundwater Division is to generate, process and disseminate information on the availability of groundwater, quantity of water to be abstracted for various uses as well as the reliability and sustainability of its recharge.

2.4.1 Groundwater Monitoring of Northern Ghana

(Project Staff: Dr. William A. Agyekum – Research Scientist and Dr. S. Dapaah-Siakwan – Principal Research Scientist)

This project ended in the reporting year. It was a collaborative research project involving the CSIR Water Research Institute, CIDA-HAP and Water Resources Commission (WRC). The objective amongst others was to improve the knowledge-base and understanding of the hydrogeological setting of northern Ghana.

During the year under review, 37 monitoring boreholes (Figure 9) were visited and groundwater level fluctuation data downloaded from an automatic water recording loggers and barometric divers installed on each monitoring borehole. The fluctuation levels were classified into low, medium, high and very high (Table 17). In addition, water levels from each monitoring borehole were recorded manually with a dip-meter during each visit. Compensation of the recorded groundwater level data was carried out using data recorded by baro-divers, which were installed together with logger divers in each borehole. The compensation took into account the corrected gravity acceleration factor, which depends upon the latitude location and elevation of each monitoring borehole.

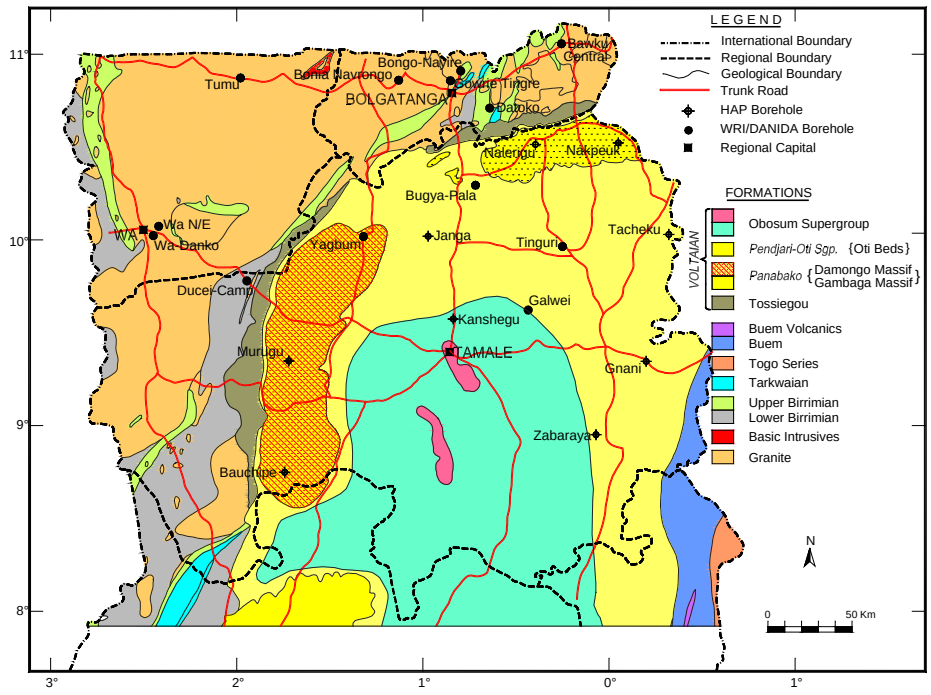


Figure 9: Location map of monitoring boreholes in Northern Ghana

Table 17: Classification of groundwater fluctuation levels in Northern Ghana

Fluctuation Classification	Fluctuation (F) Values	Monitoring Stations	No. of Boreholes	Percentage (%)
Low	F <150 cm	Gowrie-Tingre, Zabaraya, Wakawaka, Tuuni, Kabilpe, Wahabu & Murugu	7	19.0
Medium	151 cm < F < 500 cm	Wa-Danko, Wa N/E, Tumu, Bonia, Bawku, Ducei Camp, Yagbum, Kanshegu, Tachecku Kabingo, Lentinkpa, Nawuni, Palari Tantuya, Doninga, Yanyounyiri, Soma and Chepuri	18	48.6
High	501 cm < F <1,000 cm	Bongo-Nayire, Datuku, Bugya-Pala, Tinguri, Janga, Gnani, Nalerigu, Sakpeigu, Tamaligu	9	24.3
Very High	F >1,000 cm	Galiwei, Bauchipe, Nakpeuk	3	8.1

Results obtained and analysed showed that the compensated groundwater levels fluctuations corresponded favourably with the controlled manually-measured dip-meter levels (master levels), which were plotted on the same scale for each of the monitoring boreholes. At each monitoring station, the trend of groundwater levels only depicted the climatic pattern (wet and dry seasons) of the project area. Despite the high groundwater reliance and the harsh climatic conditions of northern Ghana, groundwater levels over the years were observed to be generally rising (Figures 10 – 15). This observation may be due to under-abstraction of groundwater, annual groundwater recharge exceeding abstraction, the absence of large-scale irrigation schemes and the existence of deep-seated aquifers in northern Ghana.

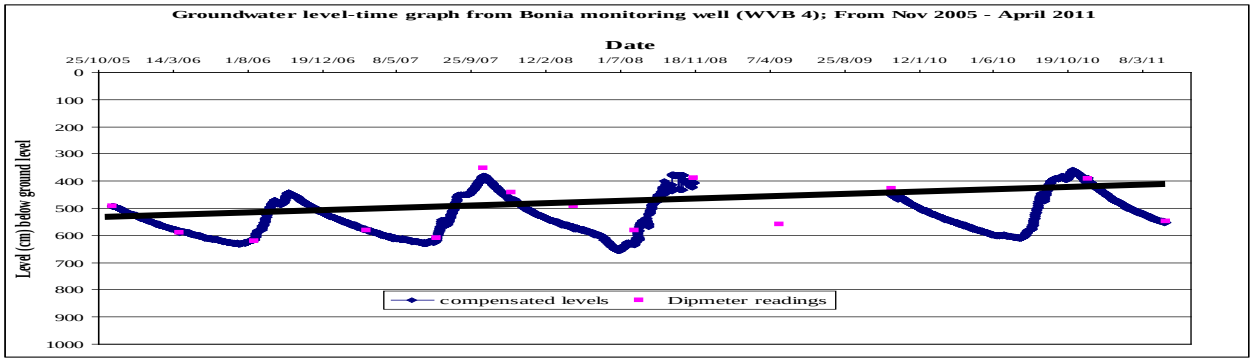


Figure 10: Groundwater level-time graph from Bonia monitoring well (WVB4) from Aug 2005-April 2011

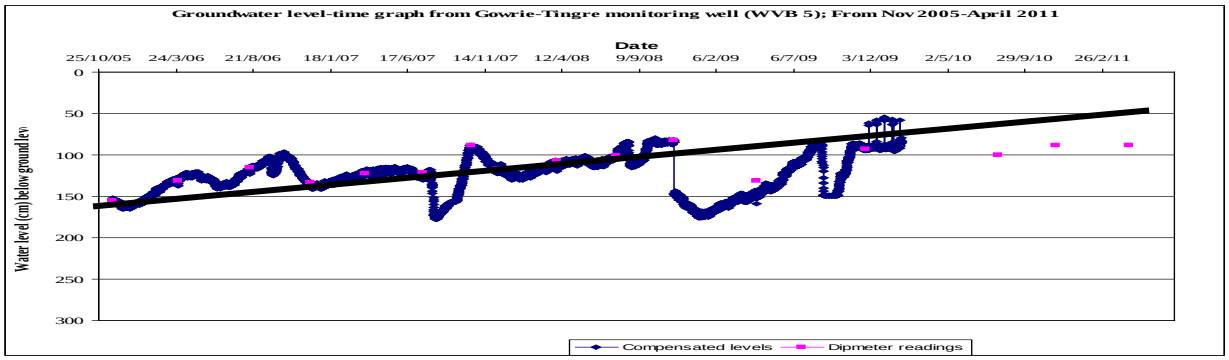


Figure 11: Groundwater level-time graph from Gowrie-Tingre monitoring well (WVB5) from Aug 2005-April 2011

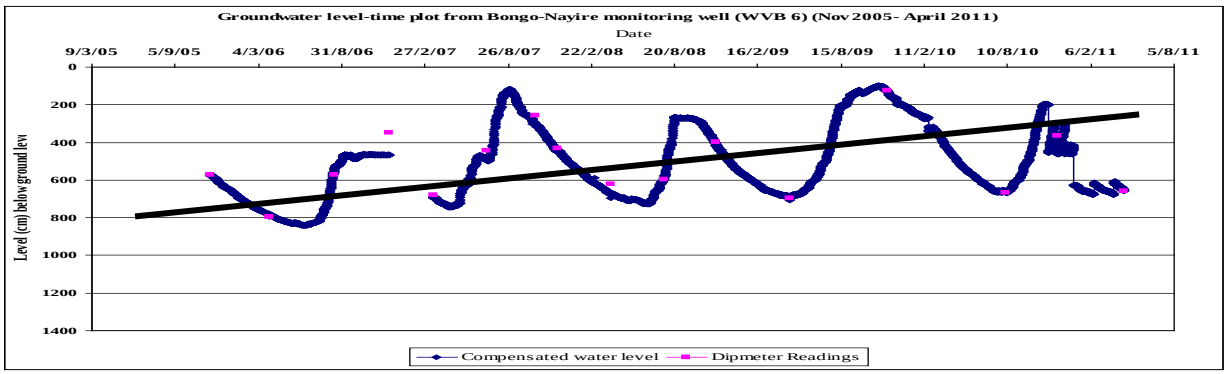


Figure 12: Groundwater level-time graph from Bongo monitoring well (WVB6) from Aug 2005-April 2011

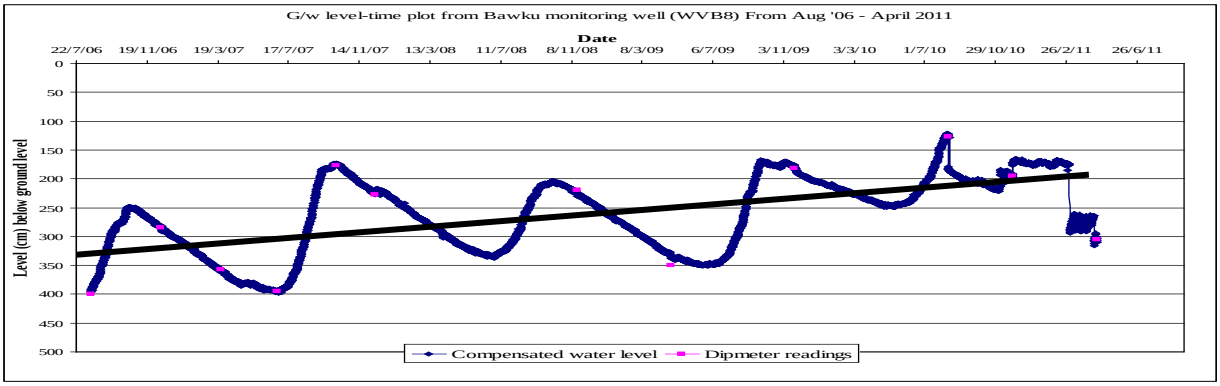


Figure 13: Groundwater level-time graph from Bawku monitoring borehole (Aug 2005 - March 2011)

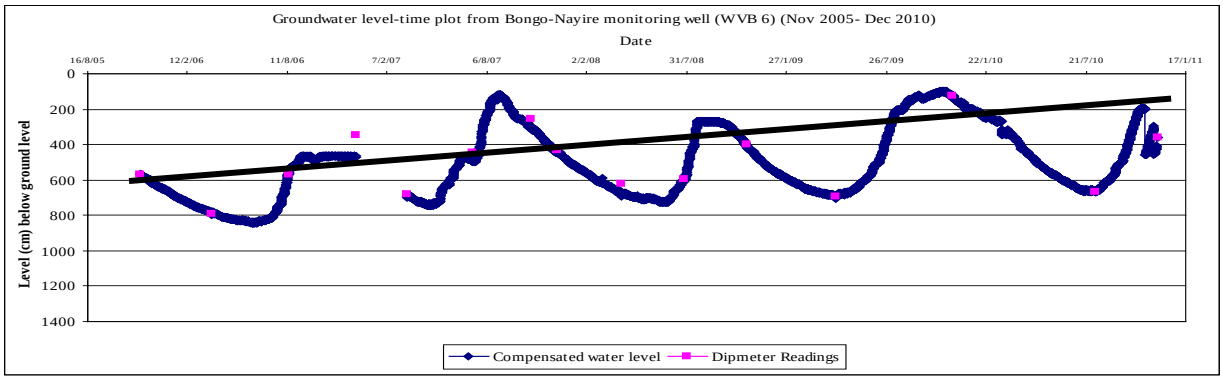


Figure 14: Groundwater level plot from Bongo-Nayire monitoring borehole (Nov 2005-Dec; 2010)

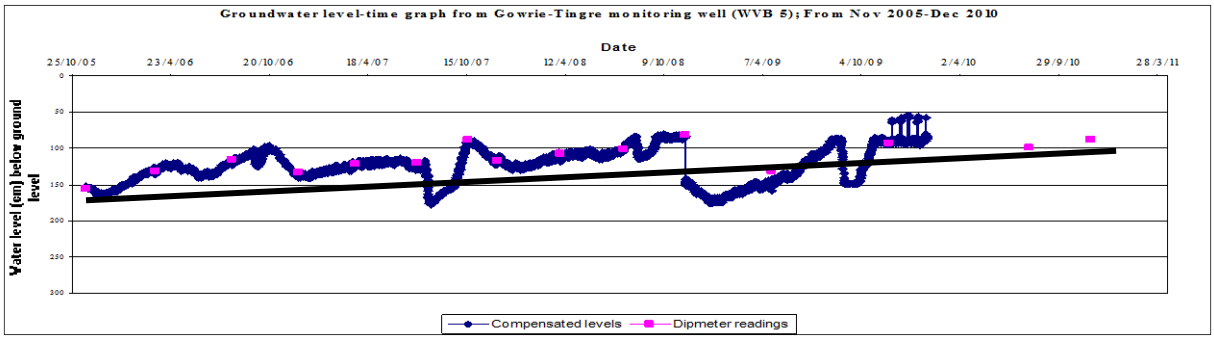


Figure 15: Groundwater level plot from Gowrie-Tingre monitoring borehole (Nov 2005-Dec; 2010)

2.4.2 Monitoring Groundwater Resource Occurrences and their Quality within Pra and Tano River Basins

(Project Staff: Mr. Collins Okrah – Research Scientist, Dr. O. D. Ansa-Asare – Senior Research Scientist, Dr. William Atuobi Agyekum – Research Scientist, Dr. Anthony Duah – Research Scientist, Mr. Patrick A. Mainoo – Research Scientist, Dr. Gloria Naa Dzama Adico – Research Scientist and Mr. Humphrey Darko – Research Scientist)

This collaborative study with Ministry of Finance and Economic Planning, Water Resource Commission (WRC) and the European Union (EU) started in 2010 and ended in the reporting year. The objective was to monitor groundwater level fluctuations and assess groundwater quality in the Pra and Tano river basins.

In the year under assessment, 20 boreholes were critically selected from a total of 3,368 existing boreholes located in the Pra and Tano basins based on geology, mining, plantation and baseline studies. These boreholes were rehabilitated and divers installed to record groundwater levels automatically at a period of six hours (6hrs) intervals for water level fluctuation analysis. Water samples were also taken for water quality monitoring.

Compensated water levels were recorded from July to December, 2011 (Figure 16) at a temperature range of 25.2^{o}C – 28.1^{o}C. The fluctuations were mostly sinusoidal and the water levels recorded by the divers conformed to the manual measurements. The output signal generally depicted a uniform groundwater level drop in the periods of August, November and December. The water level fluctuated between 25 cm at Juaso and 1100 cm at Abore-Krofofrom during the last quarter of 2011. The variation in water levels was influenced by factors such as the climatic condition of the area, extreme groundwater abstraction as in Juaso and Kyekyewere, population density and hydrogeological setup of the area. At Bechem and Kyekyewere, for instance, the rate of abstraction was higher than the rate of recharge which eventually dwindled the instantaneous water level of the monitoring well. There is therefore the need for management processes to ensure sustainable utilization of the groundwater resources within Pra and Tano basins. The monitoring period should also be extended to facilitate the achievement of comprehensive results.

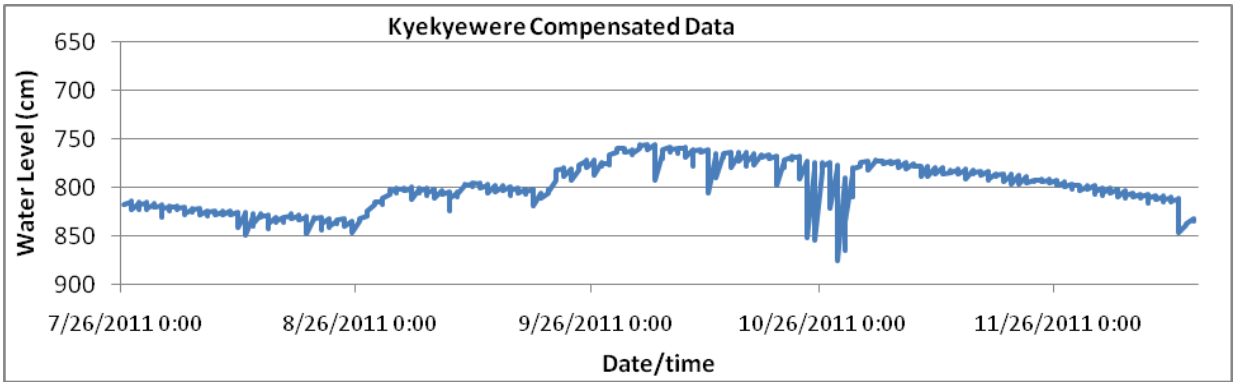


Figure 16: Compensated water level at Kyekyewere

2.4.3 Hydrogeological Consultancy Services in the Brong Ahafo Project

(Project staff: Mr. Patrick A. Mainoo – Research Scientist and Dr. William A. Agyekum – Research Scientist)

This study started in 2010 and ended in the reporting year in collaboration with Community Water and Sanitation Agency (CWSA) and the Regional Coordinating Council of Brong Ahafo Region of Ghana. The objective was to conduct hydrogeological studies to delineate zones of high groundwater potential, where high-yielding borehole could be drilled to provide sustainable

potable water in 14 selected small towns across the hydrogeologically-difficult Voltaian Geological formation in Brong Ahafo Region. The selected beneficiary towns included Jema, Amoma and Anyima in the Kintampo South District; Babtokuma, Gulumpe, Kadelso and Portor in the Kintampo North District; Manso and Busunya in the Nkoranza-North District; Nkwabeng and Ayirede in the Nkoranza-South District; Kajeji and Bantama in the Sene District; and Akokoa in the Attebubu District (Figure 17).

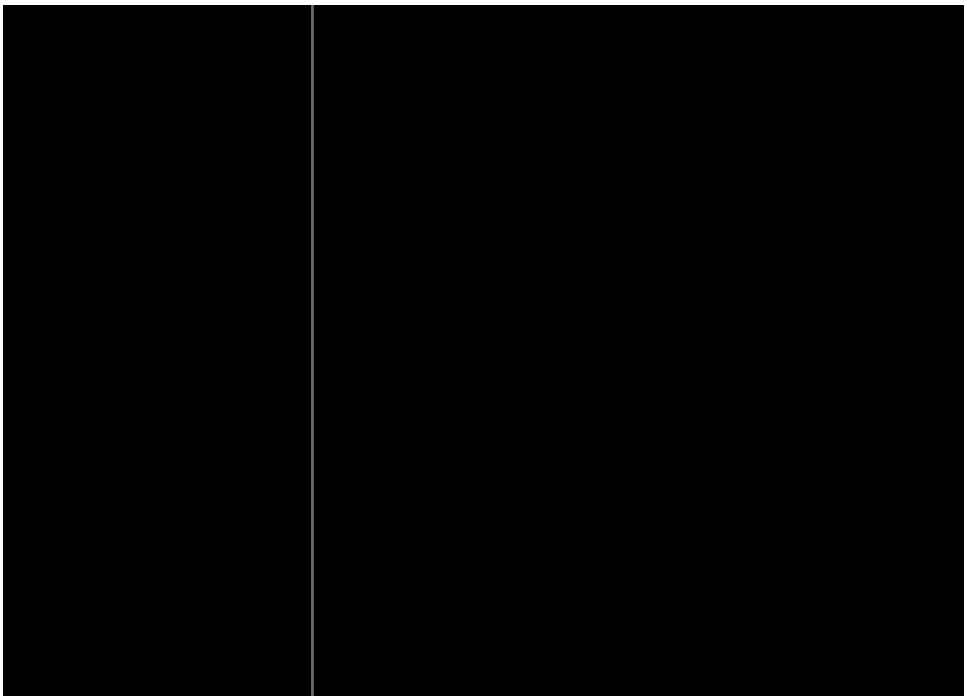


Figure 17: Geological map of Brong Ahafo Region showing Project Towns

Activities carried out in the reporting year included desk study to assess the existing hydrogeological data, use of Geo-Spatial data (satellite imagery, GIS) to delineate potential groundwater zones, reconnaissance survey, and selection and orientation of traverse lines to enhance the geophysical investigations. 2-Dimensional (2-D) Continuous Vertical Electrical Sounding [CVES] geophysical technique was used along selected traverses to produce 2D apparent resistivity pseudo-sections (Figure 18). 1-Dimensional Vertical Electrical Sounding (VES) technique was also used to investigate the variation of apparent resistivity of the sub-surface with depth at selected points, and 3-Dimensional bedrock resistivity assessment was done to ascertain the potential groundwater flow directions in the areas investigated (Figure 19).

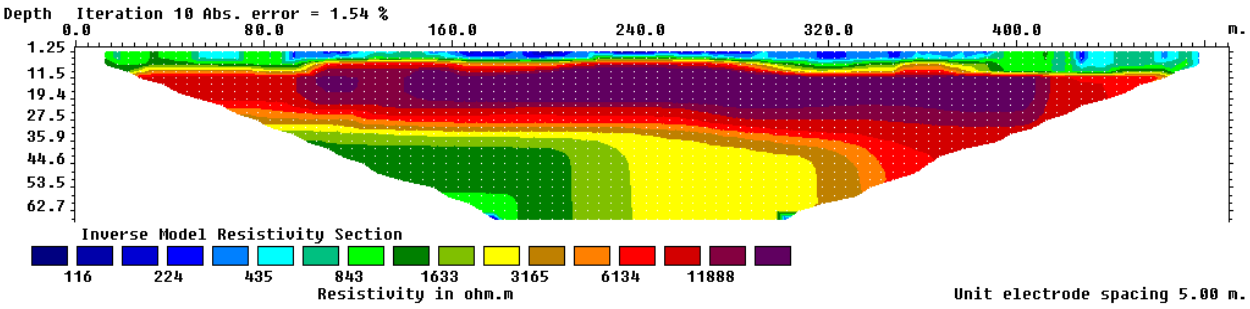
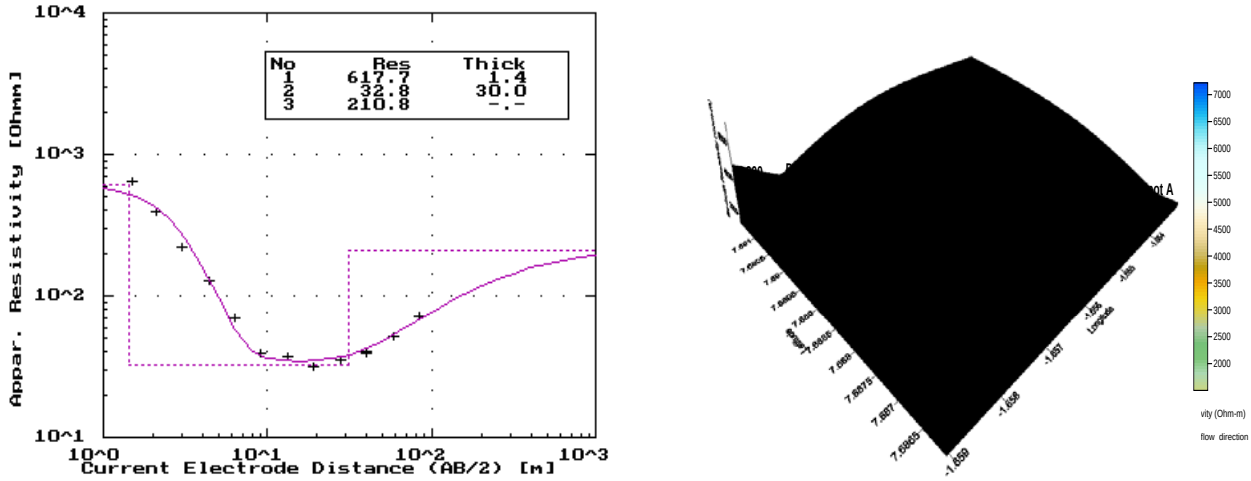


Figure 18: A typical 2D apparent resistivity along a traverse



A B

Figure 19: A typical 1D apparent resistivity section at a proposed drilling point (A) and a typical topography of bedrock resistivity at an area investigated showing potential groundwater flow direction (B)

A total of 56 test holes were drilled in all the 14 small towns. Out of these, 26 boreholes were productive, 16 boreholes were marginally productive and 14 boreholes were completely dry. Drilled depths varied from 53.0 – 203.0 m with a mean value of 145.5 m. Depth to first aquifer horizons varied across the various formations ranging between 2.0 – 129.0 m with an average value of 42.4 m. Estimated drilling yields varied widely from 12.0 – 900.0 l/min with an average value of 200.4 l/min. A total of three artesian boreholes were obtained at Jema and Kadelso.

The following observations were made:

- Most of the successful boreholes were obtained between 50 – 120 m, with maximum yields ranging between 300 – 400 l/min. These yields tend to decrease as depth approaches 200 m. Thus recommended drill depth would be about 180 m.
- Some relatively shallow boreholes (50 – 60 m) are high yielding (e.g Batatokoma = 900 l/min and Ayerede = 520 l/min).
- Relatively, shallow aquifers that were intercepted within a maximum depth of 40.0 m had higher yields than deep-seated aquifer systems.
- Most boreholes had their static water levels within 0 – 35 m but some deeper boreholes had high static water levels between 50 – 95 m.

It was concluded at the end of the study that the integrated geophysical approaches that were adopted in the groundwater exploration were successful, though involving and challenging. Groundwater potential highly varied across the various phases of the Voltaian Supergroup. The Anyaboni Sandstone had relatively higher groundwater potential, with Obosom undifferentiated formation being the least-yielding as indicated in Table 18.

It was recommended that further research using improved and integrated geophysical resistivity techniques to increase access to sustainable potable water through drilling of high yielding boreholes in Hydrogeologically-difficult terrains such as the Voltaian Formation in the Northern and Brong Ahafo regions of Ghana should be considered and encouraged.

Table 18: Groundwater potential of the Voltaian Formation in Brong Ahafo Region of Ghana

Formation	Bedrock characteristics	Groundwater Potential	Remarks
Anyaboni Sandstone	Sandstone, dune-bedded to cross-bedded, medium grained, arkosic, with mudstone towards base.	High	Groundwater potential tend to increase at geologic contacts/ stream confluences
Afram Sandstone	Mudstone and siltstone, micaceous, sporadic limestone beds.	Moderate- High	Groundwater potential tend to increase at geologic contacts/ stream confluences
Damango Sandstone	Sandstone, flaggy to laminated, fine to medium grained, micaceous	Average - Moderate	Groundwater potential tend to increase at geologic contacts/ stream confluences
Tease Sandstone	Sandstone, thinly bedded to laminated and cross-laminated, quartzose, locally coarse grained.	Average	Groundwater potential tend to increase at geologic contacts/ stream confluences
Obosom Undifferentiated	Mudstone, siltstone, sandstone, undifferentiated	Relatively low	Groundwater potential tend to increase at geologic contacts/ stream confluences

2.5 SURFACE WATER DIVISION

The long-term objective of the Surface Water Division is to generate, develop and transfer appropriate technologies, information and services for sustainable development, utilization and management of surface water resources for socio-economic development.
The specific objectives include:

- Assessment of surface water resources of the country for socio-economic development
- Assessment of sediment transport by streams/rivers and discharges into reservoirs for planning and management of water resources
- Development and adaptation of appropriate technologies and water conservation techniques for water supply to households, communities, farms and industries
- Assessment of climate change effects and adaptation strategies

2.5.1 Hydro-Meteorological Station at CSIR-WRI Head Office

(Project Staff: Dr. K. Kankam-Yeboah – Principal Research Scientist, Mr. A. A. Agyapong - Principal Technical Officer, Mr. C. K. Asante- Sasu - Principal Technical Officer and Mr. G. Appiah -Technical Officer)

Hydro-meteorological data on rainfall, temperature, evaporation, sunshine duration and wind-run were collected daily from the CSIR Water Research Institute's weather station located at 05° 35705N and 00° 11105W at an altitude of 45.72 m and digitally stored. The objectives were to describe the environmental conditions at any particular time and to determine the water balance of the area.

The total rainfall for the reporting year was 880.1 mm. The rainfall pattern was typically bimodal, with the major and minor peaks in May and October, respectively in 2011 (Figure 20). There were 81 rainy days out of a total of 365 days in 2011. Unusual rainfall amounts of 57.1 mm, 64.3 mm and 11.2 mm occurred on 10th, 22nd and 25th respectively, in February 2011. Comparatively, the rainfall trend had been decreasing in recent years (Figure 21) but the annual total rainfall had been increasing in the long-term (Figure 22). Total evaporation was 1516.6 mm and it exceeded rainfall by 652.1 mm (Figure 23). Evapotranspiration exceeded rainfall in two-thirds of the year. Crops could therefore suffer from water deficit unless supplementary irrigation was undertaken in the dry periods of the year. Data on other hydro-meteorological parameters of the CSIR WRI station in 2011 are shown in Table 19. Some gadgets such as Automatic Rainfall Recorder, Stevenson Screens, Thermograph and Barograph used for the monitoring need urgent attention.

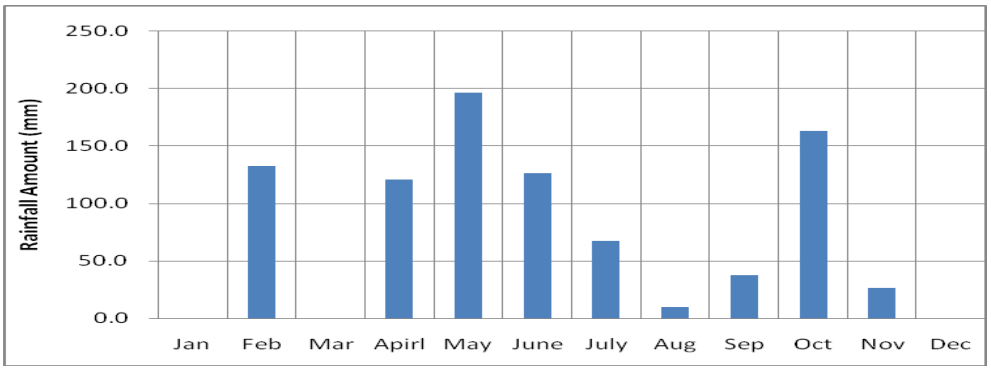


Figure 20: Rainfall pattern in 2011

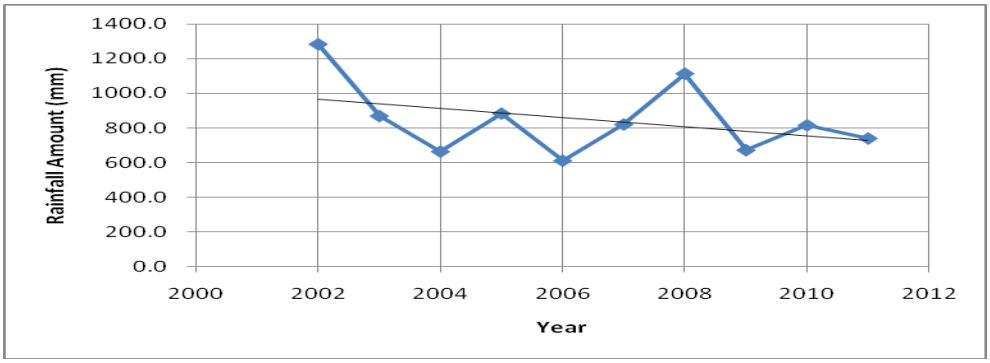


Figure 21: Annual rainfall trend from 2002-2011

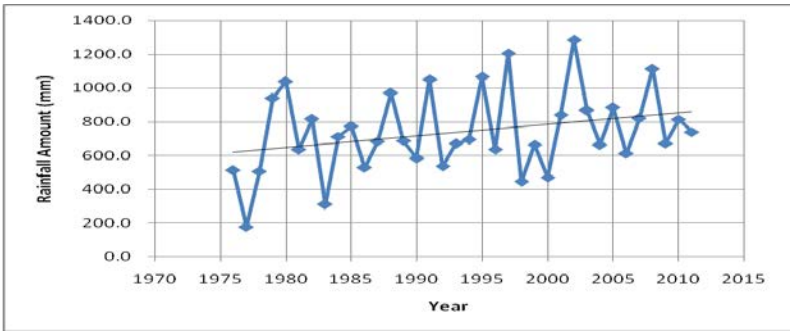


Figure 22: Annual rainfall trend from 1976 – 2011

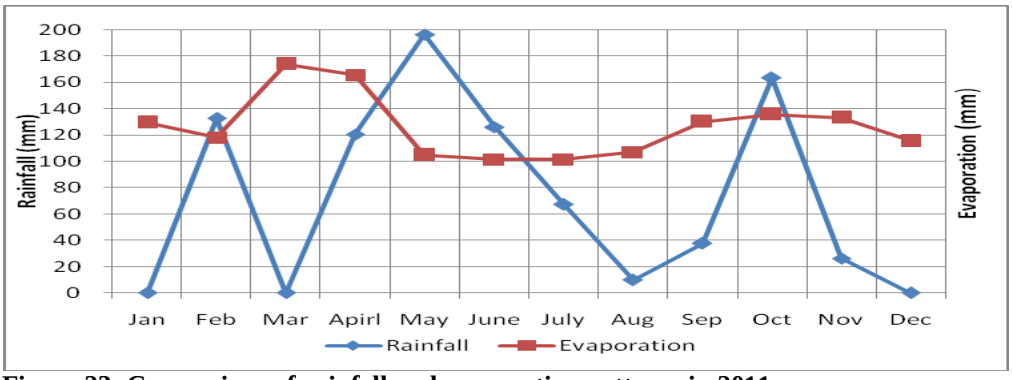


Figure 23: Comparison of rainfall and evaporation patterns in 2011

Table 19: Hydro-meteorological data-2011 at CSIR Water Research Institute Station, Accra

Parameter	Jan	Feb	Mar	April	May	June	July	Aug	Sep	Oct	Nov	Dec	Total
Rainfall (mm)	0.0	132.6	0.0	120.6	196.4	126.1	67.2	10.0	37.7	163.3	26.2	0.0	**880.1**
Rain day	0	3	0	8	12	17	8	10	11	10	2	0	**81**
Rainfall (Average Last 10 Years)	12.9	16.9	54.0	89.2	150.4	214.5	60.2	30.7	63.3	65.3	37.5	27.0	**821.9**
Rainfall (Average 1976 - 2010)	7.7	14.0	52.6	83.9	114.5	177.9	60.0	27.7	50.8	64.2	36.7	19.9	**709.9**
Evaporation (mm)	129.5	118.2	174.0	165.5	104.9	101.5	101.5	107.0	130.2	135.6	133.2	115.5	**1,516.6**
Temperature (°C)													
Mean Temperature	-	-	-	-	-	-	-	-	-	-	-	-	
Maximum Temperature	-	-	-	-	-	-	-	-	-	-	-	-	
Minimum Temperature	24	25	26	25	25	25	-	-	24	24	25	25	
Windrun (Knots)	0.34	1.56	2.59	1.82	1.29	1.16	2.26	2.68	2.8	1.78	1.39	1.32	
Sunshine (Hours)	4.8	6.8	7.8	7.5	6.1	4.6	4.6	3.9	5.5	7.5	9.2	7.5	**75.8**
Relative Humidity (%)	70	79	77	78	83	86	85	84	81	80	80	76	

2.5.2 Rethinking Water Storage for Climate Change Adaptation in Sub-Saharan Africa

(Project Staff: Dr. B. A. Amisigo – Senior Research Scientist, Dr. K. Kankam-Yeboah – Principal Research Scientist, Mr. E. Agbeko – Research Scientist, Mr. C. K. Asante-Sasu – Principal Technical Officer, Mr. A. Agyapong – Principal Technical Officer and Mr. G. Appiah – Technical Officer)

The project began in 2008 and ended in the reporting year. It was a collaborative research project involving the CSIR Water Research Institute; IWMI; Centre for Development Reserarch (ZEF) of the University of Bonn, Germany; Arba Minch University/Institute of Water Technology, Ethiopia; Institute of Statistical, Social and Economic Research (ISSER), University of Ghana, Legon; and Deutsche Gesellschaft für International Zusammenarbeit (GIZ) GmbH on behalf of the German Federal Ministry for Economic Cooperation and Development (BMZ). The overall goal was to improve livelihoods and increase resilience of rural poor in Sub-Saharan Africa (SSA) vulnerable to climate change risks through better water storage systems, improved investments and institutional support. The specific objectives among others were to:

- facilitate conceptual rethinking of water storage and formulate new conceptual framework;
- examine various water storage systems and options, their economic feasibility and suitability in various physiographic and socio-political conditions;
- examine various processes of investment decisions on water storage creation and enhancement, their impacts on land and water entitlements and access for different groups;
- explore synergies and tradeoffs of different storage systems, evaluating livelihood impacts, equity considerations, environmental effects and resilience to climate change risks; and
- provide research-backed information and guidelines for decisions on investments into water resources development and institutional arrangements in the context of climate change in SSA.

During the reporting period, findings of the project were presented to stakeholders and policy makers at a policy roundtable discussion and during the 3rd Ghana Water Forum in Accra. Research reports on the project were also prepared and presented to the Institute's editorial committee for review and publication.

The study showed that the variety of water storage systems in use in the Volta Basin of Ghana were mainly surface reservoirs and boreholes/hand-dug wells abstracting water from natural aquifers. Although the available storage systems were grossly inadequate in numbers as they did not meet all the water requirement needs of the communities they serve all year round, all the systems identified were poorly managed. Many boreholes run dry in the dry season due to factors such as over-abstraction of water. Many broken down borehole pumps were either not repaired at all or not fixed promptly thereby hampering the functionality, performance and efficiency of such boreholes. The irrigation schemes were in poor state as eroded dam walls and irrigation canals were not promptly repaired making it impossible to serve planned irrigable areas and depriving sections of the target populations of essential livelihoods. In addition, siltation of the reservoirs was a serious problem as water storage systems were rarely dredged.

However, to reduce vulnerabilities and increase resilience of communities to the impacts of climate change on water availability, communities must have access to a wide range of water storage systems. Hence, available water storage systems should be adequate, sustainably managed and maintained to meet the needs of the populations all year round.

It was recommended that other unpopular water storage systems such as roof rainwater harvesting for household use and sand storage (riverbed storage) systems should be seriously considered in the basin to make water available for domestic use and vegetable irrigation in the dry season. The numbers of the existing storage systems such as boreholes and small multi-purpose dams in the basin should be increased to meet the water needs of the communities. Artificial recharge of aquifer systems should be explored to increase groundwater storage. Deep reservoirs with large volume to surface area ratios should be constructed to reduce evaporation from their surfaces. Household water treatment and safe storage technologies should also be actively promoted, especially in rural communities depending on untreated water supply.

2.5.3 Uradapt - Managing Water at the Urban-Rural Interface: The Key to Climate Change Resilient Cities

(Project Staff: Dr. B. A. Amisigo – Senior Research Scientist, Mr. Fred Logah – Research Scientist, Mr. C. K. Asante-Sasu – Principal Technical Officer, Mr. A. Agyapong – Principal Technical Officer and Mr. G. Appiah – Technical Officer)

This project was initiated in 2009 in collaboration with IWMI, Ghana Institute of Local Government Studies (ILGS), Addis Ababa University (AAU), Ethiopia, Climate Change Adaptation in Africa (CCAA) programme of the International Development Research Centre (IDRC) of Canada and the United Kingdom's Department for International Development (DFID). The objectives were to:

- develop a shared understanding amongst multiple stakeholders of climate change and its effects on water management at the urban-rural interface using simplified scenarios for greater comprehension of the consequences;
- generate new knowledge using scenarios on the upstream and downstream implications of urban water demand, and of resulting wastewater generation, as well as on water investments needs; and
- prepare, in participation with city stakeholders, and for the benefit of the most vulnerable groups, a strategic action plan for adapting to climate change based on improved water resource management.

It is expected to be completed in 2012.

In the reporting year, literature review of flooding and flood studies in the Greater Accra Metropolitan Area (GAMA) was undertaken. Water availability and abstraction for various purposes in the Densu Basin as baseline information for climate change impact analysis was compiled and a report on water availability in the Lower Volta River to ascertain the ability of this river to serve as the main water supply source for all of Accra was prepared. The statistical downscaling of the output of the REGCM4 model for the Densu for IPCC SRES scenarios A1B and B1 was started using LARS-WG stochastic weather generator. Meetings were also held with selected national stakeholders of the project to discuss progress in climate change scenario and hydrological modelling in the Densu basin and the way forward. The necessary GIS layers (soils, topography, built areas, landuse) were constructed and field ground truthing of flood risk areas undertaken in order to prepare a flood risk map of GAMA. A base map of GAMA (Figure 24) was produced for flood risk mapping, and this was endorsed by the relevant department of the Accra Metropolitan Assembly (AMA) as a good working base map.

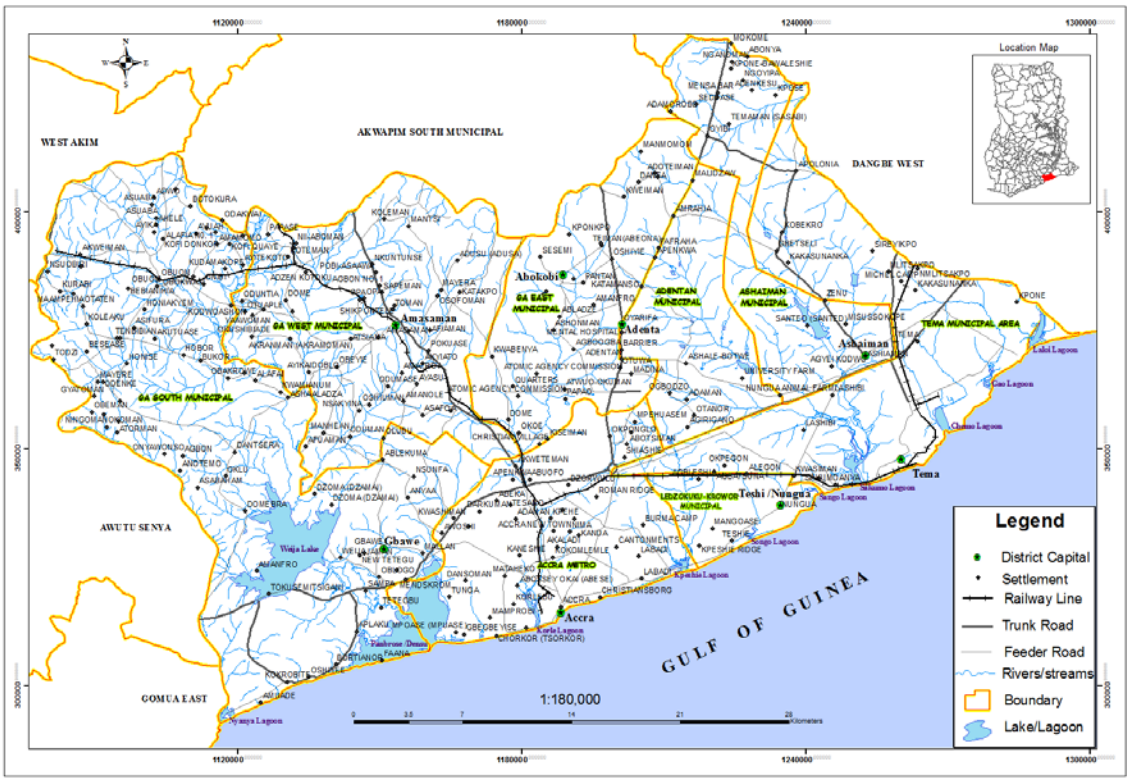


Figure 24: Base map of Greater Accra Metropolitan Area (GAMA)

2.5.4 Groundwater in Sub-Saharan Africa: Implications for Food Security and Livelihood

(Project Staff: Dr. Emmanuel Obuobie – Research Scientist, Dr. Benony Kortatsi – Principal Research Scientist and Ms. Deborah Ofori – Research Scientist)

The Institute, in collaboration with International Water Management Institute (IWMI), University for Development Studies (UDS) and Kwame Nkrumah University of Science and Technology (KNUST) initiated this research project in 2010 to enhance the role of groundwater in providing improved food security and livelihoods in Sub-Saharan Africa (SSA). The main objective was to investigate the physical groundwater resource potential for irrigation in the Talensi-Nabdam and Bawku West districts of the Upper East Region of Ghana and its sustainability under current conditions and future development scenarios. The specific objectives were to:

- characterize the groundwater aquifer systems (hydraulic conductivity, transmissivity, storativity, specific yield, water levels, etc.) of the study areas via review of existing literature, analysis of secondary data and field investigations at selected locations;
- estimate the total amount and spatial distribution of groundwater recharge using multiple recharge estimation techniques;
- evaluate the suitability of groundwater for agricultural use via water sampling and quality analysis;
- estimate the extent of groundwater use by the various sectors (domestic, industrial and agriculture including livestock and cattle) in the study area;
- estimate the total volume of groundwater currently being used in agriculture and in comparison with total agricultural water use in the study area;
- evaluate the potential for using groundwater to expand agriculture under present condition and future development scenarios;
- estimate water storages in the Volta Basin; and
- undertake literature review of groundwater status in Ghana, Burkina Faso, Niger and Mali.

It is expected to end in 2012.

Activities undertaken in the year under review included geophysical survey to characterize the groundwater aquifers in Zanlerigu and Sapeliga in the Upper East Region; groundwater sampling and water quality analysis; mapping of groundwater-irrigated vegetable sites in the Bawku West and Telensi-Nabdam districts of the Upper East Region and data analyses.

The study when completed would provide information on the groundwater status in Ghana, Burkina Faso, Niger and Mali.

2.5.5 Earth Observation for Regional Water Balance Estimation and Surface Energy Balance Assessment in the Volta Basin, West Africa

(Project Staff: Dr. K. Kankam-Yeboah – Principal Research Scientist, Mr. C. K. Asante-Sasu – Principal Technical Officer, Mr. A. A. Agyapong – Principal Technical Officer, Mr. G. Appiah – Technical Officer, Mr. K. A. Adjei – KNUST and Mr E. Kusi Minka – HSD)

The Institute, in collaboration with European Space Agency, University of Twente (ITC) and Kwame Nkrumah University of Science and Technology (KNUST), initiated this study in the reporting year to build upon research that demonstrates the use of ENVISAT data products to estimate regional water balance through the assimilation of different types of spatial datasets using computationally-efficient GIS tools. The strategy was to retrieve surface values from optical remote sensing as inputs to a distributed solution of the regional water balance equation. Through TIGER-II, the study would take advantage of a fully calibrated high spatial resolution optical satellite data from ESA's MERIS and AATSR sensors on the ENVISAT mission, SPOT HRV sensor data to estimate vegetation cover/type for selected test sites and NASA's Tropical Rainfall Measuring Mission (TRMM) to derive spatial estimates of rainfall to compliment very sparse rain gauge data and surrogate estimation of rainfall amount.The specific objectives were to:

- derive land surface variables (e.g. vegetation cover, albedo and temperature) from ENVISAT products as inputs to the SEBAL model to predict evapotranspiration (ET) and a modified PITMAN model to estimate runoff from savannah catchments within the Volta Basin; and
- assess the sensitivity of the distributed model to satellite-derived input parameters to ensure better understanding of the importance of changing surface characteristics to

runoff production based upon empirical comparison with conventional field measurements.

It is expected to end in 2012.

During the reporting year, as part of the TIGER initiative launched by the European Space Agency (ESA) to help African countries overcome water-related problems by exploiting the advantages of Earth Observation technology, the capacity of co-investigators was developed in Earth Observation (EO) data acquisition and processing through Tiger II Training Workshops to introduce the most advanced physical EO methods applicable to ESA data with a focus on water resources estimation and water management for the researchers of the current TIGER Projects. Pieces of Data Dissemination System (DDS) equipment were delivered to the Institute and installed. Access to some Earth Observation data such as ENVISAT MERIS Level 1B Reduced Resolution and Full Resolution, AATSR Gridded Brightness Temperature and Reflectance (ATS_TOA_1P), ENVISAT ASAR Global Monitoring Mode Image (EN1.ASA.GM1_1P), NASA TRMM data (Lat=[4.7N,15.3N], Lon=[5.4W,2.3E]) and SPOT Data were acquired/downloaded (Figures 25 and 26). Analysis was also conducted in the Black Volta Basin, Ghana, to determine how TRMM satellite-derived rainfall compares with ground-measured values and the possibility of using it to complement ground-measured rainfall. Bilinear interpolation was used to resample $0.25^0 \times 0.25^0$ TRMM 3B42V6 monthly rainfall grids to determine site-specific rainfall of the basin based on rain gauge locations and analyzed statistically. The study showed that correlation between monthly datasets ranged from 0.73 to 0.88. A plot of the average monthly data of all the stations gave a correlation coefficient (R) of 0.94 (Figure 27). The overall catchment rainfall was well represented by TRMM data. However, the annual station rainfalls were either underestimated or overestimated. The underestimations and overestimations were mostly below 20% and 10 %, respectively, of the rain gauge measurements. Although the TRMM rainfall data did not perfectly match with the ground measurements, it could still be used to supplement ground measurements and for estimating rainfalls in ungauged basins.

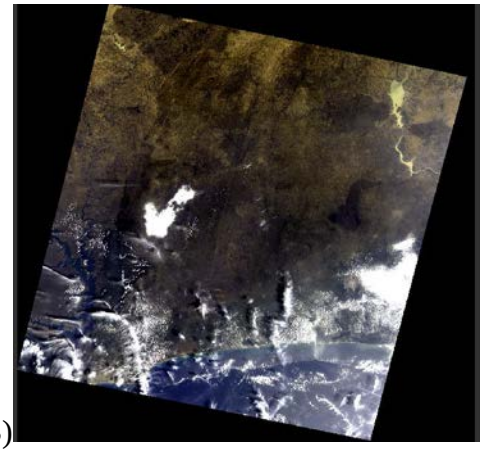
(A)  (B) 

Figure 25: MERIS Level 1B Full Resolution geolocated and calibrated TOA Radiance Image of the Volta Lake (A) and in a reprojected meris trimus RGB view (B)

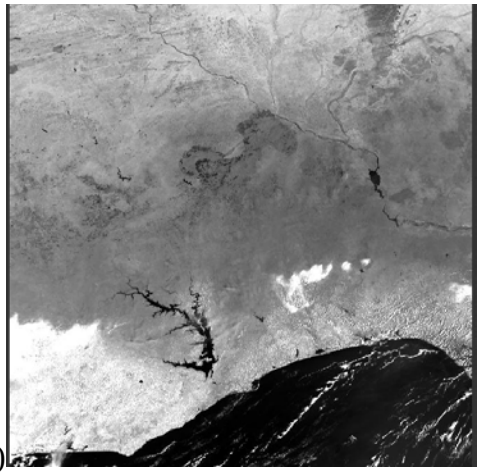
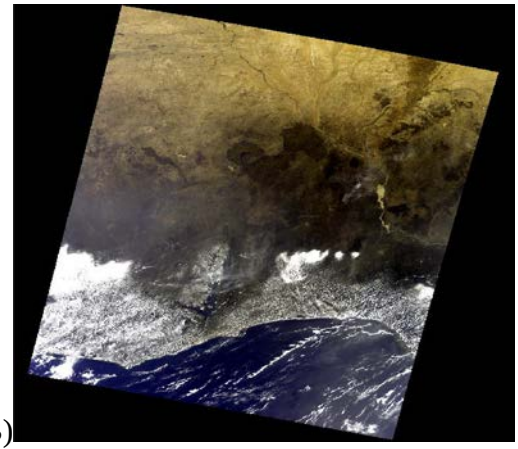
(A)  (B) 

Figure 26: MERIS Level 1B Reduced Resolution geolocated and calibrated TOA Radiance Image of the Volta Lake (A) and in a reprojected meris trimus RGB view (B).

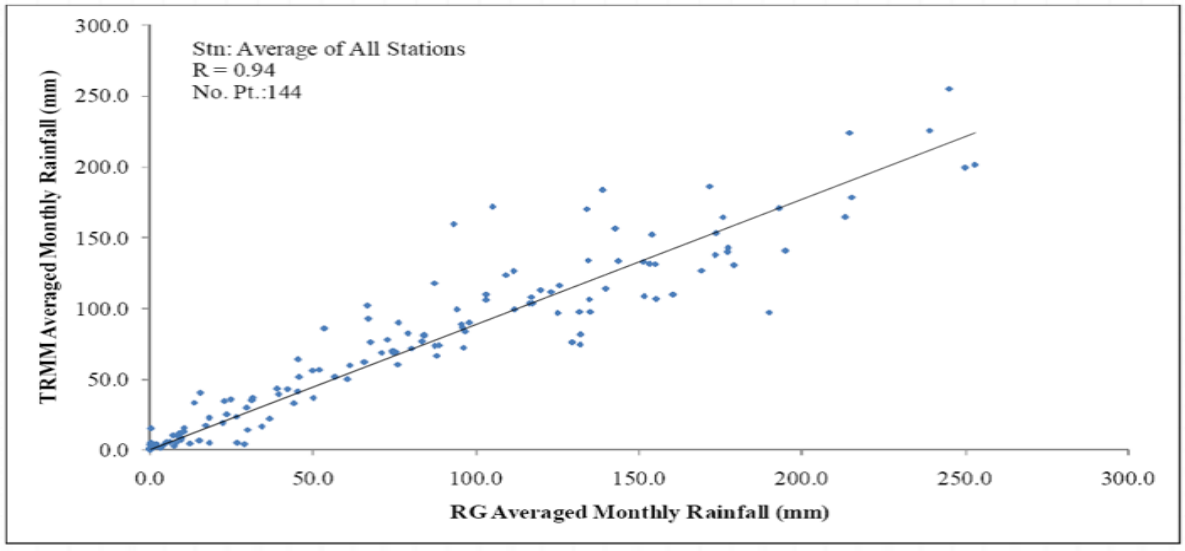


Figure 27: Plot of accumulated monthly rainfall - TRMM vrs. RG

The study when completed would help implement a model at CSIR Water Research Institute, Ghana, as an operational water balance estimation tool linked to ESA Earth Observation products. This would facilitate rapid estimation of regional water balance, overcome recognised problems with scarce and poorly distributed field-based hydrological observations in West Africa and strengthen collaboration between institutions/scientists in terms of training and research and development activities in hydrological modelling and advanced image.

2.5.6 V4 Sub-Basin Management and Governance of Rainwater and Small Reservoirs

(Project Staff: Dr. Emmanuel Obuobie – Research Scientist)

This study started in 2010 to improve rainwater and small reservoir management to contribute to poverty reduction and improve livelihoods resilience and people's well-being in the dry lands of Northern Ghana and Burkina Faso while taking account of implications for downstream water users including ecosystem services. The collaborative agencies included International Water Management Institute (IWMI), CIRAD, WRC-WVBB, SP/PAGIRE (MHARH) and UDS-Tamale. It is expected to end in 2013.

During the reporting year, watershed modelling was conducted with Soil and Water Assessment Tool (SWAT) and Water Evaluation and Planning System (WEAP) for Zebilla sub-basin in Ghana. Hydrology and sediment yields in the White Volta River channel and small reservoirs within the study sub-basin were also calibrated and validated in SWAT after sensitivity analysis on the model parameters. Water yield estimates were also assessed.

The study when completed would help improve rainwater and small reservoir management to contribute to poverty reduction in northern Ghana.

2.5.7 Eco-Health Approach to the Control of Onchocerciasis in the Volta Basin of Ghana

(Project Staff: Dr. Emmanuel Obuobie – Research Scientist)

This project was carried out in collaboration with Noguchi Memorial Institute for Medical Research and Statistical, Social and Economic Research, all of the University of Ghana, UK Meteorological Office Hadley Centre, Natural Resources Institute, University of Greenwich, UK, Ghana Meteorological Agency and Institute of Mathematical Science, Accra, to study if, and how, the effects of onchocerciasis can be reduced in Ghana using sustainable community-directed environmental management in drug ivermectin-resistant areas. It was initiated in 2009 and is expected to end in 2012. The specific objectives were to:

- analyze the climatology and trends in climate extreme events in the Pru and Black Volta river basins;
- setup a hydrological model to simulate streamflow in the two study basins;
- develop climate scenarios for the two basins for climate change impact analyses;
- estimate the impact of climate change on streamflow in the study basins;
- identify factors which explain the reasons why some areas in Ghana are developing resistance to the ivermectin control of onchocercaisis;
- identify vulnerable zones (e.g. mountainous areas where vectors could survive at higher altitudes with global warming or forest areas becoming savanna-like) and predict probable changes in vector ecologies, distributions and transmission efficiencies for policy attention;
- assess the suitability of mitigation measures to control onchocerciasis (e.g. sustained means of ivermectin distribution, vector control, immigration screening, afforestation or locally managed control measures at dams and other locations); and
- recommend adaptation strategies for endemic communities to enable them cope with the impacts of climate change on socio-economic activities.

Activities carried out in the reporting year included analyses of trends in extreme climate events in the Pru and Black Volta basins; full calibration and validation of the hydrological model (SWAT) for the Pru and Black Volta basins; developing climate scenarios including statistical downscaling of GCM data for impact analysis and participating in stakeholder workshop. A total of 20 indices which form part of the 27 core climate indices defined by a joint WMO CCI/CLIVAR expert team on climate change detection, monitoring and indices were analyzed for each basin (Table 20). Ten (10) of the indices were temperature related (TXx, TXn, TNx, TNn, TN10p, TX10p, TN90p, TX90p, WSDI and CSDI) while the other 10 indices were precipitation related (RX1day, Rx5day, R10, R20, Rnn, CDD, CWD, R95p, R99p and PRCPTOT). Data from 8 climate stations in and around the Pru basin and 11 stations in and around the Black Volta basin were analyzed.

Table 20: List of climate indices analyzed in and around Pru and Black Volta basins

ID	Indicator name	Definitions	UNITS
TXx	Max Tmax	Monthly maximum value of daily maximum temp	ºC
TNx	Max Tmin	Monthly maximum value of daily minimum temp	ºC
TXn	Min Tmax	Monthly minimum value of daily maximum temp	ºC
TNn	Min Tmin	Monthly minimum value of daily minimum temp	ºC
TN10p	Cool nights	Percentage of days when TN<10th percentile	Days
TX10p	Cool days	Percentage of days when TX<10th percentile	Days
TN90p	Warm nights	Percentage of days when TN>90th percentile	Days
TX90p	Warm days	Percentage of days when TX>90th percentile	Days
WSDI	Warm spell duration indicator	Annual count of days with at least 6 consecutive days when TX>90th percentile	Days
CSDI	Cold spell duration indicator	Annual count of days with at least 6 consecutive days when TN<10th percentile	Days
RX1day	Max 1-day precipitation	Monthly maximum 1-day precipitation	mm
Rx5day	Max 5-day precipitation	Monthly maximum consecutive 5-day precipitation	mm
R10	Number of heavy precipitation days	Annual count of days when PR >= 10mm	Days
R20	Number of very heavy precipitation days	Annual count of days when PR >= 20mm	Days
Rnn	Number of days above nn mm	Annual count of days when PR >= nn mm, nn is user defined threshold	Days
CDD	Consecutive dry days	Maximum number of consecutive days with RR<1mm	Days
CWD	Consecutive wet days	Maximum number of consecutive days with RR>=1mm	Days
R95p	Very wet days	Annual total PRCP when PR>95th percentile	mm
R99p	Extremely wet days	Annual total PRCP when PR>99th percentile	mm
PRCPTOT	Annual total wet-day precipitation	Annual total PRCP in wet days (PR>=1mm)	mm

Results for three (3) indices for Attebubu weather station in the Pru Basin (Figures 28 – 30) based on statistical downscaling of HADCM3 output for SRE A1B scenario indicated that though annual precipitation increased slightly in the future, the increase was not significant at the 95% confidence level. However, the increase for maximum of daily maximum temperature and minimum of daily maximum temperature were significant at the 95% confidence level. Sensitivity analysis (Tables 21 and 22) indicated that the initial SCS curve number II (CN2) was the most sensitive parameter followed by soil evaporation compensation factor (ESCO). Calibration and validation results for the Pru basin showed that R^2 and NSE were 0.84 and 0.82 at calibration and 0.79 and 0.75 at validation, respectively. Both the R^2 and NSE obtained at calibration and validation were higher than the minimum values (R^2 > 0.6 and NSE>0.5) required for successful calibration as suggested by Santhi et al. (2001). It was concluded from the study that the SWAT model was able to simulate the hydrology and streamflow of the Pru and Black Volta river basins at monthly time scale.

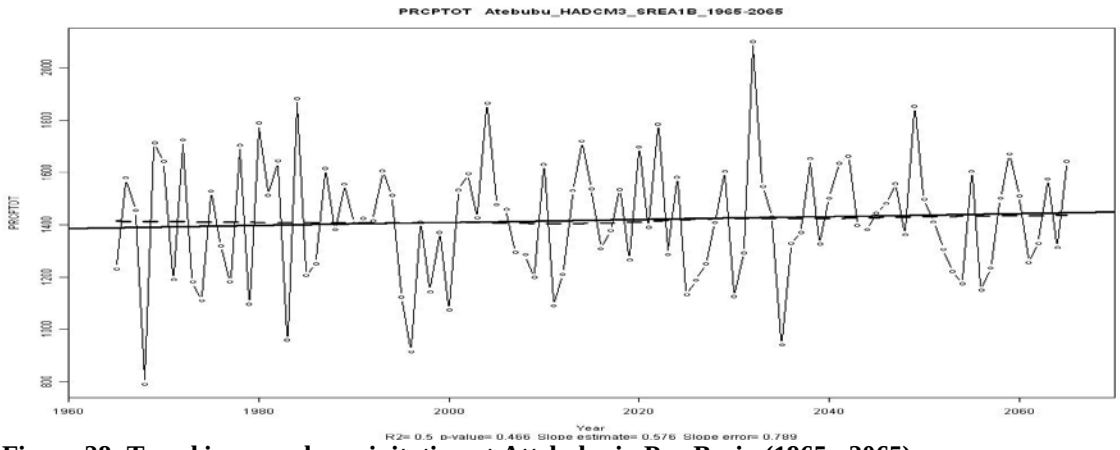


Figure 28: Trend in annual precipitation at Attebubu in Pru Basin (1965 - 2065)

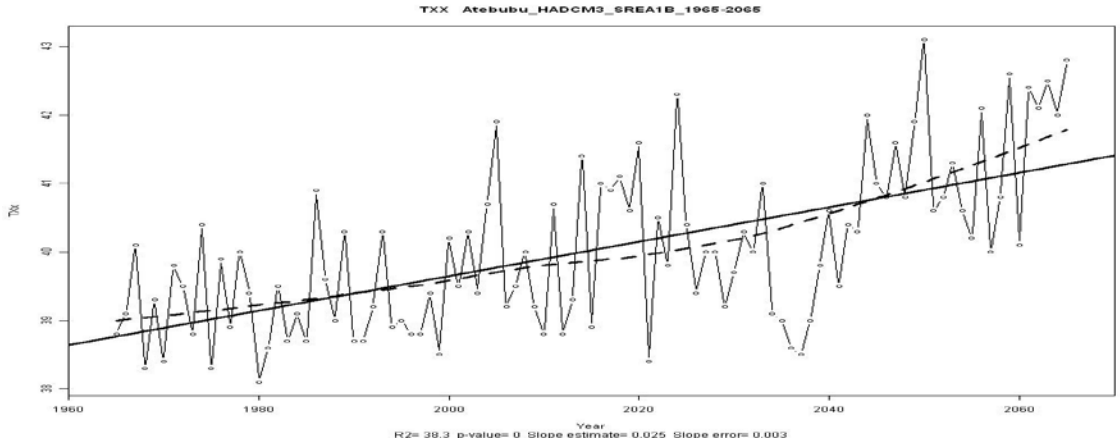


Figure 29: Trend in maximum of daily maximum temperature at Attebubu in Pru basin (1965 - 2065).

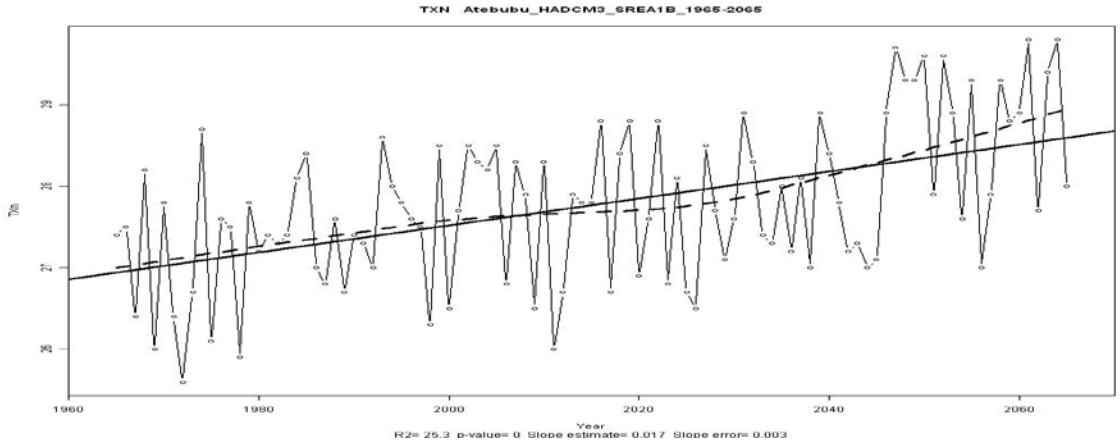


Figure 30: Trend in minimum of daily maximum temperature at Attebubu in Pru basin (1965 to 2065).

Table 21: SWAT-sensitivity analysis of model input parameters for the Black Volta basin

Parameter	Description	Sensitivity ranking
CN2	Initial SCS curve number II value	1
ESCO	Soil evaporation compensation factor	2
GWQMN	Threshold depth of water in shallow aquifer for return flow	3
ALPHA_BF	Baseflow Alpha factor	4
GW _REVAP	Groundwater "revap" coefficient	5
SOL_AWC	Available water capacity of the soil layer	6
RECHRG_DP	Deep aquifer percolation fraction	7
SOL_K	Saturated hydraulic conductivity	8
SOL_ALB	Moist soil albedo	9
SOL_Z	soil depth	10

Table 22: SWAT-sensitivity analysis of model parameters for the Pru basin

Parameter	Sensitivity ranking
CN2	1
ESCO	2
GW _REVAP	3
GWQMN	4
RECHRG_DP	5
SOL_AWC	6
SOL_Z	7
SOL_K	8
ALPHA_BF	9
SOL_ALB	10

2.5.8 Assessment of Urban Water Supply Systems in Ghana-Wa

(Project Staff: Ms. Deborah Ofori – Research Scientist, Mr Fred Logah – Research Scientist, Dr. K. Kankam-Yeboah – Principal Research Scientist, Mr. G. Appiah – Technical Officer and Mr. C. K. Asante-Sasu – Principal Technical Officer)

This study was initiated and completed in the reporting year. The goal was to assess the current state of water supply system in Wa and make recommendations to improve supply using the Black Volta River as raw water source.

During the year under review, existing water supply systems in Wa were assessed and hydrological analysis using streamflow data for the Black Volta River at Lawra was undertaken. Estimation of current and future water demands for 2020 and 2050 for the study area was also considered.

The study indicated that current water supply coverage is 33% of the population in Wa municipality excluding surrounding communities. The low yields from the existing boreholes were therefore inadequate to meet the supply demand resulting in lower coverage of the water distribution network. Residents depended on secondary and tertiary water sources of questionable quality for domestic purposes. Water demand (8,250m^3/s) and supply (1,800m^3/s) for 2011 in Wa municipality suggested that the water supply system had inadequate capacity (1,830m^3/s) to meet water demand for 2020, 2030 and 2050 as shown in Table 23.

Table 23: Water demand for Wa Municipality and selected communities

Water Use Category	Water Demand (m^3/day)			
	2010 (Pop:101,785)	**2020 (Pop:120,476)**	**2030 (Pop:163,869)**	**2050 (Pop:193,959)**
House connection	3,257	3,855	5,244	6,207
Public standpipes	1,832	2,169	2,950	3,491
Institutions, Industrial and Commercial	1,527	1,807	2,458	2,909
Physical losses	794	940	1,278	1,513
Abstractions/Treatment losses	662	783	1,065	1,261
Total	**8,072**	**9,554**	**12,995**	**15,381**

On the other hand, hydrological analyses showed that the Black Volta River could be used as a source of raw water for the proposed water treatment plant (WTP) in the study area. Flow duration curve indicated that 95% dependability value for the Black Volta River were 105,408 m^3/day (1.22 m^3/s) and 75,773 m^3/day (0.877 m^3/s) for the complete flow values and dry season flows, respectively (Figure 31 and Table 24). A 99% dependability value of 21,082 m^3/day (0.244 m^3/s), which exceeded the water demands for 2020, 2030 and 2050 planning years as shown in Table 24 was observed for the most extreme case. It was thus recommended that a new conventional treatment system could be built based on surface water abstraction from the Black Volta River.

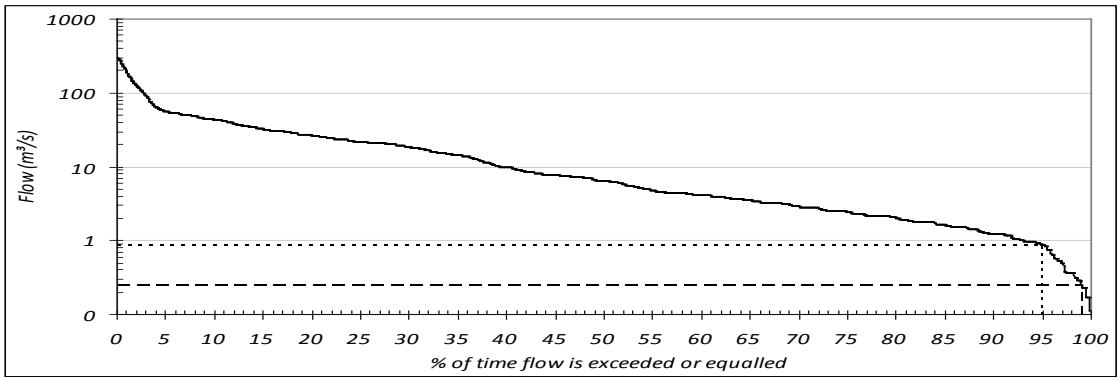


Figure 31: Flow duration curve developed for the Black Volta Basin at Lawra using dry season streamflow data

Table 24: Estimates of minimum streamflows requirement in the Black Volta Basin at Lawra

Streamflows	Percentage of time streamflow is equaled or exceeded	
	95%	**99%**
	m^3/day	**m^3/day**
Complete flow series	107,136	26,870
Dry season flows	75,773	21,082

2.5.9 Feasibility Studies on Water Abstraction from the Black Volta River at Lawra for Wa Water Supply Scheme

(Project Staff: Mr. F. Y. Logah - Research Scientist, Dr. K. Kankam-Yeboah - Principal Research Scientist and Dr. B. A. Amisigo - Senior Research Scientist)

This project was initiated and completed in the reporting year. The objective was to investigate the impact of a proposed Water Treatment Plant (WTP) at Janbuse in the Wa metropolis on the hydrological situation of the Black Volta River. It was undertaken through the collaborative effort of CSIR Water Research Institute and Hydrological Service Department of the Ministry of Water Resources, Works and Housing, Accra, Ghana.

Activities carried out included selection of stations with good records of mean daily streamflows in the basin, estimation of low streamflow requirements of the basin, extraction and analysis of low flow sections from the streamflow records, estimation of base-flow contribution to low streamflow in the basin and assessment of the effects of the proposed Water Treatment Plant (WTP) and the risk of river drying out.

The study showed that streamflows of 1.24 m³/s and 0.88 m³/s for the complete flow and the dry season flows, respectively, were equaled or exceeded 95% of the time in the Black Volta Basin at Lawra. In the most extreme case, streamflow of 0.244 m³/s was equaled or exceeded 99% of the time during the dry season (Figure 32).

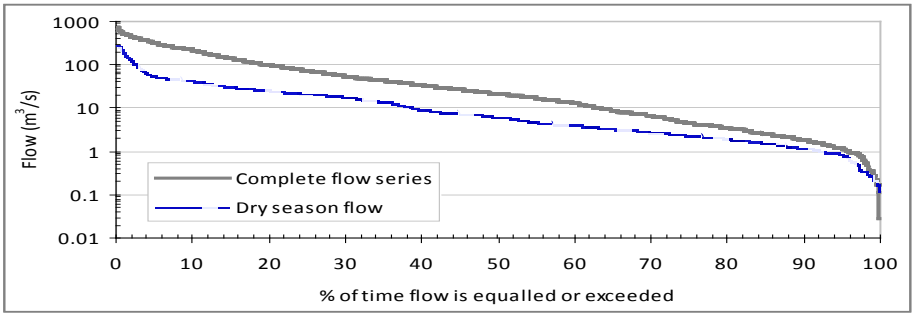


Figure 32: Flow duration curve developed for the Black Volta Basin at Lawra

The results from the flow frequency analysis showed with 100% probability that streamflow of 0.19 m³/s is expected to occur in the basin at Lawra at least once every year. Similarly, low streamflows of 0.103 m³/s, 0.071 m³/s and 0.054 m³/s are expected to occur at least once in a 10, 100 and 1000-year periods, respectively, in the basin at Lawra (Figure 33).

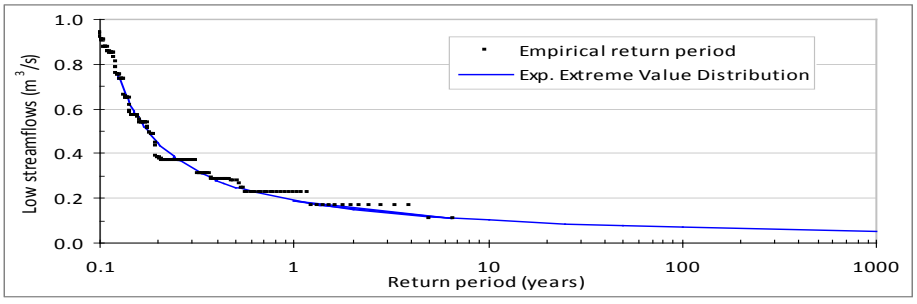


Figure 33: Return period plots for the Black Volta River using low flows at Lawra

It was concluded from the study that the probability of occurrence of extreme low flows in the Black Volta Basin was very low. Water abstraction was below 1.24 m³/s at Lawra, hence considered reliable and sustainable for domestic, industry and agricultural uses in Wa and its environs. It was however recommended that net withdrawal from the river should be restricted

to 0.37 m³/s especially during the drought period but not prohibited when abstraction is lower than the minimum flow. The government and relevant agencies should also devote adequate resources to set up more monitoring stations to facilitate the collection of meteorological and hydrological data for research, policy and decision making purposes.

2.5.10 Update of Flood Phenomenon in Ghana

(Project Staff: Dr. P. Gyau-Boakye - Principal Research Scientist, Dr. K. Kankam-Yeboah - Principal Research Scientist and Mr. F. Y. Logah - Research Scientist)

This project started in 2010 and ended in 2011. The objective was to give an overview on flood situation in Accra, Ghana, through secondary information gathering and hydrological analysis. The collaborating agencies were CSIR Water Research Institute, Hydrological Service Department of the Ministry of Water Resources, Works and Housing and Ghana Meteorological Agency, Accra, Ghana.

Activities undertaken during the reporting year included gathering of secondary data through research publications and anecdotal sources, acquisition of figures on major flood events in Accra and collection of monthly mean streamflow and rainfall data for hydrological analysis. Stations with good records of mean daily streamflows and rainfall were selected, peak flow threshold of the basin was estimated, high flow sections from the streamflow records were extracted, base-flow contribution to high streamflow in the basin was estimated and high streamflow frequency of occurrence was estimated using the return period curve.

It was shown from the study that flooding in Accra is regarded as both natural and non-natural disaster. Flood is expected to occur at least once every year in Accra during the rainy season, bringing untold hardship on displaced people. The minimum values above which all flows were high flows were estimated to be 995 m^3/s, 273 m^3/s and 30 m^3/s from the Volta, South Western and Coastal river systems, respectively at 90% probability of non-exceedance. The number of occurrence, trends and magnitudes of high streamflows increased within the last decades (2000 - 2010) (Figure 34). High streamflows of 650.6 m^3/s, 296.4 m^3/s and 36.5 m^3/s is expected to occur at least once every year in the Volta (Bamboi), South Western (Twifu Praso) and the Coastal (Okyereko) river systems, respectively. Similarly, streamflow of magnitudes 3529 m^3/s, 561 m^3/s and 105 m^3/s had the chance to occur at least once every 10 years in the Volta, South Western and Coastal river systems, respectively.

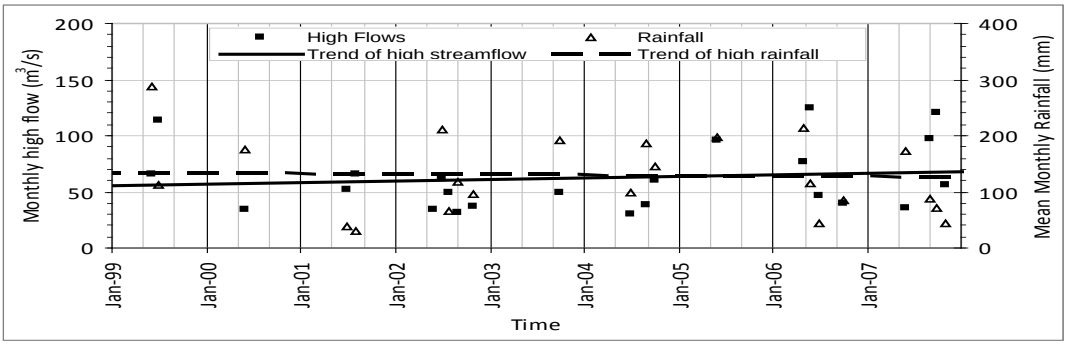


Figure 34: Occurrence, trends and magnitudes of high flows in the Coastal system at Okyereko

It was concluded that rainfall was not the major cause of high floods in recent times in the urban areas in Ghana. Drain clogging resulting from siltation, design flaws and improper waste management systems were the major causes of flooding in Accra. The impacts of flood on affected communities included loss of human lives, property damage, disease epidemic,

emotional and psychological stress and disruption in commercial and business activities. To reduce flood in urban areas, it was recommended that drainage channels should be deepened, widened and lined in order to accommodate recent runoff volumes. Chocked drains should be desilted regularly and drainage constructors, road agencies and district assemblies should focus on prevention and demolishing of unauthorized structures on layouts earmarked for drainage and flood plains to provide adequate storage and detention volumes for floods.

2.5.11 Low Flows Characterization of the Black Volta, Ayensu and Pra Rivers in Ghana

(Project Staff: Mr. F. Y. Logah – Rsearch Scientist, Dr. K. Kankam-Yeboah – Pincipal Research Scientist, Dr. B. A. Amisigo – Senior Research Scientist and Dr. E. O. Bekoe – Rsearch Scientist)

The Institute, in collaboration with Hydrological Service Department of the Ministry of Water Resources, Works and Housing, Accra, Ghana, started this study in 2008 and completed it in the reporting year. The aim was to characterize low streamflow regime of the South-Western River System, Coastal River System and Volta River System in Ghana using mean daily streamflow data from the Pra, Ayensu and Black Volta basins, respectively.

Activities carried out during the reporting period included selection of stations with good records of mean daily streamflows, estimation of low streamflow requirements of each basin, extraction of low flow sections from the streamflow records, estimation of base-flow contribution to low streamflow in the basins, splitting of low streamflow records into calibration and validation data sets, and calibration and validating of various extreme-value probability distribution functions using low flow data sets and selection of the function that performs better.

Results obtained from the Black Volta Basin indicated that streamflow of 1.24 m³/s, 0.31 m³/s and 0.21 m³/s were equaled or exceeded 95% of the time at Lawra, Bamboi and Bui, respectively. In the most extreme case, streamflow amount of 0.37 m³/s, 0.001 m³/s and 0.015 m³/s were equaled or exceeded 99% of the time at Lawra, Bamboi and Bui, respectively (Figure 35). The results showed with 100% probability that the Black Volta Basin records 0.19 m³/s, 0.17 m³/s and 0.13 m³/s of low streamflow at least once every year at Lawra, Bamboi and Bui, respectively. Similarly, streamflows of 0.07 m³/s, 0.067 m³/s and 0.08 m³/s are expected to occur at least once in a 100-year period at Lawra, Bamboi and Bui, respectively. Generally, all the distribution functions under calibration and validation modes fitted very well but the Gamma distribution best fitted the low streamflows in the Black Volta Basin.

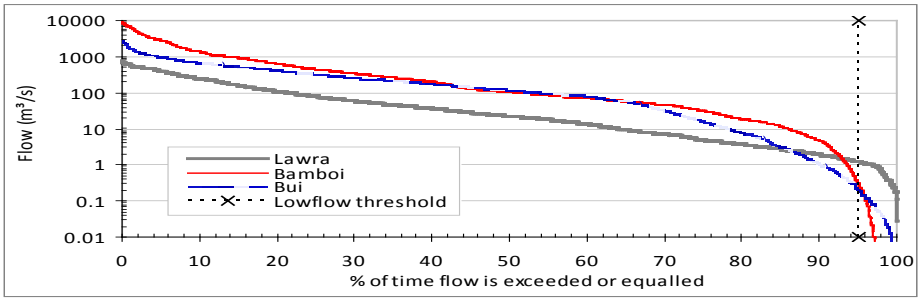


Figure 35: Flow duration curve for the Black Volta Basin at Lawra, Bamboi and Bui

Results obtained from the Ayensu Basin indicated that streamflow of 0.20 m³/s was equaled or exceeded 95% of the time at Okyereko. In the most extreme case, streamflow amount of 0.06 m³/s was equaled or exceeded 99% of the time at Twifu Praso (Figure 36). The results showed with 100% probability that the Ayensu Basin records 0.10 m³/s of low streamflow at least once every year at Okyereko. Streamflows of 0.016 m³/s, 0.01 m³/s and 0.009 m³/s are expected to

occur at least once in a 10-, 50- and 100-year periods, respectively. Generally, all the distribution functions under calibration and validation modes fitted very well. However, the normal distribution best fitted the low streamflows (Figure 37) with NSE equaled to 99.17%.

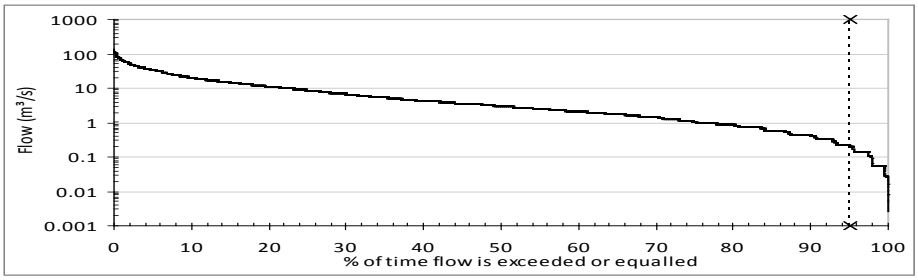


Figure 36: Flow duration curve for the Ayensu Basin at Okyereko

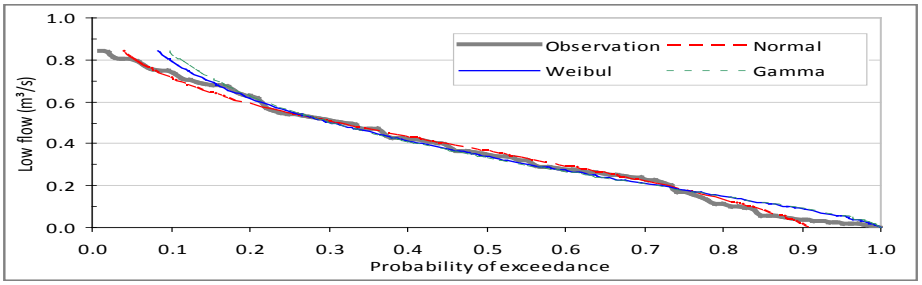


Figure 37: Fitting distribution functions to low flows in the Ayensu Basin at Okyereko

Streamflow of 6.09 m³/s was equaled or exceeded 95% of the time in the Pra Basin at Twifu Praso. In the most extreme case, streamflow amount of 1.70 m³/s was equaled or exceeded 99% of the time at Twifu Praso (Figure 38).

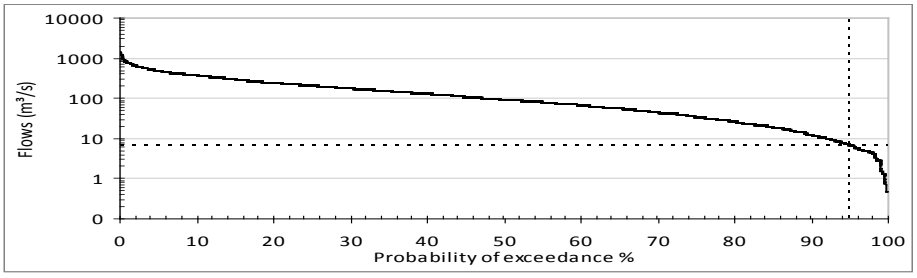


Figure 38: Flow duration curve for the Pra Basin at Twifu Praso

The results showed with 100% probability that the Pra Basin records 1.02 m³/s of low streamflow at least once every year at Twifu Praso. Streamflows of 0.53 m³/s and 0.35 m³/s are expected to occur at least once in a 10- and 100-year periods, respectively. Generally, all the distribution functions under calibration and validation modes fitted very well. However, the normal distribution best fitted the low streamflows (Figure 39) with NSE equaled to 99.16%.

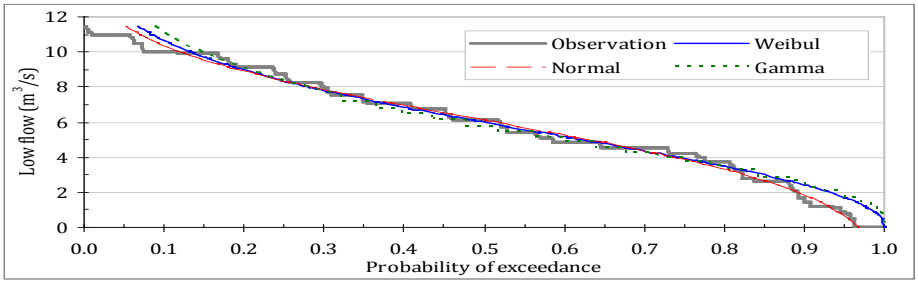


Figure 39: Fitting distribution functions to low flows in the Pra basin at Twifu Praso

It was concluded from the study that the probability of occurrence of extreme low flows in the Black Volta, Ayensu and Pra basins was low. Water abstraction below 1.24 m³/s at Lawra, 0.31 m³/s at Bamboi and 0.21 m³/s at Bui were considered reliable and sustainable for domestic, industry and agricultural purposes. However, in the most extreme case, net withdrawal should be restricted to 0.37 m³/s, 0.001 m³/s and 0.015 m³/s at Lawra, Bamboi and Bui, respectively, during the drought period but restricted when abstraction is lower than the minimum flows. To ensure sustainable and reliable streamflows for domestic, industry and agricultural water supply purposes in the Ayensu basin, abstraction should be kept below 0.20 m³/s especially during the dry season. It was however recommended that the government and relevant agencies should devote adequate resources to set up more monitoring stations to collect both meteorological and hydrological data for research, policy and decision making purposes.

2.6 COMMERCIALIZATION AND INFORMATION DIVISION

The Commercialization and Information Division promotes commercialisation of research and development activities of the Institute. The specific objectives that guide the Division's activities are:

- developing programmes and strategies for commercialization;
- providing requisite information and documentation on the Institute;
- providing specialized services in support of research and development;
- performing public relations functions; and
- organizing open days and internal seminars on research and development activities of the Institute.

2.6.1 Cartography Section

The Cartography Section provided hydrogeological maps and borehole profiles to support research and consultancy services during the year under review. Some old hydrogeological maps and graphs were also updated. Detailed layout of all existing structures at the Institute's premises and drawings for a proposed laboratory to be sited at the Institute were also prepared. A total of thirty-four (34) drawings were prepared for three (3) Divisions and the Estate Section as detailed in Table 25.

Table 25: Cartographic drawings prepared during the year 2011

Divisions	No. of drawings
Groundwater	22
Environmental Chemistry	4
Environmental Biology and Health	2
Estate (Section)	6

Coloured hydrogeological maps of Greater Accra, Volta, Eastern, Ashanti, Western and Central regions of Ghana for sale to groundwater consultants, institutions and individuals could be obtained from the drawing office of the Cartography Section.

2.6.2 Development of Research Library and Water Resources Documentation System

During the year under review, 226 books and some journals were added to the library stock. The library user visits stood at 2,345 and this was 22.96 % less compared to user visits in 2010. As part of FAO's Aquatic Sciences and Fisheries Abstract (ASFA) project, library input were sent to be incorporated into the ASFA database. The library's resources were computerized and binding of technical reports, books and newspaper publications were carried out. Current Awareness Services were also provided for both internal and external users.

2.6.3 Internal Seminars

Three seminars to provide fora for participants to discuss and also bring into the public domain current research activities of the Institute were organized during the reporting year. A total of six presentations on various research topics being addressed by the Institute were made (Table 26). Scientists from allied institutions and the media attended.

Table 26: Internal seminars during the year 2011

Month	Presenters/Speakers	Topics
March	Dr. William Agyekum	Application of geophysical borehole logging for hydrogeological studies in Northern Ghana
September	Mr. Francis A. Anani	Economic analysis on Tilapia Fingerling production using on-station and commercial feeds
	Dr. Joseph K. Ofori	The impact of microfinance on production parameters and economics of small scale Tilapia cage culture
November	Dr. Laurent Longuevergne, Université de Rennes 1, France	Estimation of water storage using GRACE satellite images
	Dr. Emmanuel Obuobie	Estimation of groundwater potential using modelling technique
	Mr. Collins Okrah	Groundwater exploration in the Middle Precambrian province of Upper Denkyira District using integrated geophysical techniques

2.6.4 Industrial Tour

An industrial tour was organized for students of Ola College of Education Mathematics and Science Club, Cape Coast, to expose them to some practical aspects of their syllabus during the year.

2.6.5 Exhibitions

Some of the major and current research activities and findings of the Institute were showcased during exhibitions organised during the year to bring to the public domain how the technologies could be accessed and commercialized. These included:

- Forum on Water, Sanitation and Environmental Security: Our Future through Science;
- Scientific Renaissance Day of Africa;
- AGRIFA 2011;
- 1st Ghana Science Congress;
- 22nd Annual General Meeting (AGM) of the CSIR Research Staff Association (RSA); and
- 27th National Farmers Day.

During such exhibitions, the Institute's stand was patronised by dignitaries, farmers, students and others from all walks of life (Figures 40 – 42). Some of these came for consultation and collaborative research work after the exhibitions.

A B

Figure 40: Dignitaries from the Central Regional House of Chief (A) and students (B) at WRI's stand during the 27th National Farmers Day at Agona Nsaba

Figure 41: Mr. Collins Okrah explaining how the 3-D LS Resistivity equipment operates to dignitaries at WRI stand during the 1st Ghana Science Congress exhibition

A

B

Figure 42: Some farmers during AGRIFA 2011 (A) and students from Abuakwa State College during the 22nd AGM of CSIR RSA (B) exhibitions at WRI's stand

2.7 CONSULTANCY AND OTHER SERVICES

2.7.1 Consultancy and Advisory Services

Consultancy and advisory services were carried out by the Institute for various donor agencies, corporate bodies, governmental and non-governmental organizations, universities and polytechnics, public and private sector institutions as well as individuals. The significant ones included:

- Geophysical survey at Nankese to drill additional boreholes to supplement the existing water supply source (Client: CSIR Mineral Water Co. Ltd.)
- Geophysical survey, analyses and interpretation of data to select suitable drilling locations to supply underground water to Berekum GWCL Headworks to serve Kato, Jendede and Adom communities (Client: GWCL/CWSA)
- Pumping test to determine the potential yield of an existing borehole at Kibi in the Eastern Region (Client: Private Individual)
- Drilling boreholes in residences to solve domestic water problems (Client: Private Individuals)
- Geophysical investigations using the Electromagnetic (EM) profiling and Vertical Electrical Sounding (VES) techniques to select sites to drill boreholes in eighteen (18) communities in the Agona West Municipal and eight (8) communities in the Agona East District of the Central Region (Client: CWSA)
- Reconnaissance Survey leading to geophysical investigations to select sites for borehole drilling at Atomic Hills Estate (Client: Presbyterian Church of Ghana)
- Assessment of groundwater potential using integrated geophysical method at Sapeiman and Medie, Ga West (Client: Pacific Coast Industry)
- Integrated geophysical investigation for borehole drilling at Assin Sibinso (Client: Rock Well Mineral Co. Ltd.)
- Geophysical investigations to delineate zones for drilling high-yielding boreholes as sources of potable water supply in six selected towns in the Northern Region of Ghana (Client: NORST)
- Geophysical investigations to delineate zones for drilling high-yielding boreholes as sources of potable water supply in some selected communities in the Awutu Senya District of Central Region (Client: CWSA)
- Geophysical investigations to delineate zones for drilling high-yielding boreholes as sources of potable water supply in some selected communities in the Mfantseman District of Central Region (Client: CWSA)
- Physico-chemical and bacteriological quality of water storage facility of the Awosu Stream (Client: Newmont Ghana Gold Ltd.)
- Leachate quality assessment at Sabah Landfill site in Accra West (Client: Zoomlion Ghana Ltd.)
- Advisory services on ways to improve the quality of bottled and sachet water (Clients: Bottled and Sachet Water Producers)
- Physico-chemical and microbial water quality assessment of a water storage facility to determine its suitability for discharge into the Subri River (Client: Newmont Ghana Gold Ltd)
- Hydrological survey to determine whether a 200 day, 200 l/s (0.20 m^3/s) release proposed by NGGL to enable it achieve 2 m free board at the spillway of its water storage facility was appropriate (Client: Newmont Ghana Gold Ltd)

- Physico-chemical and bacteriological analyses of raw and treated water for potable use (Client: Vicco Ventures Limited)
- Physico-chemical and bacteriological tests on potable and swimming pool waters (Client: Golden Tulip Hotel)
- Final effluent quality monitoring (Client: Golden Hotel Limited)
- Independent assessment of drinking water quality in Accra-Tema Metropolis (Client: Public Utilities Regulatory commission)
- Hydrogen Peroxide spillage at Assin Bireku: Assessment of impact on soil and water quality (Client: AngloGold Ashanti limited, Obuasi Mine)
- Community participatory programme – Water quality monitoring training workshop (Client: Newmont Ghana Gold Limited).
- Update on flood phenomenon in Ghana (Client: UNESCO Accra Cluster Office)
- Managing water as a shared responsibility across geographical and social boundaries by promoting IWRM in the cluster countries: The case of Tano and Keta basins (Client: UNESCO Accra Cluster Office)
- Assessment of innovative institutional arrangement and technical interventions in irrigated farming in northern Ghana (Client: IWMI)

2.7.2 Training Services

Through the Technical Divisions of the Institute, individual research and technical staff offered training in various forms to individuals, groups, non-governmental organizations and students of the Universities and Polytechnics. Among them were:

- External examination of M.Phil Environmental Science Program and M.Phil. African Regional Programme for Insect Science students from the University of Ghana, Legon
- Training of Mathematics and Science Club students of OLA College of Education
- Training of students of Business Management and Financial Institution
- Training of biotechnology students from the University for Development Studies (UDS) on basic microbiology and water quality analysis
- Supervision of Bachelor Degree student at the University for Development Studies (UDS), Department of Ecotourism and Environmental Management on a Project titled: The Effect of Storage on the Quality of sachet Water in the Tamale Metropolis.
- HND Laboratory technology students from Accra Polytechnic and students from the Environmental Science Programme and the Department of Botany, University of Ghana, were assisted with their various project works in the laboratory.
- Part-time teaching of undergraduate students at the Department of Botany, and post-graduate students of Environmental Science Programme and the Department of Botany, all of the University of Ghana.
- Water quality monitoring training workshop for representatives of five communities located within the catchment area of Newmont Ghana Gold Ltd (NGGL), Ahafo.
- External Examination of M.Phil. thesis from the University of Ghana, Legon, entitled "Household Choice of Water Sources in Jasikan District and Implication on the Health Status of Rural Communities".
- External Examination of M.Phil thesis from the University of Ghana, Legon, entitled "Assessment of Water Quality of Major Coastal Lagoons in Ghana"
- External Examination of Ph.D. thesis from the University of Ghana, Legon, entitled "Modelling Precipitation and Crop Water Use and Simulating Buffer Zones for Water Resources Management".

- Training of World Vision International on staff water quality.
- Training of students from the Department of Biotechnology, Faculty of Agriculture, University for Development Studies, on principles and techniques in phyto-remediation and bio-remediation.
- Training of students from Department of Ecotourism and Environmental Management on water quality analysis.
- Supervision of M.Phil. Environmental Science Programme, University of Ghana, Legon, student thesis entitled Assessing the Impact of Management Activities on the Densu River Basin – Ghana.
- Training of fish farmers in African Catfish propagation methods and general aquaculture
- Training of five students from the University of Cape Coast in aquaculture
- Part-time lectureship of students at the Graduate School of Nuclear and Allied Sciences (SNAS), University of Ghana
- Supervision of M.Phil. Students of the Graduate School of Nuclear and Allied Sciences (SNAS), University of Ghana

3.0 ADMINISTRATION

3.1 Management

The Institute was managed by an eight-member Management Board chaired by the Dean of the Faculty of Arts and Social Sciences, Central University College and an eighteen-member Internal Management Committee (IMC) chaired by the Acting Director. Membership of the Board and IMC are given in Appendices I and II, respectively.

3.2 Staff Strength

Staff strength at the end of the year 2011 stood at 240. This was made up of 57 senior members, 82 senior staff and 101 junior staff. Staff distribution and the list of senior members and senior staff are presented in Appendix III.

3.3 Statistics on Human Resource Activities

The number of appointments, promotions/upgrading, resignations, retirements, deaths, etc. in 2011 is shown in Table 27. The details are, however, shown in Appendix IV.

Table 27: Appointments, promotions/upgrading, retirements, deaths, etc. during the year 2011

	Activities	**Senior Members**	**Senior Staff**	**Junior Staff**	**Total**
1	Promotions/Upgrading	3	11	16	**30**
2	Retirements	1	5	1	**7**
3	Retirement (Voluntary)	1	-	-	**1**
4	Resignation	1	-	-	**1**
5	Vacation of Post	-	1	-	**1**
6	Temporary Appointment	10	10	7	**27**
7	Death(s)	1	0	1	**2**
8	New Appointments	1	-	-	**1**
9	Transfers	2	1	-	**3**
10	Leave-Without-Pay	1	-	-	**1**
11	Contract Appointment	1	-	-	**1**

3.4 Human Resources Development

To enable staff acquire the necessary skills and knowledge for the enhancement of their performance in the Institute, as at the end of 2011, thirty-two (32) members of staff were pursuing various programmes at various levels both locally and abroad. Nine (9) other members of staff who successfully completed their respective programmes during the year returned to post. The statistics are given in Table 28 and details presented in Appendix V.

Table 28: Statistics on Human Resources Development

No.	Programmes	No. of Staff pursuing programmes Abroad	No. of staff pursuing programmes Locally	No. of staff completing programmes in 2011	Total No. of staff pursuing programmes at various levels
1	**PhD**	1	3	0	**4**
2	**MSc/MBA/MPhil**	-	7	2	**5**
3	**Undergraduates/Univ. Diploma**	-	22	3	**19**
4	**HND/Non-tertiary diploma**	-	7	3	**4**
5	**Certificates**	-	1	1	**0**
	Total No.	**1**	**40**	**9**	**32**

Short-term training programmes attended by some staff of the Institute were:

- E-Sources training of trainers course, Accra, November 2011
- Training on food safety in Ghana: A situational analysis, Accra, December 2011
- Training on scientific report writing with Word and Excel, Kumasi, November 2011
- Short course on water quality assessment, UNESCO-IHE Institute for Water Education, Delft, The Netherlands, 7 – 25 February 2011
- Online training course on water evaluation and planning system (WEAP Model), Stockholm Environment Institute, USA, 1 – 2 November 2011.
- Postgraduate Course on water management: Decision making, environmental aspects and risk assessment, Rehovot-Israel, 22 October – 22 November 2011

3.5 Participation in Scientific Meetings

Some research and technical staff participated in a number of workshops, seminars and conferences held at the national, regional and international levels during the year. Among them were:

- ISARM International Workshop on Transboundary Aquifers of West and Central Africa, Douala, Cameroon, 16 – 19 May 2011.
- Workshop on Novoasoft software, Accra, 5 – 9 December 2011.
- Workshop on Knowledge Assessment on Climate Change and Peri-urban/Urban Agriculture in Sub-Saharan Africa: The Case of Tamale, UDS – Tamale, 21 May 2011.
- Workshop on African Adaptation Programme – Leadership for Results Programme, Ho, 12 – 17 June, 12 – 16 September and 21 – 25 November, all in 2011.
- 27th Biennial Conference: Promoting the development of agro-processing industries to enhance value addition for local and export market: The role of science and technology, Kumasi, 10 – 15 July 2011.
- 1st Ghana Science Congress: Water, sanitation and environment – securing our future through science, Accra, 2 – 5 August 2011.
- Northern regional celebration of World Environmental Day: Forest – nature at your service, Kusowgu, Tamale, 18 October 2011.
- Integrated Management of Aquatic Weeds Project, Sogakope, 13 – 14 December 2011.
- Integrated management of invasive aquatic weeds project, Sogakope, 1 – 3 November 2011.
- Rainwater harvesting scheme validation workshop, Accra, 15 December 2011.
- 1st Pan African Chemistry Network (PACN) congress on agricultural productivity, Accra, 21 – 23 November 2011.

- AuthorAid post PACN congress workshop on research writing, Accra, 24 – 25 November 2011.
- The right to water and sanitation in Ghana: A national action plan for implementation, Accra, 28 July 2011.
- Meeting to explore institutional links with Aberdeen University researchers, Accra, 23 August 2011.
- National Atlas Committee meeting, ODINAFRICA Project, Marine Fisheries Research Unit, Tema, 3 March 2011.
- Sub-regional workshop on mariculture development and environmental sustainability, Accra, 23 – 25 February 2011.
- Advanced corporate governance workshop, Akosombo, 23 – 24 September 2011.
- Workshop on understanding the roles and responsibilities of stakeholders for environmental health and sanitation under the Ghana WASH sector AWAP, Accra, 22 – 23 June 2011.
- Workshop on final draft policy on the environment, Accra, 9 – 12 November 2011.
- Government of Ghana Annual Review of the natural resource and environment sector, Elmina, 27 July – 1 August 2011
- Open Forum on Agricultural Biotechnology in Africa (OFAB) - Ghana Chapter Monthly Session Meeting, Accra, 27 October 2011.
- National oil spill contingency plan simulation exercise workshop, Accra, 3 – 5 May 2011.
- Technical report/scientific writing for agriculturalists and environmental scientists workshop, Kumasi, 28 – 30 November 2011.
- Workshop on strengthening environmental governance of the Oil and Gas Sector in Ghana, Accra, 1 – 2 February 2011.
- Workshop on development of Intellectual Property Right Policy for Council for Scientific and Industrial Research, Accra, 24 – 25 March 2011.
- Workshop on agriculture policies in Ghana, Kumasi, 8 – 9 August 2011.
- Africa adaptation programme on climate change workshop on leadership for results programme, Ho, 13 – 17 June, 12 – 17 September and 21 – 25 November, all in 2011.
- International conference on sustainable development of natural resources in Africa, Accra, 5 – 7 December 2011.
- Stakeholders workshop on review of hazardous waste regulations, Accra, 19 December 2011.
- 3rd Ghana Water Forum (GWF), Accra, 5 – 7 September 2011
- Climate change and peri-urban/urban agriculture in Sub-Saharan Africa: The case of Tamale, Tamale, 7 June 2011
- 3rd International Forum on Water and Food, Tswane – South Africa, 14 – 17 November 2011
- Workshop on Agricultural Policies in Ghana, Kumasi, 8 – 9 August 2011
- TIGER workshop, ESA/ITC/TIGER II, Muldersdrift - South Africa, 12 – 13 December 2011
- International workshop on "Sawah" eco-technology and rice farming (SERIF) in Ghana, Nigeria and Sub-Saharan Africa, *AfricaRice*/JIRCAS/JICA/MOFA/CSIR SRI, Kumasi, 22 – 24 November 2011
- Thirty-Sixth (36th) Biennial Conference of UNESCO, Ghana National Commission for UNESCO, Paris, 1 – 4 November 2011

- Dryland systems regional planning working meeting, ICARDA, Nairobi, 27 – 30 June 2011
- Regional stakeholders review of large water infrastructures, ECOWAS Water Resources Co-ordinating Centre (WRCC)/Volta Basin Authority (VBA)/International Union for Conservation of Nature (IUCN), Ouagadougou, February, 2011
- Africa geospatial forum, Nairobi, 6 – 8 September 2011
- GEF African Regional Workshop on technology needs assessment (TNA) for climate change adaptation, Navaisha-Kenya, 28 – 30 June 2011
- Workshop on using WEAP as decision support tool for water resources management and climate change adaptation, Madrid, Spain, 12 – 15 April 2011
- Workshop on climate observations and regional modelling in support of climate risk management and sustainable development, Nairobi, 21 – 26 February 2011 and Arusha, 28 February – 4 March 2011
- Workshop on provision of climate products and services for long-term adaptation planning for Western, Central and Northern African countries, Accra, 22 – 31 August 2011
- Workshop on acquiring, processing and analyzing data from GRACE satellite for use in hydrological modeling, Accra, 31 October – 4 November 2011
- Roundtable discussion on irrigation development as a way of modernizing agriculture in Ghana, Accra, 28 March 2011
- Workshop on Network of African Science Academies (NASAC) water programme in West Africa, Dakar, 18 – 19 July 2011
- Ghana-India groundwater exchange meeting, Accra, 31 October – 3 November 2011
- Training on the water evaluation and planning (WEAP) tool for water resources planning in the Volta Basin, Accra, 21 – 23 November 2011
- Workshop on technical report writing for agriculturalist and environmental scientists, Kumasi, 28 – 30 November 2011
- Seminar on water storage for climate change adaptation, Accra, 2 September 2011
- Synthesis workshop of climate change adaptation project in the three northern regions, Accra, 3 August 2011
- Workshop on the use of ScienceWord and Pagemaker, Accra, 5 – 9 December 2011
- Learning alliance on life-cycle cost approach to WASH service delivery in Ghana, Accra, 27 January 2011
- Learning alliance on scaling-up sanitation and hygiene: A case of community-led total sanitation (CLTS), Accra, 4 March 2011
- Policy dialogue on innovations for climate change adaptation, Accra, 28 March 2011
- Seminar on climate change and food security: how prepared is Ghana?, Accra. 28 June 2011

3.6 Membership of Committees and Boards

Staff served on various committees and boards such as:

- CSIR-WRI Estate Committee
- CSIR-WRI Internal Management Committee
- CSIR-WRI Procurement/Tender Committee
- Darwin Initiative – Ghana
- GCLME Project Steering Committee-Ghana
- Ghana Chemical Society
- Ghana Institute of Biology

- Ghana-Iran Joint Commission for Co-operation and Development, Ministry of Foreign Affairs, Accra
- Ghana National Committee for International Hydrological Programme (IHP), UNESCO/CSIR-WRI, Accra
- Ghana Science Association
- Ghana Technology Needs Assessment for Climate Change Adaptation Committee
- Governing Board, Ghana Meteorological Agency, Accra
- Governing Board, Irrigation Development Authority, Accra
- Governing Commissioners, Water Resources Commission, Accra
- Human Resources Committee, Ghana Meteorological Agency, Accra
- Inter-Ministerial Committee, Ghana-Iran 3rd Joint Commission for Co-operation and Development, Ministry of Education and Sports/Ministry of Foreign Affairs, Accra
- Local Organising Committee of the 1st Pan African Chemistry Network Congress on Agricultural Productivity
- Mineral Water Production Committee, CSIR Water Research Institute
- National Atlas Team of ODINAFRICA IV Project of the Fisheries Commission
- National Filariasis Taskforce of the Ministry of Health (MoH)
- National Malaria Taskforec of the Ministry of Health (MoH)
- Northern Regional Environmental Impact Assessment (EIA) Technical Review Committee of EPA
- Northern Regional Environmental Management Committee
- Pra Basin Board, Kumasi
- SAGA-EO Network, Ghana Meteorological Agency, Accra
- Situational Analysis and Needs Assessment (SANA) committee of the EPA/MoH
- Specialised Committee for Natural Sciences, Ghana National Commission for UNESCO (Ministry of Education), Accra
- Steering Committee of Technical Co-operation Africa Project RAF/7/008-9002
- Technical Committee, Ghana Meteorological Agency, Accra.
- Technical/Engineering Committee, Ghana Irrigation Development Authority, Accra

3.7 National Service and Industrial Attachment

The Institute supported tertiary institutions towards training of students as part of its capacity building activities. The duration of the training programmes was between four (4) weeks and twelve (12) weeks. A summary is given in Table 29 and the details presented in Appendix VI.

Table 29 Summary on national service/industrial attachment during 2011

National Service	No.	Industrial Attachment	No.
University of Cape Coast	12	University of Cape Coast	5
University of Development Studies	4	University of Ghana	5
Kwame Nkrumah Univ. of Science and Tech.	3	University of Development Studies	1
University of Ghana	2	Kwame Nkrumah Univ. of Science and Tech.	7
Accra Polytechnic	2	Methodist University	2
Bolgatanga Polytechnic	1	University Of Mines and Technology	1
Kumasi polytechnic	1	Central University College	2
		Regent University College	1
		Institute of Professional Studies	1
		Ho Polytechnic	1
		Young Women Christian Association	1
		Government Secretariat	1
Total	**25**	**Total**	**28**

3.8 Staff Publications

Several technical and non-technical reports, conference and journal papers were produced by staff during the reporting year. Most of the technical papers and thesis have been shelved at the Institute's library as reference material. The details are given in Appendix VII.

4.0 FINANCE

A total amount of GH¢4,398,813.09 was received for the year 2011. Out of this amount, 81.38 % represented government subvention, 12.98 % represented internally-generated funds and 5.64 % represented donor assistance to the Institute.

4.1 Recurrent and Development Budget in 2011

Receipt for recurrent and development expenditure was GH¢3,579,555.40 based on an approved budget of GH¢3,536,577.00. This constituted 81.38 % of total receipt for the year. The details are given in Table 30.

Table 30: Receipts and Expenditure of Government Funds in 2011

		2010 Budget (GH¢)	
	Type of Expenditure	**Approved**	**Released**
1.	Personnel Emoluments	3,316,895.00	3,359,873.44
2.	Administrative Activities	219,682.00	219,681.96
	Total	**3,536,577.00**	**3,579,555.40**

4.2 Internally-Generated Funds (IGF) in 2011

An amount of GH¢571,098.34 was generated from consultancy services out of which an expenditure of GH¢439,117.66 was made. The IGF constituted 12.98 % of total receipts for the year.

4.3 Donor Assistance in 2011

Receipt for donor assistance was GH¢248,159.35 during the year. However, an expenditure of GH¢260,274.60 was made. Donor assistance receipts represented 5.64 % of total receipts for the year.

APPENDICES

APPENDIX I - Membership of the Management Board

1.	Prof. C. Dorm-Adzobu Chairman	-	Dean, Faculty of Arts and Social Sciences, Central University College
2.	Dr. R.E.M. Entsua-Mensah (Mrs) Member	-	Deputy Director-General, CSIR Research and Development
3.	Mr. Christopher Manu Member	-	Technical Co-ordinator, Friends of the Earth - Ghana
4.	Mr. Edward O. Nsenkyire Member	-	Director, West Africa Fish Limited
5.	Mr. R.K.D. Van-Ess Member	-	Director, Community Water and Sanitation Agency
6.	Mr. Eugene Atiemo Member (Cognate Director)	-	Director, Building and Road Research Institute
7.	Dr. Philip Gyau-Boakye Member	-	Ag. Director, CSIR Water Research Institute
8.	Margaret Azara Sedziafa (Mrs) Secretary	-	Head of Admin., CSIR Water Research Institute

APPENDIX II - Membership of the Internal Management Committee

1.	Dr. Philip Gyau-Boakye	-	Acting Director (Chairman)
2.	Dr. K. Kankam-Yeboah	-	Head, Surface Water Division
3.	Dr. W. A. Agyekum	-	Head, Groundwater Division
4.	Dr. Joseph A. Ampofo	-	Head, Environmental Biology and Health Division
5.	Dr. Osmond D. Ansa-Asare	-	Head, Environmental Chemistry Division
6.	Dr. J. K. Ofori	-	Head, Fishery Division
7.	Marian A. Jiagge (Mrs.)	-	Head, Commercialization and Information Division
8.	M. Azara Sedziafa (Mrs.)	-	Head, Administration Division
9.	Mr. Paul Fabalona	-	Head, Finance Division
10.	Dr. Felix Y. Attipoe	-	Officer-In-Charge, ARDEC
11.	Dr. K. Kwafo-Apegya	-	Officer-In-Charge, WRI Tamale
12.	Mr. Johnson C. K. Eworde	-	Acting Head, Personnel Section
13.	Mr. Simon Anane	-	Acting Head, Estate Section
14.	Mr. Samuel Teivi	-	Head, Transport Section
15.	Mr. Rex Sapah	-	Head, Cartographic Drawing Section
16.	Ex. WO David S. N. Kotei	-	Acting Head, Security Section
17.	Mr. Anthony Karikari	-	Representative, Research Staff Association (RSA)
18.	Mr. James Owusu	-	Representative, Senior Staff Association (SSA)
19.	Mr. Francis A. Boakye	-	Representative, TUC (Local Union)

APPENDIX III - Staff Distribution among the Divisions and Sections

Division/Section	**Senior Members**	**Senior Staff**	**Junior Staff**	**Total**
Directorate	1	-	-	**1**
Surface Water	7	3	-	**10**
Groundwater	5	3	2	**10**
Environmental Chemistry	9	10	1	**20**
Environmental Biology and Health	10	6	1	**17**
Fishery Division	8	5	6	**19**
Commercialization and Information Division				
• *Scientific Secretariat Section*	3	1	-	**4**
• *Library Section*	2	1	-	**3**
• *Printing Section*	-	1	1	**2**
• *Cartographic Section*	-	3	-	**3**
• *Computer Section*	-	1	1	**2**
Finance Division	1	13	3	**17**
Administration Division				
• *Personnel Section*	1	11	10	**22**
• *Transport/Mech. Workshop Section*	-	12	14	**26**
• *Estate Section*	-	1	28	**29**
• *Security Section*	-	1	27	**28**
Temporary Staff	9	10	7	**26**
Contract Appointment	1	-	-	**1**
Total	**57**	**82**	**101**	**240**

List of Senior Members

Name	Designation	Qualification
Philip Gyau-Boakye	Principal Research Scientist, Acting Director	B.Sc. (Hons) Civil Eng. (UST) M.Sc. Water & Waste Eng. (L'borough) Ph.D. Hydrology (Bochum, Germany)
Benony K. Kortatsi	Principal Research Scientist	B.Sc. (Hons) Physics/Maths, (Legon) M.Sc. Hydrogeol. (Univ. of B'ham) Ph.D Geology (Univ. of Ghana)
Osmund D. Ansa-Asare	Principal Research Scientist	B.Sc. (Hons) Chem.Dip.Ed. (UCC) P.G. Dip. Water Quality Mgt. (Delft, The Netherlands) PhD. Env. Chem. (Aberdeen)
Joseph A. Ampofo	Principal Research Scientist	B.Sc. (Hons) Botany & Dip. Ed. (UCC) MPhil. Botany (Legon) Ph.D Botany(Bacteriology) (Legon)
Kwabena Kankam-Yeboah	Principal Research Scientist	BSc. Agric. & Dip. Ed. (UCC) MSc. Tropical Agric. (KULeuven, Belgium) MSc. Irrig. Eng. (KULeuven, Belgium) PhD. Earth Science & Env. Eng. (Okaya., Japan)
Alex A. Opoku	Senior Research Scientist	BSc. (Hons) Biology (UST) Dip. Env. Mgt. (TU Dresden) Dip. Insect Taxomology (Cardiff) PhD Applied Entomology (Cardiff)
Joseph K. Ofori	Senior Research Scientist	BSc. (Hons) Biology (UST) MTech. Aquaculture (Port Harcourt) PhD Biol. Sciences (UST)
Sampson A. Akrasi	Senior Research Scientist	B.Sc. (Hons) Maths/Stats (Legon) MSc. Soil Conservation & Land Reclamation Eng. (Southampton)
Frederick K. Amu-Mensah	Senior Research Scientist	BSc. Agric Eng. (UST) MSc. Soil & Water Eng. (Wageningen) PhD. Bioenv. Science (Tottori, Japan)
Isaac O.A. Hodgson	Senior Research Scientist	B.Sc. (Hons) Chem.Eng. (UST), MSc. Chem. Eng. (UBC, Canada) PhD Chem. Eng. (LU, UK)
Hederick .R. Dankwa	Senior Research Scientist	BSc. (Hons) Zool./Bot. (Legon) MSc. Marine Ecol. (Brussels) Dip. Fish Mgt. (Bergen, Norway) PhD Fish Biol./Aquac. (UCC)
Barnabas A. Amisigo	Senior Research Scientist	BSc.(Hons) Agricultural Eng. (UST) MSc. Water Res. Eng. (Guelph) PhD. Hydrology/Water Res. Eng. (Delft, The Netherlands)
Collins Tay	Senior Research Scientist	B.Sc. Chem. KNUST M.Sc. Env. Res. Mgt. KNUST
Anthony Y. Karikari	Senior Research Scientist	B.Sc. (Hons) UST MSc. Chem. (Univ. of Ryukyus, Japan)

Name	**Designation**	**Qualification**
Kwadwo A. Asante	Senior Research Scientist	B.Sc. (Hons) Chem.(UST) Cert. Protection & Utilization Of Oceans (Hamburg) MSc. Env. Chem. and Exotoxicology (Ehime Univ., Japan)
Mike Osei-Atweneboana	Senior Research Scientist	BSc. Biological Scien/Nursing (Legon) MPhil Zoology (Legon) Ph.D Medical Parasitology and Molecular Epidemiology (McGill, Canada)
Margaret A. Sedziafa	Senior Administrative Officer	BA (Hons) English & Hist.Dip.Ed. (UCC) Graduate Dip. in Library Std. (Legon) MBA Human Resource Mgt. (Legon)
Emmanuel O. Bekoe	Research Scientist	BSc. Agric. Eng. (UST) MSc. Soil & Water Eng. (Wageningen, Neth.) PhD. Water & Environment (Cranfield, UK)
Fredrick Yaw Logah	Research Scientist	BSc. Agric. Eng. (KNUST) MSc. Water Res. Eng. (KULeuven, Belgium)
Emmanuel Obuobie	Research Scientist	BSc. Agric Eng. (UST) MSc. Soil & Water Eng. (Wageningen, Neth.) PhD. Natural Science (Univ. Bonn, Germany)
William A. Agyekum	Research Scientist	B.Sc. Geol. Eng. (UST) M.Eng. (IHE, Delft, The Netherlands) P.G. Dip.-Groundwater Exploration (Rehovot, Israel) PhD Geology (Univ. of Gh.)
Anthony A. Duah	Research Scientist	B.Sc. (Hons) Geol. Eng (UST) M.Sc.Hydrogeology & Remote Sensing (ITC) P.G. Dip.-Groundwater Exploration (Rehovot, Israel)
Patrick A. Mainoo	Research Scientist	BSc Physics (KNUST) MSc Physics (KNUST)
Collins Okrah	Research Scientist	BSc (Physics) & Dip. Ed. (UCC) MSc Geophysics (KNUST)
Asmah Ruby (Mrs)	Research Scientist	B.Sc. (Hons) Chem. (UST) M.Sc. Ecol. Marine Mgt. (Brussels, Bel.) Ph.D Aquaculture (Stirling, UK)
Joyce Amoako (Mrs.)	Research Scientist	BSc Chem. (UST) MSc Env. Sanitation (Belgium)
Humphrey F. Darko	Research Scientist	B.Sc. Chem. (UCC) MSc Ecological Marine Mgt. (Brussels, Bel.)
Samuel Obiri	Research Scientist	BED Chemistry/Integrated Science (UEW) MPhil Inorganic/Analytical Chemistry (UCC)
Gloria D. Addico	Research Scientist	BSc. (Hons) Nat. Res. Mgt. (UST) M.Phil. Biological Sciences (UST) Ph.D Biological Sciences (Univ. Hull, UK)

Name	**Designation**	**Qualification**
Ebenezer D. O. Ansa	Research Scientist	BSc. Zoology (Legon) M.Phil. Parasitology (Legon)
Felix Akpabey	Research Scientist	BSc Zoology/Botany (UCC) MSc Entomology (UG)
George T. Mensah	Research Scientist	BSc. (Hons) Biol. Sciences (KNUST) MPhil Zoology (Legon) P.G. Dip. In Education (UCC)
Victoria Afutu-Vanderpuye	Research Scientist	B.Sc. (Hons) Zoology/Bot. (Legon). M.Sc. Med. Ento. (Pondcherry)
Regina Banu (Mrs)	Research Scientist	BSc Botany (Legon) MPhil Botany (Legon)
Samuel Armoo	Research Scientist	BSc. Zoology (Legon) MPhil. Public Health (Legon)
Joseph N. Padi	Research Scientist	BSc. (Hons) Zool./Bot (Legon) MSc. Aquaculture (Auburn) PhD Aquaculture (Auburn)
Felix Y. K. Attipoe	Research Scientist	BSc. (Hons) Zool/Bot. (Legon) MSc. Aquaculture (Stirling, UK) Ph.D Zoology (UCC)
Francis Y. K. Amevenku	Research Scientist	BSc. (Hons) Nat. Res. Mgt. (UST) MPhil. Agric. Economics (UG, Legon)
Theodore Quarcoopome	Research Scientist	BSc. (Hons) Nat. Res. Mgt. (UST) MPhil Biological Sciences (UST)
Seth K. Agyakwah	Research Scientist	BSc. (Hons) Biological Sci. (UST) MPhil Fisheries Science (UG) PhD Fisheries Science (UG)
Francis Assogba Anani	Research Scientist	BSc Zoology(UG, Legon) MPhil Fishery Science (UG, Legon)
Marian A. Jiagge (Mrs.)	Librarian	BLS. (A.B.U Zaria, Nigeria) MLS (UG, Legon)
Marian Amu-Mensah (Mrs.)	Research Scientist	BSc. Art (UST) MPhil Sociology (UG)
Benson Kwabena Owusu	Scientific Secretary	BEd. Science (UCC) MPhil. Env. Science (UG)

Name	Designation	Qualification
Paul Fabalona	Accountant	BSc. Accounting (IPS) Chartered Accountant (ICA-Gh.)
Thomas K.F. Adom	Asst. Marketing Officer	B.A. Dip. Educ. (UCC) CIM(UK)-Advanced Cert.
Georgina Badu (Mrs)	Assistant Librarian	Dip. Library & Info.Sci. (Legon) BA – Information Studies & Religions (UG)

List of Senior Staff

Name	Designation	Qualification
Patience Atsakpo (Mrs)	Principal Technologist	Higher Dip.Microbio. Lab. Techq. (UG)
Wilhemina Tetteh	Senior Technologist	Higher Dip.Microbio. Lab. Techq. (UG)
Kenneth N. Atsakpo	Senior Technologist	H.Dip. Analytical Chem. Lab. Techq. (UG)
Grace Dartey (Ms)	Senior Technologist	Higher Dip.Microbio. Lab. Techq. (UG)
Michael Dorleku	Senior Technologist	BSc. Laboratory Technology (UCC)
Nana Y. Biritwum	Chief Stores Superintendent	Cert. Storekeeping (IPS)
Samuel Baah	Chief Technical Officer	TO Cert. Hydrology (Kenya)
Rex John Sapah	Chief Draughtsman	Snr. Sup. Cert. Civil-Building/Roads (ITS-Weija)
James Owusu	Chief Technical Officer	Cert. Gen. Drilling Theory/Practice (UMaT)
Mohammed M. Bello	Chief Technical Officer	HND. Science Lab. Tech. (Accra Poly)
Godwin N. Dohertso	Chief Accounting Asst.	BSc. Accounting (IPS) MBA Finance (UG, Legon)
Kwame Osei-Mensah	Chief Accounting Asst	Bachelor of Accounting (GIMPA)
Charles K. Dzokoto	Chief Accounting Asst	HND Accounting (Tamale Poly)
Johnson C. K. Eworde	Chief Admin. Asst.	GCE ‘O’ Level
William E. Arko	Principal Technical Officer	BSc. Chemistry (UCC)
Martha D. Agyemang	Principal Technical Officer	BSc. Chemistry (KNUST)

Name	**Designation**	**Qualification**
Zita Naangmenyele	Principal Technical Officer	BSc. Applied Chemistry (UDS)
Salifu Abdul-Latif	Prin. Technical Officer	HND Ind. Chemistry (Inst. Of Chem.-Cuba)
H. Komladzei	Principal Draughtsman	Snr. Sup. Cert. Civil-Building/Roads (ITS-Weija)
S. Siaw-Krodua	Principal Draughtsman	Snr. Sup. Cert. Civil-Building/Roads (ITS-Weija)
Collins K. Asante-Sasu	Principal Technical Officer	BSc. Agric. Eng. (KNUST)
Sena Niampomah	Principal Technical Officer	GCE "A" Level
Lady A. Frimpong	Principal Technical Officer	BSc. Botany (UG)
Ruth Amole (Mrs)	Prin. Technical Officer	Dip. Nat. Res. Mgt. (KNUST)
Edward Jenner Tettevi	Prin. Technical Officer	BSc. Molecular Bio. & Biotech. (UCC)
Lilly K. Osei	Principal Technical Officer	BSc. Biological Science (KNUST)
E.K. Amerdome	Technologist	Higher Dip. Microbiol. Techniques (UG)
Sylvia Amponsah	Principal Technical Officer	BA. Political Science (India)
J. H. Baffoe	Principal Accounting Asst.	RSA Stage III Accounting
Joshua Osuteye	Principal Stores Supt.	City & Guilds Adv. Accounting
Claudia Bentum (Mrs)	Principal Admin. Asst.	BSc. Public Admin. (GIMPA)
Joyce Osibo	Principal Admin. Asst. (Sect.)	Cert. Private Secretary
Samuel Q. Teivi	Principal Works Supt. (Auto)	Cert. (Jnr) Mech/Elect. Wrkshp. (ITS-Weija)
Godfried P. K. Acquaah-Arhin	Senior Admin. Asst.	BBA Management (VVU)
Benedicta Awisi	Senior Admin. Asst.	BSc Human Res. Mgt. (Pent.Univ. Col.)
Rebecca Yankson	Senior Admin. Asst (Sect.)	RSA Stage III Secretaryship
Vivan Osae	Senior Admin. Asst (Sect.)	HND Secretaryship & Mgt. (Accra Poly)
Emmanuel Adu-Ofori	Asst. Technologist	H.Dip. Analytical Chem. Lab. Techq. (IST)
Michael Dankwa Afram	Senior Technical Officer	HND. Science Lab. Tech. (Accra Poly)

Name	**Designation**	**Qualification**
Emmauel A. Ayizemi	Senior Technical Officer	Cert. Gen. Drilling Theory/Practice (UMaT)
Francis Annor Boakye	Senior Technical Officer (Computer)	City & Guilds. Infor. Technology
Alexander A. Dei	Senior Accounting Asst.	RSA Stage III Accounting
E. Nii. Dodoo Koranteng	Senior Accounting Asst.	DBS Accounting (Accra Poly)
John A. Akuoko-Baafi	Senior Accounting Assistant	Cert. Procurement & Material Mgt. (GIMPA)
Esther Mate-Ahmed (Mrs)	Senior Accounting Assistant	DBS Accounting (Accra Poly)
Robert Azongo	Snr. Works Supt. (Machine)	Cert. (Jnr) Civil-Building/Roads(ITS-Weija)
Kenneth K. Opare	Snr. Works Supt. (Auto)	Cert. (Jnr) Mech/Elect. Wrkshp. (ITS-Weija)
Gabriel Appiah	Technical Officer	HND. Civil Eng. (Cape Coast Poly)
Eric Yaw Darko	Technical Officer	HND. Civil Eng. (Takoradi Poly)
Martin A. Adakpeya	Technical Officer	Cert. Gen. Agric. (Damango Agric. College)
Eric J. Darko	Technical Officer	Cert. Gen. Agric. (Damango. Agric. College)
Agnes Darko	Admin. Asst. (Sect)	Dip. Management Studies (UCC)
Priscilla Ampofo-Yeboah (Mrs)	Admin. Asst. (Sect)	HND Secretaryship & Mgt. (Accra Poly)
Dorothy Krodua (Mrs)	Admin. Asst. (Sect)	ABCD Stage III Secretaryship
Bernice Essegbey (Mrs)	Technical Officer	ABCE. Catering (Accra Poly)
Murjanatu Abdul-Hamid	Technical Officer	HND. Science Lab. Tech. (Accra Poly)
Genevieve G. Kwogana	Admin. Asst. (Sect)	DBS Secretaryship & Mgt. (Tamale Poly)
Richard Kwapong Kwayisi	Assistant Printer	Cert. Printing (ITS-Weija)
Alex Yeboah	Accounting Asst.	HND Accounting (Accra Poly)
Doris Ohene-Lartey (Mrs)	Accounting Asst.	ABCD Stage III Accounting
Mark Boateng Ofori	Stores Superintendent	HND Purchasing & supply
Samuel O. Agyei	Asst. Transport Officer	Cert. of Att. Defensive Driving (STC-Accra)

Name	**Designation**	**Qualification**
John K. Kpamah	Asst. Transport Officer	Cert. of Att. Transport Mgt. (STC-Accra)
Alex A. Yeboah	Asst. Transport Officer	Cert. of Att. Transport Mgt. (STC-Accra)
Samuel Annang	Asst. Transport Officer	Cert. of Att. Transport Mgt. (STC-Accra)
Edem K. Ayegbe	Asst. Transport Officer	Cert. of Att. Transport Mgt. (STC-Accra)
Matthew Kwara	Asst. Transport Officer	Cert. of Att. Transport Mgt. (STC-Accra)
Samuel K. Nikoi	Asst. Transport Officer	Cert. of Att. Transport Mgt. (STC-Accra)
Benjamin K. Kodjo	Works Superintendent	Cert. Wielding Technician
Samuel K. Osafo	Works Superintendent	Cert. (Jnr) Mech/Elect. Wrkshp. (ITS-Weija)
Ex. WO1 Samuel D.N. Kotei	Security Officer	MSLC
Anthony Arko	Security Officer	MSLC
Simon K. Anane	Estate Assistant	Full Tech. Cert., Const. Tech. (Accra Poly)

APPENDIX IV: Human Resource Activities

New Appointment

No.	Name	Designation	Category of Staff	Division/Section	Date of Appointment
1	Dr. Philip Gyau-Boakye	Acting Deputy Director	Senior Member	Directorate	01/03/11

Temporary Appointment

No.	Name	Designation	Category of Staff	Division/Section	Date of Appointment
1	Evans Osei	Technical Assistant Gd. I	Junior Staff	CID-Computer	01/10/10
2	Lawrence Yawson	Senior Technical Assistant	Junior Staff	Env. Chemistry	01/11/10
3	Michael Kumi	Research Scientist	Senior Member	Evn. Chemistry	17/11/10
4	Deborah Ofori	Research Scientist	Senior Member	Surface Water	01/01/11
5	Millicent Adu-Boakye	Principal Tech. Officer	Senior Staff	Env. Biology & Health	01/02/11
6	Ayishetu Wortey	Tel./Receptionist GdI	Junior Staff	Administration	01/02/11
7	Linda Akosua Nuamah	Principal Tech. Officer	Senior Staff	Env. Biology & Health	01/04/11
8	Mark Osa Akrong	Research Scientist	Senior Member	Env. Biology & Health	11/04/11
9	Christopher Yom Nfojoh	Principal Tech. Officer	Senior Staff	Env. Chemistry	18/04/11
10	Jude Ofei Quansah	Principal Tech. Officer	Senior Staff	Env. Chemistry	18/04/11
11	Hawa Ahmed	Principal Tech. Officer	Senior Staff	Env. Biology & Health	01/05/11
12	Etornyo Agbeko	Research Scientist	Senior Member	Fishery	01/07/11
13	Ex. WO1 Samuel D.N. Kotei	Security Officer	Senior Staff	Security	04/07/11
14	Samuel Kanati	Administrative Assistant	Senior Staff	Administration	04/07/11
15	Kassim Buah Seidu	Security Assistant Gd.I	Junior Staff	Security	14/07/11
16	Emmanuel Tetteh-Doku Mensah	Research Scientist	Senior Member	Fishery	01/08/11
17	Mercy Johnson-Ashun	Principal Tech. Officer	Senior Staff	Fishery	01/08/11
18	Simon K. Kaledzi	Junior Library Assistant	Junior Staff	CID-Library	01/08/11
19	Daniel Nsoh Akongyuure	Research Scientist	Senior Member	Fishery	01/09/11
20	Michael Carl Ofori-Agyeman	Research Scientist	Senior Member	Groundwater	01/09/11
21	Lucy Adu	Typist Gd.I	Junior Staff	Administration	01/09/11
22	Esther Anyele Sowah	Technical Officer	Senior Staff	Env. Chemistry	05/09/11

No.	Name	Designation	Category of Staff	Division/Section	Date of Appointment
23	Samuel Owiredu	Driver Gd. II	Junior Staff	Transport/workshop	10/10/11
24	Solomon Amoah Owiredu	Research Scientist	Senior Member	Fishery	01/12/11
25	Emmanuel Sackey	Research Scientist	Senior Member	Surface Water	01/12/11
26	Frank Oblim Teye	Technical Officer	Senior Staff	Surface Water	01/12/11

Promotions

Senior Members

No.	Name	Division	From	To	Date of Promotion
1	Marian Amu-Mensah (Mrs.)	Comm. & Infor.	Asst. Scientific Secretary	Research Scientist	31/12/07
2	Dr. Kwabena Kankam-Yeboah	Surface Water	Senior Research Scientist	Prin. Research Scientist	01/07/09
3	Kwadwo A. Asante	Env. Chemistry	Research Scientist	Senior Research Scientist	01/07/09

Senior Staff

No.	Name	Division	From	To	Date of Promotion
1	Emmanuel A. Ayizemi	Groundwater	Technical Officer	Senior Tech. Officer	01/01/08
2	Joyceline J. Osibo	Administration	Senior Admin. Assistant	Principal Admin. Asst.	01/01/10
3	Dorothy Krodua (Mrs)	Administration	Senior Clerk (Sect)	Administrative Assistant	01/01/10
4	Micheal A. Danquah	Env. Chemistry	Technical Officer	Senior Tech. Officer	01/01/11
5	Rebecca Yankson (Mrs)	Administration	Administrative Assistant	Senior Admin Assistant	01/01/11
6	Mohammed Bello	Env. Biol.& Health	Principal Tech. Officer	Chief Technical Officer	01/01/11
7	Ruth A. A Amole (Mrs)	Env. Biol.& Health	Technical Officer	Principal Tech. Officer	01/01/11
8	Alex Yeboah	Finance	Senior Accts Clerk	Accounting Assistant	01/01/11
9	Doris Ohene- Lartey (Mrs)	Finance	Senior Accts Clerk	Accounting Assistant	01/01/11
10	Genevieve G. Kwogana	Administration	Senior Clerk (Sect)	Administrative Assistant	01/01/11
11	Vivian Anane (Mrs)	Administration	Administrative Assistant	Senior Admin Assistant	01/01/11

Upgrading

Junior Staff

No.	Name	Division/Section	From	To	Date of Promotion
1	Samuel Abbey	Estate	Supervisor Gd.II	Supervisor Gd.I	01/01/08
2	Joseph K. Danso	Transport/Workshop	Driver Inspector	Traffic Supervisor	01/01/09
3	John K. Mensah	Finance	Accounts Clerk Gd.I	Senior Accounts Clerk	01/01/09
4	Cephas Dzah	Security	Security Man	Security Asst. Gd.II	01/01/09
5	Kofi B. Asante	Estate	Supervisor Gd.II	Supervisor Gd.I	01/01/09
6	Sandow Anyorka	Security	Supervising Watchman	Supervisor Gd.II	01/01/10
7	Daniel K. Amoah	Env. Chemistry	Technical Asst. Gd.I	Senior Technical Asst.	01/01/11
8	Emmanuel O. Ayim	Security	Security Asst. Gd.II	Security Asst. Gd.I	01/01/11
9	Mahama S. Forko	Estate	Artisan	Junior Foreman	01/01/11
10	Michael Arthur	Transport/Workshop	Driver Gd.I	Driver Inspector	01/01/11
11	Jonas Darkey	Estate	Cleaner	Headman (Ordinary)	01/01/11
12	Stephen Kwabena Agyeman	Estate	Headman (Ordinary)	Senior Headman	01/01/11
13	Mahamudu T.Alhassan	Security	Supervisor Gd.II	Supervisor Gd.I	01/01/11
14	Sumani Abdul-Fatawu	Security	Senior Headman	Supervisor Gd.II	01/01/11
15	Abraham Tetteh	Estate	Supervisor Gd.II	Supervisor Gd.I	01/01/11
16	Issah Yakubu	Transport/Workshop	Senior Headman	Artisan	16/03/11

Leave-Without-Pay

No.	Name	Designation	Category of Staff	Division/Section	Date of Leaving
1	Joyce Amoako (Mrs)	Research Scientist	Senior Member	Env. Chemistry	09/11/11

Vacation of Post

No.	Name	Designation	Category of Staff	Division/Section	Date of Leaving
1	Irene D. Adu-Poku (Mrs.)	Prin. Technical Officer	Senior Staff	Env. Chemistry	31/12/09

Tranfers

No.	Name	Designation	Category of Staff	Division/Section	Organization
1	Dr. Benony K. Kortatsi	Prin. Res. Scientist	Senior Member	Groundwater	Min. of Env. Science & Technology
2	Samuel Kotey Nikoi	Asst. Transport Officer	Senior Staff	Transport/Workshop	CSIR-Head Office
3	M. Azara Sedziafa (Mrs)	Snr. Admin. Officer	Senior Member	Administration	CSIR-WRI

Resignations

No.	Name	Designation	Category of Staff	Division/Section	Date of Resignation
1	Samuel Jerry Cobbina	Research Scientist	Senior Member	Env. Chemisitry	31/03/11

Voluntary Retirement

No.	Name	Designation	Category of Staff	Division/Section	Date of Retirement
1	Kofi Agbogah	Research Scientist	Senior Member	Fishery	15/11/11

Compulsory Retirement

No.	Name	Designation	Category of Staff	Division/Section	Date of Retirement
1	Samuel A. Tagoe	Chief Admin. Assistant	Senior Staff	Administration	30/04/11
2	Johnson Adonkor	Senior Works Supt	Senior Staff	Transport/Workshop	31/05/11
3	Samuel O. Ankrah	Security Officer	Senior Staff	Security	30/06/11
4	Issah Osmanu	Supervising Watchman	Junior Staff	Security	30/06/11
5	Sampson Abu	Senior Technical Officer	Senior Staff	Env. Chemistry	31/08/11
6	Dr. Kwadwo Kwarfo-Apegyah	Research Scientist	Senior Member	Fishery	30/09/11
7	Manasseh Sappor	Prin. Technical Officer	Senior Staff	Env. Biology & Health	31/10/11

Contract Appointment

No.	Name	Designation	Category of Staff	Division/Section	Date of Appointment
1	Dr. Kwadwo Kwarfo-Apegyah	Research Scientist	Senior Member	Fishery	01/10/11

Death

No.	Name	Designation	Category of Staff	Division/Section	Date of Death
1	Dr. Stephen Dapaah-Siakwan	Acting Director	Senior Member	Directorate	29/04/11
2	Abubakari Agumah	Security Assistant Gd.II	Junior Staff	Security	13/09/11

APPENDIX V: Staff Pursuing Courses

Staff Pursuing Various Courses

No.	Name of Officer	Designation	Division/Section	Training Institution	Course Title	Duration	Date Started	Expected Date of Return	Sponsorship Status
1	Kwadwo A. Asante	Research Scientist	Environ. Chemistry	Ehime Univ.-Japan	**PhD**-Env. Chem. & Ecotoxicology	3years	Apr-09	Apr. 2012	Ehime Univ. & CSIR
2	George T. Mensah	Research Scientist	Env. Biology & Health	UG Medical School	**PhD**-Microbiology	3years	Aug. 2010	Jul. 2013	CSIR
3	Collins Tay	Snr. Res. Scientist	Environ. Chemistry	Univ. of Ghana	**PhD**-Environmental Science	3years	Jan. 2011	Jan.2014	CSIR
4	Joycelin Osibo	Snr. Priv. Secretary	Administration	Univ. of Ghana	**BA**-Sociology/Information Studies	3years	Aug. 2009	Aug. 2012	CSIR
5	Bernice K. Essegbey (Mrs)	Technical Officer	CID-Library	Inst. of Prof. Stds	**BSc**-Marketing	4years	Aug. 2009	Aug. 2013	CSIR
6	Alfred A. Adjei	Snr. Accts. Clerk	Finance	Inst. of Prof. Stds	**BSc**-Accounting	4years	Aug. 2009	Aug. 2013	CSIR
7	Genevieve G. Kwogana	Senior Clerk (Sect.)	Administration	Tamale Poly.	**HND**-Secretaryship/Management	3years	Sept. 2009	Aug. 2012	CSIR
8	Harrison Komladzie	Prin. Draughtsman	CID-Cartography	Gh. Sch. Of surveying and Mapping	**HND**-Surveying & Mapping	2years	Aug. 2011	Jul. 2013	CSIR
9	Francis Anani Assogba	Research Scientist	Fishery	Univ. of Ghana	**PhD**-Fisheries Science	3years	Aug. 2011	Jul. 2014	CSIR
10	Mustapha B. Mohammed	Chief Tech. Officer	Env. Biology & Health	Accra Poly	**BTech**-Science Lab. Technology	18months	Nov. 2011	Mar. 2013	CSIR

Short Training Courses

No.	Name of Officer	Designation	Division/Section	Training Institution	Course Title	Duration	Date Started	Expected Date of Return	Sponsorship Status
1	Bernard L. Lartey	Printing Asst. Gd.II	CID-Printing	Gh. Publishing Company Ltd	Printing	6months	Jul.2011	Dec. 2011	CSIR

APPENDIX VI: National Service and Industrial Attachment

National Service Personnel Posted to the Institute in 2011

No.	Name	Institution	Division/Section Attached to
1	Akenya Isaac Mensah	University of Cape Coast	Fishery - ARDEC
2	Yakubu Faiza	University of Cape Coast	Fishery - ARDEC
3	Asmah Karyin Ewurama	University of Cape Coast	Fishery - ARDEC
4	Afoakwa Paul Asare	University of Cape Coast	Fishery - ARDEC
5	Amposah Daniel Owusu	University of Cape Coast	Fishery - ARDEC
6	Andoh Isaac Akornor	University of Cape Coast	Fishery - ARDEC
7	Godfred Yeboah	University of Cape Coast	Fishery - ARDEC
8	Aidoo Gilbert	University of Cape Coast	Fishery - ARDEC
9	Appiah Nicholas	University of Cape Coast	Fishery - ARDEC
10	Twum Samuel Kwame	University of Cape Coast	Fishery - ARDEC
11	Nkansah Isaac	University of Cape Coast	Fishery - ARDEC
12	Gyapong Matilda Asantewaa	University of Cape Coast	Fishery - ARDEC
13	Mohammed Rafik	University of Development Studies	Environmental Biology & Health
14	Abigail Nunoo	University of Development Studies	Groundwater
15	Netty David Annan	University of Development Studies	Fishery - ARDEC
16	Linda A.Bour	University of Development Studies	Fishery - ARDEC
17	Aseni Patrick N. K	KN Univ. of Science & Technology	Environmental Chemistry
18	George Hosuna	KN Univ. of Science & Technology	Fishery
19	Alhassan Abdul- Hag Sungumo	KN Univ. of Science & Technology	Fishery
20	Agadzi Yaa Asabea	University of Ghana	Fishery
21	Francis Shamo	University of Ghana	Environmental Chemistry
22	Frank Oppong Twumasi	Accra Polytechnic	Commercialization & Information
23	Iddi Sadique	Accra Polytechnic	Environmental Chemistry
24	Abdulai Salima	Bolgatanga Polytechnic	Administration
25	Isaac Kwarteng	Kumasi Polytechnic	Transport/Workshop

Attachment Personnel Posted to the Institute in 2011

No.	Name	Course	Institution	Division/Section Attached to
1	Richard Asare Opuku	Biological Sciences	Univ. of Cape Coast	Env. Biology & Health
2	George Quagraine	Biological Sciences	Univ. of Cape Coast	Env. Biology & Health
3	Adzo A. Amenuveve	Environmental Science	Univ. of Cape Coast	Env. Biology & Health
4	Bernard Osae	Biological Sciences	Univ. of Cape Coast	Env. Biology & Health
5	Agbenyagah Akley	Biological Sciences	Univ. of Cape Coast	Fishery
6	Joshua Wemegah	Chemistry	Univ. Of Ghana	Env. Chemistry
7	George Buer Kpentey	Biological Chemistry	Univ. Of Ghana	Env. Biology & Health
8	Helena Asantewaa	Geology	Univ. Of Ghana	Groundwater
9	Ernest Antwi	Geology	Univ. Of Ghana	Groundwater
10	Naomi Derdo Tetteh	Sociology/Archaeology	Univ. Of Ghana	CID-Library
11	Kwadwo Ofori	Earth Science	Univ. of Development Studies	Groundwater
12	Thelma Zulfawu Abu	Environmental Science	KN Univ. of Science & Technology	Env. Chemistry
13	Nti Nana Yaw Amanfo	Environmental Chemistry	KN Univ. of Science & Technology	Env. Chemistry
14	Ama Frempomaa Donkor	Biological Chemistry	KN Univ. of Science & Technology	Env. Biology & Health
15	Albert Coleman	Land Reclamation	KN Univ. of Science & Technology	Groundwater
16	Yaw Ohene Afrane	Agricultural Engineering	KN Univ. of Science & Technology	Surface Water
17	Amoako H. Gyekye	Agricultural Engineering	KN Univ. of Science & Technology	Surface Water
18	Bernard Owusu	Agricultural Engineering	KN Univ. of Science & Technology	Surface Water
19	Gifty Oppong	Accounting	Methodist University	Finance
20	Alfred Owusu Osei	Accounting	Methodist University	Finance
21	Desire Emefa Awuye	Mineral Engineering	Univ. of Mines and Technology	Env. Chemistry
22	Nadia Abena Kofie	Human Resource Mgt	Central University College	Administration
23	Emmanuella N. Ontonyi	English	Central University College	CID-Secretariat
24	Sarah Nana-Amankwaah	Accounting	Regent University College	Finance
25	Samuel Essandoh	Business Administration	Institute of Professional Studies	Administration
26	Godwin Akagbo	Marketing	Ho Polytechnic	CID-Secretariat

No.	Name	Course	Institution	Division/Section Attached to
27	Lucy Adu	Secretaryship	Young Women Christian Association	Administration
28	Zenab Abubakari	Secretaryship	Government Secretariat	Administartion
29	Evelyn Denkyi	Network/Software	IPMC	CID-Copmuter
30	Kwame Kassim	Science Lab. Technology	Accra Polytechnic	Env. Chemistry
31	Eugene Ofori	Science Lab. Technology	Accra Polytechnic	Env. Chemistry
32	Seth Takyi	Science Lab. Technology	Accra Polytechnic	Env. Chemistry
33	Eunice Attia	Science Lab. Technology	Accra Polytechnic	Env. Chemistry
34	Eric Owusu-Ansah	Science Lab. Technology	Accra Polytechnic	Env. Chemistry
35	Martin Agamah	Science Lab. Technology	Accra Polytechnic	Env. Chemistry
36	Josephine Addo-Yobo	Science Lab. Technology	Accra Polytechnic	Env. Chemistry
37	Janet Safoah Bredu	Secretaryship	Accra Polytechnic	Administration
38	Iddrisu E. Abdallah	Accounting	Accra Polytechnic	Finance
39	Bernard T. Akrong	Biological Science	Accra Polytechnic	Env. Biology & Health
40	Elizabeth Quarm	Purchasing & Supply	Accra Polytechnic	Finance

Appendix VII: List of Staff Publications

Conference Papers

Agbeko, E. and Amisigo, B. (2011) Effects of climate change – the anthropogenic factor on Vea Reservoir. Paper presented at the 3rd Ghana Water Forum, 5 – 7 September 2011, Accra.

Agyekum William, A. (2011) Integrated management of Ghana's Tano and Keta Transboundary Aquifers. Paper presented at the ISARM International Workshop on Transboundary Aquifers of West and Central Africa, 16 – 19 May 2011, Douala.

Agyekum, W. A., Okrah, C., Kankam-Yeboah, K. and Dapaah-Siakwan, S. (2011) Integrated management of transboundary aquifers: The case of Keta and Tano Basins. Paper presented at the UNESCO ISARM Conference, June 2011, Douala, Cameroun

Amisigo, B. A. (2011) Some water resources development solutions for adaptation to climate change. Paper presented at the 1st Ghana Science Congress, 2 – 5 August 2011, Accra.

Amisigo, B. A. (2011) Importance of technology in climate change adaptation. Paper presented at the workshop on climate change experiences in Ghana, December 2011, Accra

Ansa, E. D. O, Lubberding, H. J. and Gijzen, H. J. (2011) Combined constructed wetlands and stabilization ponds- a key eco-technology for treating Africa's wastewater. Paper presented at the International Conference on sustainable development of natural resources in Africa: creating a nexus between research and policy for sustainable management of Africa's natural resources, United Nations University (UNU) INRA, 5 – 7 December 2011, Accra.

Asmah, R. and Karikari, A. Y. (2011) Water quality impacts of cage and pen aquaculture on Volta Lake. Paper presented at the Ghana Science Association 17th Bi-annual Conference, 10 – 15 July 2011, Kumasi.

Banu, R. A. (2011) Analysis of sachet water samples from selected neighbourhoods in Accra. Paper presented at the 4th Ghana Biomed Conference, Kumasi.

Obiri, S. (2011) Cancer and non – cancer human health risk from exposure to arsenic, lead and cadmium in drinking water by residents in Obuasi Municipality. Paper presented at the 3rd Ghana Water Forum, 4 – 10 September 2011, Accra.

Obiri, S. (2011) Climate change and food security in drought sensitive regions of Ghana. Paper presented at UDS annual Harmatan School, 4 – 5 April 2011, Tamale.

Obiri, S. (2011) Institutional and legal framework governing solid waste management in Ghana. Paper presented at the 7th EU Framework on Environment and Climate – Integrated Waste Management in Western Africa, 15 – 18 June 2011, Dakar.

Obiri, S. (2011) Evaluation of neurotoxic health risk from exposure to lead and manganese by resident children in Bogoso in Prestea Huni-Valley District, Ghana. Paper presented at the Environmental Health Risk Assessment Conference l, 9 – 15 February 2011, El – Savdor.

Obuobie, E. (2011) The water situation in Ghana. Paper presented at the workshop on Network of African Science Academies (NASAC) water programme in West Africa, Dakar, 18 – 19 July 2011

Consultancy Reports

Ametefe, W., Allotey, E., Minkah, E., Asmah, R., Kankam-Yeboah, K. and Gyau-Boakye, P. (2011) Subri River water release management report – Newmont Ghana Gold Ltd, Ahafo, CSIR WRI, Accra.

Asmah, R. and Banu, R. A. (2011) Physico-chemical and bacteriological quality of a water storage facility and the Awosu Stream – Newmont Ghana Gold Ltd., Ahafo, CSIR WRI, Accra.

Asmah, R., Owusu, B. K. and Karikari, A. Y. (2011) Water quality monitoring training report – Newmont Ghana Gold Ltd, Ahafo, CSIR WRI, Accra.

Banu, R. A. (2011) Leachate quality assessment at Sabah landfill site in Accra West, CSIR WRI, Accra.

Darko, H. F., Ansa-Asare, O. D., Ampofo, J. A. (2011) Physico-chemical and bacteriological analyses of raw and treated water for potable use, CSIR WRI, Accra.

Gyau-Boakye, P., Kankam-Yeboah, K., Asmah, R., Wise, X., Allotey, E. and Minka, E. K. (2011) Subri River water release management, Newmont Ghana Gold Limited (NGGL), Ahafo, Hydrological Services Department/CSIR WRI, Accra.

Kankam-Yeboah, K., Dapaah-Siakwan, S., Okra, C., Agyekum, W. A., Ofori, D. and Amoah-Adarkwah, E. S. (2011) Managing water as a shared responsibility across geographical and social boundaries by promoting integrated water resources management in the cluster countries: The case of Tano and Keta basins (ISARM), UNESCO Accra Cluster Office, CSIR-WRI, Accra.

Kankam-Yeboah, K., Gyau-Boakye, P., Logah, F. and Ofori, D. (2011) Update of flood phenomenon in Ghana, prevention of hydro-hazard (flood) disasters in Ghana, UNESCO Accra Cluster Office, CSIR WRI, Accra

Karikari, A. Y. (2011) Final effluent quality monitoring – Golden Tulip Hotel, CSIR WRI, Accra.

Karikari, A. Y. and Akuffo, E. (2011) Hydrogen Peroxide spillage at Assin Bireku: Assessment of impact on soil and water quality, CSIR WRI, Accra.

Karikari, A. Y. and. Ampofo, J. A. (2011) Physico-chemical and bacteriological tests on potable and swimming pool water in Golden Tulip Hotel, CSIR WRI, Accra.

Karikari, A. Y., Ampofo, J. A. and Banu, R. (2011) Independent assessment of drinking water quality in Accra-Tema metropolis, CSIR WRI, Accra.

Karikari, A. Y., Banu, R. Akrong, M. and Ampofo, J. A. (2011) Leachate quality assessment at Sabah landfill site in Accra West, CSIR WRI, Accra.

Mainoo, P. A. (2011) Draft Action Plan: Hydrogeological and drilling supervision services for two small towns (Wapuli and Wanjuga – Kudani), CSIR WRI, Accra.

Mainoo, P. A. and Dapaah-Siakwan, S. (2011) Geophysical investigations to locate suitable sites for exploratory drilling to re-assess the groundwater potential for small towns water supply systems in two selected towns in East Gonja District of Northern Region of Ghana, CSIR WRI, Accra.

Mainoo, P. A. and Dapaah-Siakwan, S. (2011) Geophysical investigations to locate suitable sites for exploratory drilling to re-assess the groundwater potential for small towns water supply systems in two selected towns in West Mampusi District of Northern Region of Ghana, CSIR WRI, Accra.

Mainoo, P. A. and Dapaah-Siakwan, S. (2011) Geophysical investigations to locate suitable sites for exploratory drilling to re-assess the groundwater potential for small towns water supply systems in two selected towns in Kpandae District of Northern Region of Ghana, CSIR WRI, Accra.

Mainoo, P. A. and Dapaah-Siakwan, S. (2011) Geophysical studies to locate suitable sites for borehole drilling within the premises of ECOBANK, Tamale Branch for domestic potable water supply, CSIR WRI, Accra.

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