WATER RESOURCES COMMISSION, GHANA

WHITE VOLTA RIVER BASIN -

Integrated Water Resources Management Plan

December 2008

PREAMBLE

Right from the establishment of the Water Resources Commission (WRC) a priority task has been to introduce the basic principles of Integrated Water Resources Management (IWRM) at decentralised level in selected river basins. The first IWRM Plan elaborated was for the Densu River Basin which was finalised towards the middle of 2007.

The present White Volta River Basin IWRM Plan is the second of its kind, and this basin was chosen due to the trends witnessed here, including detrimental land and water quality degradation, water shortages in an otherwise perennial river system caused, among other factors, by an accelerating increase in irrigation demand, and establishment of numerous smaller dams and dug-outs in the upstream parts of the river system. Additionally, as experienced in the rainy season of 2007, occasional devastating flood events also occur.

These hazards may very well also be indirect caused by new patterns in river runoff as result of an ongoing climate change. In instituting proper water resource management mechanisms, the White Volta River Basin is also unique in the Ghanaian context being a true frontier river system, which calls for special "trans-boundary" considerations in the approach towards water resources planning and development of this internationally shared resource.

A number of activities have been invested over the past few years in creating a basin-based IWRM structure for the White Volta River Basin. The decentralised IWRM structure, which has evolved through a targeted participatory and consultative process, combines the following partners: a broadly anchored stakeholder-oriented coordinating body, i.e. the White Volta Basin Board, planning and executive units of the District Assemblies and WRC's Basin office in Bolgatanga, which serves as secretariat for the Board.

In parallel to the organisational arrangements, activities of a more technical and hydrological nature have been ongoing, which eventually resulted in the present White Volta River Basin IWRM Plan. This plan should also be viewed as an integral part of the stipulations in the WRC Act 522 of 1996 to "propose plans for utilisation, conservation, development and improvement of water resources" in adherence with the overall National Water Policy of June 2007.

Inasmuch as IWRM is a cyclic and long-term process, the document can be seen as a milestone in this process, in which the status of the water resources situation is documented – a process that should be subject to continuation and updates as the need arises in the future.

It is WRC's sincere hope that this plan can be a useful catalyst towards accelerating concrete water management activities in the White Volta River Basin, and importantly, may also serve as a source of inspiration to advance collaboration among the riparian communities on both sides of the international border.

Oduro K. Gyarteng
Chairman, Water Resources Commission
Accra, December 2008

LIST OF CONTENTS

Page

LIST OF TABLES

LIST OF FIGURES AND MAPS

Page

FIGURES

MAPS

ABBREVIATIONS

CBO	Community-Based Organisation
CIDA	Canadian International Development Agency
CWSA	Community Water and Sanitation Agency
DA	District Assembly
Danida	Danish International Development Assistance
EPA	Environmental Protection Agency
GIS	Geographic Information System
GWCL	Ghana Water Company Limited
ha	hectare
HAP	Hydrogeological Assessment Project (CIDA/WRC)
HSD	Hydrological Services Department
IDA	Irrigation Development Authority
IWRM	Integrated Water Resources Management
km^2	square kilometre
mg	milligram
mm	millimetre
m^3	cubic metre
MDAs	ministries/departments/agencies
MOFA	Ministry of Food and Agriculture
MWRWH	Ministry of Water Resources, Works and Housing
NADMO	National Disaster Management Organisation
NGO	Non-Governmental Organisation
NR	Northern Region
PAGEV	Project for Improvement of Water Governance in the Volta Basin
pop	population
SEA	Strategic Environmental Assessment
sec	second
UER	Upper East Region
UN	United Nations
UWR	Upper West Region
VRA	Volta River Authority
WEAP	Water Evaluation and Planning Model
WHO	World Health Organisation
WVBB	White Volta Basin Board
WRC	Water Resources Commission
WRI	CSIR-Water Research Institute
WSSD	World Summit on Sustainable Development (August 2002)
WQI	Water Quality Index

1. INTRODUCTION

1.1 IWRM in an international context

At the World Summit on Sustainable Development (WSSD) held in Johannesburg in 2002, the international community took an important step towards more sustainable patterns of water management by including, in the WSSD Plan of Implementation, a call for all countries to develop "*integrated water resources management and water efficiency plans*". Activities aimed at enhancing "water efficiency" are considered important components of IWRM, and hence should be included as an integral part of an IWRM plan.

The term integrated water resources management (IWRM) has been subject to various interpretations, but the following definition by the Global Water Partnership[1] has been adopted in the Ghanaian context:

> *"... a process which promotes the coordinated development and management of water, land and related resources in order to maximise economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems ..."*

Due to competing demands for the water resource (in the worst case resulting in limiting economic development, decreasing food production, or basic environment and human health and hygiene services), the process is intended to facilitate broad stakeholder input in order to build compromise and equitable access. This is particularly the case for developing countries like Ghana, which allocates much effort in addressing poverty reduction and in implementing the UN Millennium Development Goals.

IWRM is a broad based approach to the development of water, addressing its management both as a resource and within the framework of providing water services.

The Global Water Partnership models the IWRM process as a cycle of the following activities:

- establishing the status and overall goals;
- building commitment to the reform process;
- analysing gaps;
- preparing a strategy and action plan;
- improving the legal and institutional management framework; and
- monitoring and evaluating progress.

The goal of preparing IWRM plans as called for at the WSSD has set the tone for a world wide initiative, which Ghana has adopted with the purpose "to promote an ef-

[1] *Global Water Partnership (GWP): Integrated Water Resources Management, Technical Advisory Committee, TAC Background Paper No. 4 (2000)*

ficient and effective management system and environmentally sound development of all its water resources"[2] based on IWRM principles.

1.2 IWRM planning in the Ghanaian context

In Ghana, IWRM plans are thought initially to be prepared at the river basin level starting with the most "water stressed" basins of the country. At a later stage, this exercise can provide input to preparation of an IWRM strategy/plan at national level incorporating trans-boundary water resource related issues. The IWRM plans and strategies shall be prepared with the overall purpose of addressing major problems at a river basin level related to:

- water resource availability;
- water quality; and
- environmental/ecosystem sustainability.

Due account shall be taken to water use, and the social and economic implications of implementing an IWRM plan. Actions to be taken as a consequence of planning shall be prepared based on scenarios describing different approaches for solving major management problems (that might be described with natural resources, socio-cultural, economic and regulatory, administrative and institutional indicators) within a defined time period.

As such the prime outcome to be provided are prioritised and ranked sets of programmes/actions, which from a political, legal, technical, sociological and economic point of view are considered as the most sustainable and efficient solutions. Political (democratic) aspects of IWRM planning in this regard require, that plans shall be elaborated with a participatory approach guided by principles which are imbedded in the concept of Strategic Environmental Assessment (SEA).

Generally, SEA is applied with two purposes:

- to evaluate environmental impacts and to rank the environmental effects of plans and programmes; and
- to evaluate conformity and/or conflicting stipulations between various related plans and programmes.

SEA tools have in Ghana been applied in assessing the first Ghana Poverty Reduction Strategy and during formulation of the National Water Policy. As a continuation of these approaches, a SEA Practical Guide[3] has been prepared, which presents a number of SEA tools applicable to the water and sanitation sector, including water resource planning, development and management.

[2] *National Water Policy - Government of Ghana, Ministry of Water Resources, Works and Housing (June 2007).*

[3] *SEA of Water and Environmental Sanitation – a Practical Guide. Ministry of Water Resources, Works and Housing; Ministry of Local Government, Rural Development and Environment; and Environmental Protection Agency (April 2007).*

Key aspects, therefore, in the IWRM-SEA process is a participatory approach involving users, planners and policy makers to build commitment; a holistic view that calls for cross-cutting interaction within basins; an integration in terms of upstream-downstream catchment implications; and recognition to the fact that water is an economic good.

As part of a process, the basin-based IWRM plan shall form a widely accepted and easily understood document describing the current state of the water resources and outlining strategies that enable basin-based water management, which adheres to stipulations in the National Water Policy. Thus, the IWRM plan can be considered a "blueprint", that describes steps to be taken towards realising the visions.

1.3 Purpose and institutional setting of the IWRM plan

The target group of the basin-based IWRM plans is planners and decision-makers operating in the water sector, including the river basin boards, who are provided with a tool for "what to do" and for detailing activities and programmes concerning specific interventions. More specifically, the purpose of the IWRM plan is to:

- contribute to the provision of sufficient supply of good quality surface water and groundwater as needed for sustainable, balanced and equitable water use;
- prevent further deterioration and protect the status of aquatic ecosystems with regard to their water needs;
- protect terrestrial ecosystems directly depending on the aquatic ecosystems;
- contribute to mitigating the effects of floods and droughts; and
- provide appropriate water management with efficient and transparent governance in the sector whether at local, district or basin-based level.

IWRM is a cyclic and long-term process. Hence, the IWRM plan can be seen as a milestone in this process, where the status of the process is documented, and the plan inevitably will need to be kept up-to-date when new knowledge surfaces, e.g. related to changes in the hydrological regime and projections of future water requirements.

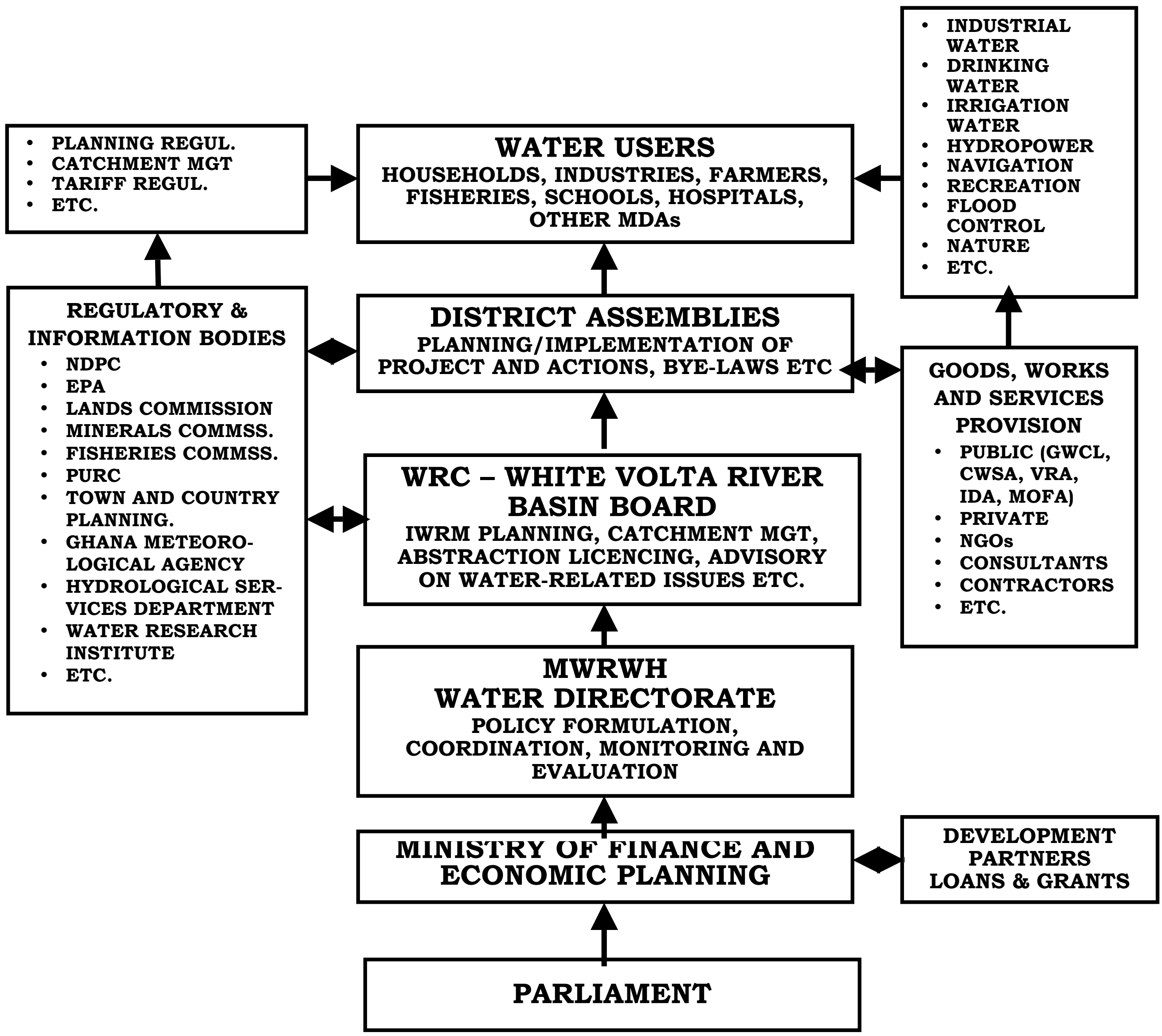
For the IWRM plan to be successfully implemented, it is imparative that the WRC collaborates with institutions and major water abstractors affected by the plan. This is because the plan impacts on a variety of societal aspects, viz. utilisation and protection of natural resources, social and cultural situations, economics and production, and the legal, administrative and institutional frameworks. It is evident that there must be effective collaboration with planning efforts in these areas.

For instance, Water Resources Commission (WRC) has to collaborate with –

- MDAs, CWSA and GWCL in water demand projections;
- MDAs, Lands Commission, Minerals Commission, EPA, MOFA and traditional authorities in catchment management;
- MDAs and EPA in controlling various wastes into water bodies; and
- EPA, Forestry Commission, Fisheries Department, Water Research Institute and HSD in assessing environmental flow requirements.

The overall institutional setting as it relates to the further planning and implementation of activities and measures outlined in the IWRM plan is depicted in Figure 1.1.

Figure 1.1: Overall institutional setting



1.4 Status of IWRM activities in the White Volta River Basin

For quite many years Ghana has been planning for and engaged in the introduction of IWRM at various levels of society, and as such has advanced in the IWRM process resulting in a new national water policy and legislation facilitating water resources management and development based on IWRM principles. Furthermore, an enabling institutional framework has been introduced at national level, i.e. establishment of the Water Resources Commission and the Water Directorate under the Ministry of

Water Resources, Works and Housing, and at local river basin level in the form of creation of River Basin Boards.

The White Volta Basin Board (WVBB) was the second river basin management set-up to be established and was officially inaugurated in July 2006. WVBB has a consultative and advisory role as it relates to the management of the the White Volta Basin's water resources and represents a wide sphere of interest groups within the Basin, including the traditional authorities. Its work is facilitated by a secretariat as a decentralised entity of the WRC. The WVBB membership combines the following:

(a) A chairperson appointed by the WRC,

(b) A representative of the WRC,

(c) One person representing each of the following within the basin.

- West Mamprusi District Assembly
- Kasenna-Nankana District Assembly
- Bolgatanga Municipal Assembly
- Talensi-Nabdam District Assembly
- Bongo District Assembly
- Bawku Municipal Assembly
- Garu-Tempani District Assembly
- Bawku West District Assembly
- Upper East Regional Coordinating Council
- Ministry of Food and Agriculture
- Ministry of Women and Children's Affairs
- Environmental Protection Agency
- Community Water and Sanitation Agency
- Savannah Agricultural Research Institute
- Upper East Regional House of Chiefs
- Non-Governmental Organisations

(d) The Basin Officer as ex-officio member appointed by the WRC in charge of the Board's Secretariat.

Over the past few years quite many specifically targeted studies and related activities have been completed aimed at providing data and new information of relevance for the IWRM planning. In the following chapter "Baseline Description" these various sources of information and reports are acknowledged as and when used.

Furthermore, in the White Volta Basin a number of IWRM activities have also been initiated by the WVBB and WRC as well as NGOs and other development partners, all with the purpose of addressing the growing water variability and water quality degradation facing the Basin. Some of these activities are:

- holding of quarterly Board meetings annually for the formulation of strategies to enhance coordination of the management and utilisation of the water resources of the basin;
- organisation of sub-committee meetings of the White Volta Basin Board to draw-up and review work programmes for implementation;

- promotion and support for target groups' awareness creation and education within the basin (in communities and schools), and development of educational materials;
- collaboration with agencies/organisations and communities working towards the recovery of the ecological health of the Basin, including activities such as tree-planting, clean-up exercises, river channel clearance and river bank protection;
- identification of raw water users (to assist in the process of registering and granting water rights/issuance of permits);
- establishment of links with the Basin's District Assemblies, traditional authorities/landowners to tackle specific issues relating to pollution and degradation of the catchment area, e.g. relocation of waste dump sites away from the river banks;
- establishment of "buffer" zones; and
- provision of information services for students during preparation of their special studies and theses works, researchers, consultants, NGOs, CBOs and concerned individuals.

Under the Project for the Improvement of Water Governance in the Volta Basin (PAGEV) various activities are also undertaken in collaboration with the counterparts from Burkina Faso, such as -

- facilitating the reduction in farming activities along the river banks through rehabilitation of a broken dam to create an alternative water source for irrigation;
- holding sensitization, capacity building and planning meetings with technical service providers (forestry, agriculture and planners) and communities;
- holding trans-boundary (Ghana-Burkina Faso) joint community fora on river bank protection interventions; and
- establishment of a Ghana-Burkina Faso local trans-boundary committee on the management of the White Volta River Basin and adoption of code of conduct/operational guidelines for this committee.

1.5 Preparation and structure of the IWRM plan

The WRC has elaborated the present IWRM plan for the White Volta River Basin as part of WRC's mandate to "*propose comprehensive plans for utilisation, conservation, development and improvement of water resources*" [4] with due consideration to stipulations in the National Water Policy.

The IWRM plan is based on a number of dedicated assessment studies and information reviews all unveiling implications relevant for decisions made during the process of prioritising measures forming the IWRM plan. Guided by SEA procedures and application of "tools", consultative meetings and workshops have taken place during the course of preparation, specifically targeting the WVBB members as well as District Assemblies and their planning officers.

[4] *Water Resources Commission (WRC) Act No. 522 of 1996*

Following the present introductory chapter, Chapter 2 presents the baseline description, which provides the background against which the planning and identification of actions can be made. In Chapter 3 water demand projections are presented based on district development plans and other information notably the 2000 census results. Furthermore, in this chapter a number of scenario analyses are presented comprising different development options and strategies for the utilisation of the basin's water resources, including likely climate change impacts on the water resources.

Chapter 4 describes the consultative process followed towards identification and ranking of water resource management problems and issues as perceived by local stakeholders and planners of the basin. As result of this process the chapter further presents an action plan comprising of a number of prioritised activities and measures for implementation required to meet the water resource management challenges of the basin. The final Chapter 5 concludes the IWRM Plan by outlining the steps to be initiated to move forward towards implementation of the action programme.

2. BASELINE DESCRIPTION

2.1 Physical, demographic and socio-economic features

The White Volta River Basin is one of the four main sub-basins of the Volta River system and spans Togo (small portion), Burkina Faso and Ghana. In the context of this IWRM Plan the interest is on the Ghana part of the basin, i.e. from the national border in the north and northeast to the inflow into Volta Lake.

The water resources of the basin are increasingly being exploited, which is mostly felt in the dry season due to the increasing number of irrigation schemes, many of which are associated with construction of dams, ponds etc. The prevailing flood hazard during the wet season along the stream banks and in the vicinity of the main river and its tributaries is also a distinct water resource issue characterizing the basin. Furthermore, a progression in land degradation and unchecked waste disposal in the river system are also experienced, although it can be noted that in general terms water pollution as such is not yet a major concern.

The White Volta River contributes on an annual basis in average some 20% of the inflow to the Volta Lake, and hence, is an important element of the hydropower generation at Akosombo Dam and Kpong power stations in the lower Volta River system. Any alteration of the river flow regime upstream, due for instance to larger-scale irrigation developments, would therefore have an impact on the potential output from the power plants.

2.1.1 Location, topography and river network

The White Volta River Basin in Ghana is located between latitudes 8°50'N - 11°05'N and longitudes 0°06'E - 2°50'W. The basin is bounded to the east by the Oti River Basin, to the west by the Black Volta River Basin and to the south by the Main/Lower Volta sub-basins. Burkina Faso forms its northern boundary.

The Ghanaian part of the basin is characterised by fairly low relief with few areas of moderate elevation in the north and east. The mean elevation is about 200 m and the highest portion reaches 600 m. The topography of the basin is depicted in Map 1 (inserted at the end of the chapter).

The drainage area of the Ghanaian part of the basin is about 50,000 km^2 (a good 20% of Ghana's total land area), and constitutes about 44% of the total area of the White Volta River Basin (named Nakanbé River in Burkina Faso). The White Volta River and its main tributaries in the northern part, the Red Volta (Nazinon) and the Kulpawn/Sissili rivers, take their sources in the central and north-eastern portions of Burkina Faso.

The river first flows south on entering Ghana, turns west to be joined by the Red Volta, continues westwards through the Upper East Region and then turns south, where it is joined by several tributaries, including the Kulpawn/Sissili and Nasia rivers. It continues southwards to Nawuni, flows westwards to Daboya and then southwards again where it is joined by the Mole river before entering the Volta Lake.

2.1.2 Administrative setting, population and settlement pattern

The White Volta River Basin spans 3 administrative regions, i.e. all of the Upper East Region (UER), 70% of the Upper West Region (UWR) and about 50% of the Northern Region (NR). After the creation of new districts and municipalities in 2004 with some readjustment in 2007, a total of 29 districts are represented within the basin. These districts comprise of all the 9 districts in UER, 7 of the 8 districts in UWR and 13 of the 18 districts in the NR. Approximately 17% of the basin lies within the UER, 25 % within the UWR and the remaining 58% within the NR. The districts as they exist today within the basin boundary are depicted in Map 2 (inserted at the end of the chapter).

The population within the basin, extracted from the 2000 Census[5] results, is shown in Table 2.1 and listed for each district in accordance with the settlement classification “rural” and “urban”. A settlement is defined as urban if its population is larger than 5,000 people. The location of a number of the major settlements/towns within the basin is indicated on Map 2. The portion of a district’s rural population living within the basin is estimated from the proportion of the area of the district located within it. The population density (pop/km^2) is also indicated in Table 2.1.

It should be noted that for the purpose of extracting and using the population figures correctly and transparently as given in the 2000 Census, the district listing given in Table 2.1 represents the old district set-up, i.e. before the recent local administration restructuring.

A total of 9 districts within the basin were affected by the 2004/2007 reforms. An overview of how the old districts have been split into two new districts (or in one case three) is provided as follows:

- Bolgatanga → (i) Bolgatanga Municipal and (ii) Talensi-Nabdam
- Bawku East → (i) Bawku Municipal and (ii) Garu-Tempane
- Kasina-Nankana → (i) Kasina-Nankana and (ii) Chiana-Paga
- Wa → (i) Wa Municipal, (ii) Wa East and (iii) Wa West
- Sissala → (i) Sissala East and (ii) Sissala West
- Bole → (i) Bole and (ii) Sawla-Tuna-Kalba
- West Gonja → (i) West Gonja and (ii) Central Gonja
- Gushiegu-Karaga → (i) Gushiegu and (ii) Karaga
- East Mamprusi → (i) East Mamprusi and (ii) Bunkpurugu-Yonyoo

In summary it can be derived from Table 2.1, that the total population (year 2000) within the basin was 1,911,400 – equivalent to around 10% of Ghana’s total popula-

[5] *Ghana Statistical Service: 2000 Population and Housing Census (official results on CD-ROM, January 2002)*

tion. Worth noting is also that close to half of the basin's population reside in UER, which constitutes only some 17% of the basin area as mentioned above. The figures in Table 2.1 also show that the districts of East Gonja and Yendi contribute very little both in population and area to the basin.

The population growth rates recorded in the basin during the latest inter-censual period (i.e. between 1984 and 2000) indicate that for the UER, UWR and NR the rates were 1.1, 1.7 and 2.8, respectively. The growth rates for the UER and UWR were lower than the national average of 2.7 – in fact, the growth rate for the UER was the lowest of any region of the country. In contrast, however, the population density of 104 for the UER was much higher than those of the UWR (31) and NR (25), and also higher compared to the national average of 77 pop/km^2. The population density in the White Volta River Basin as a whole (year 2000) was 41 pop/km^2, i.e. just a little more than half of the national average.

The population in the basin is mainly rural constituting some 80% of the basin's population (excluding the majority of the Tamale Metro population living just outside the basin boundary as explained in the footnote to Table 2.1). These characteristics are clearly depicted in the settlement pattern (split between rural and urban population cutting across all the districts) as well as the population density figures given in Table 2.1.

Table 2.1: Districts and population within White Volta River Basin (2000 Census)

Region	District	Settlement category	Population (2000)	Part of district in basin (%)	District area within basin (km^2)	District area within basin (%)	Density (pop/km^2)
Upper East	Builsa	rural	75,400	100	2,020	4.3	37
		urban	0				
	Kasina-Nankana	rural	125,700	100	1,565	3.3	96
		urban	23,800				
	Bongo	rural	77,900	100	400	0.9	195
		urban	0				
	Bolgatanga	rural	179,700	100	1,515	3.2	151
		urban	49,100				
	Bawku West	rural	72,500	100	920	2.0	88
		urban	8,100				
	Bawku East	rural	244,700	100	1,960	4.2	157
		urban	63,300				
Upper West	Wa	rural	110,200	70	3,420	7.4	46
		urban	46,600				
	Sissala	rural	76,600	100	6,410	13.8	13
		urban	8,800				
	Jirapa-Lambusie	rural	19,400	20	340	0.7	57
		urban	0				
	Nadowli	rural	41,400	50	1,320	2.8	31
		urban	0				
Northern	Bole	rural	28,000	25	2,270	4.9	14
		urban	3,800				
	West Gonja	rural	71,800	60	9,480	20.4	9
		urban	11,800				
	East Gonja	rural	200	< 1	10	< 0.1	20
		urban	0				
	Yendi	rural	800	< 1	20	< 0.1	40
		urban	0				
	Gushiegu-Karaga	rural	89,000	90	4,850	10.5	23
		urban	23,800				
	Savelugu-Nanton	rural	54,500	95	1,880	4.0	45
		urban	31,000				
	Tamale	rural	9,100	10	70	0.2	418
		urban[(i)]	20,200[(i)]				
	Tolon-Kumbungu	rural	112,000	100	2,170	4.7	61
		urban	20,900				
	West Mamprusi	rural	101,500	100	4,330	9.3	27
		urban	13,600				
	East Mamprusi	rural	82,400	55	1,550	3.4	57
		urban	13,800				
White Volta Basin, total		rural	1,572,800	-	46,500	100	41
		urban	338,600				

[(i)] *The 2000 Census population of Tamale Metro was 197,200 of which 20,200 resided within the White Volta Basin.*

2.1.3 Socio-economic profile

The water resources of the White Volta River Basin contribute substantially to the economic livelihood of the people living in the basin. Water is used for a variety of purposes in the domestic, agriculture and industrial sectors.

Agriculture (including animal husbandry), fishery, hunting and forestry together constitute the main economic activity in the basin, particularly in the rural areas and provide occupation and employment for a vast majority of the people. The figures presented in Tables 2.2a and 2.2b are derived from the 2000 Census data[6], and are given as percentages of the economically active population (above 15 years of age). Due to differences in the presentation of the analyses published by the Ghana Statistical Service, two tables are given here, one covering the UER and UWR (Table 2.2a) and one for NR (Table 2.2b).

The tables show the importance of the agricultural sector, which in this context also includes animal husbandry, fishery, forestry and hunting. In average for the basin, this combined sector provides employment/occupation for more than 70% of the population. Furthermore, the table values also depict the differences between the rural and urban areas, where the economic activities are more diversified. The most common occupations in the urban settings include manufacturing, transport, wholesale and retail trading and various commercial services.

The major industrial activities, mainly agro-based, in the basin are:

- Northern Star Tomato Factory (NSTF), Pwalugu
- Meat Factory, Bolgatanga (presently not in operation)
- Ghana Cotton Company, Tamale and Bolgatanga
- Integrated Tamale Fruit Company (ITFC), Savelugu
- Shea-butter processing plants (several smaller facilities)

Small scale industries and commercial activities include auto servicing shops, saw milling, carpentry, block making, local soap manufacturing and black-smith and metal working. In addition, manufactured goods are sold at large markets, which also form points of contact and trading connections between rural and urban residents.

Agricultural activities are practiced both commercially and as subsistence farming. Improper farming practices such as slash and burn, and bush burning, are common practices. These result in further degradation of both the land and water resources of the basin. The cultivation of crops along river banks is also undertaken in many sections of the White Volta River, resulting in the removal of the top soil and increasing the risk of siltation in the river through upland erosion and subsequent transport of sediment into the open water courses.

Large and medium scale irrigation systems in the White Volta Basin can be found in the Tono (Kasina-Nankana District), Vea (Bongo District) and Bontanga (Tolon-Kumbungu District) localities. All 3 schemes are built on tributaries of the White

[6] *Ghana Statistical Service: 2000 Population and Housing Census: Analysis of District Data and Implications for Planning (August 2005)*

Volta River and supply water primarily for the cultivation of rice and vegetables. A large scale sugarcane irrigation project is also being planned in the basin near Nawuni (Tolon-Kumbungu District) by the Ghana Sugar Development Company.

There are also a number of small scale irrigation systems based on small dams, ponds and dug-outs in the basin. Another means of small scale irrigation farming – which is gaining popularity – is the use of portable water pumps to extract water from streams for watering of crops, i.e. mainly vegetables, in the dry season. This is practiced particularly along the main White Volta River, which in recent years has carried a rather steady dry season flow, as a result of the operation of the Bagré hydropower and irrigation dam in upstream Burkina Faso.

Harvesting of fuel wood and charcoal burning are important economic activities since the use of these for cooking is still predominant in both rural and urban homes in the basin. These activities result in further degradation of the basin's land resources.

Fishing activities are practiced in the basin, especially in the main White Volta River where fishing can be done throughout the year. Major tributaries such as the Red Volta, Kulpawn, Nasia and Mole as well as the large irrigation dams in the basin are also being used for fishing. Apart from the traditional methods of draw-net and hook-and-line fishing, some fishermen use illegal methods such as chemicals and explosives, but this practice with its adverse effects on the water quality, is being addressed effectively by the relevant authorities.

Small-scale gold mining activities (galamsey) and stone quarrying are also common in some parts of the basin, particularly in the Upper East Region. In this region, mining activities are undertaken mostly in the Nangodi area in the Talensi-Nabdam District, whereas the commercial stone quarrying activities are mainly centred around Pwalugu and Tongo also in the Talensi-Nabdam District.

In general terms, the employment situation in the basin is such – with differences experienced between regions and among districts – that about 65%-80% are self-employed (i.e. private informal sector activities, including working on own farms), 10%-15% are in full-time formal employment and 10%-20% are classified as unemployed.

Table 2.2a: Occupation (in %) of the economically active population (UER and UWR)

District	Economic activity							
	Profes-sional and technical	Adminis-trative and manager-ial	Clerical and related workers	Sales workers	Service workers	Agriculture, incl. animal husbandry, fishery, and forestry	Production, transport and equipment	Other acti-vities
Builsa	2.6	0.1	0.8	8.5	2.7	75.2	9.1	0.8
Kasina-Nankani	3.5	0.1	1.4	9.2	5.6	68.7	10.4	0.9
Bongo	2.6	0.1	0.5	6.8	2.3	57.9	29.3	0.3
Bolgatanga	4.3	0.2	2.8	10.6	5.7	50.6	24.8	1.0
Bawku West	1.9	~ 0	0.5	5.1	2.0	84.7	5.4	0.2
Bawku East	2.2	0.1	1.3	11.3	3.2	71.9	9.4	0.5
Wa	4.7	0.2	2.6	8.5	4.2	66.6	12.0	1.1
Nadowli	3.4	0.1	0.6	1.7	3.3	71.1	19.6	0.2
Sissala	2.8	0.1	0.8	2.9	2.9	84.2	5.5	0.6
Jirapa-Lambusie	2.9	0.1	0.9	3.1	4.7	80.0	8.0	0.4
Average for UER & UWR	3.1	0.1	1.3	6.8	3.7	71.0	13.4	0.6

Table 2.2b: Occupation (in %) of the economically active population (Northern Region) [i]

District	Economic activity							
	Agriculture and forestry	Fishing	Mining and quarrying	Manu-factur-ing	Wholesale and retail trade	Con-struc-tion	Hotel and restau-rants	Services, and other activities
Bole	78.8	0.8	1.1	7.6	4.3	0.7	0.7	4.9
West Gonja	78.3	5.0	0.7	4.3	3.5	0.4	0.7	6.1
Gushiegu-Karaga	81.6	0.9	1.0	4.2	4.7	0.5	1.2	4.8
Savelugu-Nanton	62.2	1.9	0.5	14.8	10.3	1.0	1.7	7.5
Tamale	31.2	2.2	1.0	14.4	24.3	4.3	3.2	17.4
Tolon-Kumbungu	75.7	1.4	0.6	6.9	6.0	0.7	1.4	6.3
West Mamprusi	77.4	2.1	0.5	5.6	5.8	0.9	0.9	6.7
East Mamprusi	77.3	1.0	1.0	5.7	4.1	0.4	0.8	8.8
Average for Northern R.	70.3	1.9	0.8	7.9	7.8	2.2	1.3	7.8

[i] *East Gonja and Yendi districts omitted due to their less than 1% contribution to the basin (in area and population)*

2.1.4 Land use pattern and ecological trends

The original ecology of the White Volta River Basin was moist Guinea savannah with a considerable cover of broad-leaved trees forming closed canopy of branches in some places. It was relatively rich in species of flora and fauna (teeming game of browsing and grazing animals that were in ecological balance with the vegetation). Human activities through time have significantly modified this fragile ecology. A marked deterioration in the ecology has been realised in the basin within the past 10-20 years. The forested area and tree cover has thinned considerably leading to significant increase in the area coverage of what is classified as open savannah woodland.

At present the vegetation of the basin consists of shorter grasses and a few fire-resistant trees. This kind of vegetation has resulted mainly from prolonged grazing, burning and cultivation. Two physiognomic types of savannah may be recognized in the White Volta Basin. The north-eastern corner of the basin has been so disturbed by intensive farming that few trees remain apart from the baobab (*Adansonia digitata*).

The traditional savannah woodland with light canopy which characterized the greater part of the area has gradually been replaced with a type of open savannah with scattered trees that rarely form closed canopy. Annual bushfires have acted to influence the dominance of grasses to the detriment of the former woodland. What remains of the original vegetation occurs along the wetter banks of rivers and streams as gallery forest and in fire protected forest reserves.

Food crop farming and cattle grazing constitute the predominant agricultural activities in the basin. Farming is intensive (compound farming system) and requires less land than bush fallow. Large numbers of chickens and guinea fowls are also kept by the farmers. The farmers produce mainly food crops such as rice, millet, guinea corn, beans and groundnuts.

From various perspectives, the water resources are under pressure in the dry, low-flow season. Original people settled in the valley bottoms where adequate supplies of water ensured plentiful harvests. Soil fertility in the valley bottoms declined over time, forcing the populations to settle on watersheds placing the water resources under siege. The introduction of sizeable irrigation schemes, e.g. at Tono, Vea and Botanga, lead to large scale cultivation of tomatoes, rice, sorghum and fibre plants.

Map 3 (inserted at the end of the chapter) provides a simplified overview of the land use/cover situation as derived from satellite image maps produced in the year 2000. From similar image maps representing the year 1990, Table 2.3 summarises the development in area coverage of the forested land and other zones described above as it has occurred during this ten-year period.

Table 2.3: Development in land use/cover of the White Volta River Basin (1990-2000)

Year	Forested area	Savannah woodland	Arable land	Settlements and build-up (bare) areas	Unclassified and water bodies
1990	18%	29%	51%	0.2%	1.8%
2000	8%	40%	51%	0.5%	0.5%

2.1.5 Protected areas

Forest Reserves

The White Volta Basin has several (28) forest reserves of various sizes, the largest being the Gambaga Scarp Forest Reserve, which are administered by the Forest Service Division of the Forestry Commission. Although these are protected areas, bushfires and illegal logging and encroachment have led to significant reductions in vegetation cover and in the tree species populations.

Mole National Park and Gbele Resource Reserve (Game Production Reserve)

The Mole National Park is by far the largest protected area in the White Volta Basin. It is a major tourist destination in Ghana. Its park-like vegetation is home to a wide range of vulnerable and endangered fauna. Notable among these are the charismatic animals such as the African elephant (*Loxodonta africana*), the lion (*Panthera leo*), the leopard (*Panthera pardus*) and the African wild dog (*Lycaon pictus*). In addition to these are several large antelopes e.g. the Topi or Sassaby (*Domaliscus lunatus*). These animals are globally endangered and enjoy complete protection status under Ghana's wildlife regulations.

The Gbele Resource Reserve is considerably smaller in size compared to the Mole National Park, but it is also home to the leopard and the endangered red-fronted gazelle (*Gazella ratifrons*). The Mole National Park and the Gbele Resource Reserves are managed by the Wildlife Division of the Forestry Commission. Habitat destruction, through bushfires, is a major threat to the existence of these two important tourist destinations in the basin.

The forest reserves and parks are indicated on Map 4 (inserted at the end of the chapter).

2.1.6 Flood hazards

Flooding has been identified as one of the major water management problems in the basin (WRC, 2000[7]). Recent devastating floods in the basin include the 1994, 1999 and 2007 floods. In the 1999 floods, for example, the WRC study indicates that 52

[7] *Water Resources Commission: Water Resources Management Problems Identification, Analysis and Prioritization Study. CSIR-Water Research Institute (September 2000).*

lives were reported lost in the northern regions of the country with an estimated USD 21 million required to rehabilitate flood victims in those areas. The floods experienced in September 2007 have been the most widespread and devastating of the recent floods in the basin. Map 5 (inserted at the end of the chapter) provides an overview of the areas which were inundated at that time[8]. From the GIS produced map it has been calculated that approximately 2,600 km^2 of land adjacent to the main river and its tributaries became flooded in September 2007, equivalent to some 5% of the entire White Volta Basin area.

According to UN Integrated Regional Information Networks[9], NADMO and Ministry of Interior, figures indicate that a total of nearly 266,000 people in the 3 northern regions were affected by the 2007 floods with 22 reported deaths, over 11,000 destroyed homes and more than 12,000 ha of farmland destroyed in the UER alone. Government estimates for immediate aid to the 3 regions were reported to be nearly USD 48 million. Additionally, in all these floods the threat to human health through pollution of potable water sources such as boreholes/wells have also been significant.

The causes of the devastation to people and property from flooding in the basin were identified in the WRC (2000) report to include lack of flood control measures upstream coupled with the growing trend of settlements, farms and other properties being located in flood plains of the rivers, low lands and valleys. Since the human and socio-economic costs of the effects of these recurrent floods in the basin are indisputably high, it is important to get started on implementing at least some of the intervention measures proposed in the WRC (2000) report. These measures include:

- constructing a flood retention reservoir on the White Volta River near the border with Burkina Faso;
- undertaking flood flow/inundation studies in the basin in order to provide the necessary information for establishment of warning systems for flood control;
- enforcing set-back zones from river banks, and discouraging settlements, farms and other properties in flood plains and lowlands.

2.2 Water resources

2.2.1 Meteorological characteristics and impact of climate change

Meteorological conditions

Data concerning the meteorological conditions are obtained from the Ghana Meteorological Agency, which operates a number of climatologic, synoptic and rainfall stations in the basin. The location of these monitoring stations is indicated on Map 6 (inserted at the end of the chapter).

The White Volta River Basin falls under the tropical continental or interior savannah climatic zone characterised by a uni-modal rainfall regime. The rainy season extends

[8] *Map produced as a simplified representation based on information available from satellite images map produced by UNOSAT and UNITAR (United Nations Institute for Training and Research) using Modis Terra data recorded on 12-16 September 2007.*
[9] *UN Integrated Regional Information Networks (IRIN) News: Ghana: Floods displace 'nearly 275,000' in little-known disaster (September, 2007). http://www.irinnews.org/Report.aspx?ReportId=74278*

from April to October, peaking in August or September. This is followed by a prolonged dry season from November to March. These features can be observed in Table 2.4, which is a summary of monthly rainfall data at the Navrongo and Tamale meteorological synoptic stations.

Table 2.4: Mean monthly rainfall (mm), Navrongo and Tamale (1961-2005)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Navrongo met. Station												
1	3	15	53	100	132	189	270	165	51	4	2	985
Tamale met. Station												
4	9	44	84	122	154	159	201	219	86	10	3	1,095

Both the spatial and temporal distributions of rainfall in the basin are high. The meteorological statistics show that the mean annual number of rainy days is between 60 and 90 days. The annual rainfall increases southwards and ranges between 950 mm and 1,150 mm. The mean annual rainfall distribution over the basin is also shown on Map 6.

The 1961-2005 meteorological data at the synoptic stations in Navrongo and Tamale indicate that the White Volta Basin is characterised by uniformly high temperatures throughout the year with a mean annual temperature of about 28°C. The months of March and April are the hottest periods with a temperature of about 32°C. August is the coolest month with a mean temperature of about 26°C. Diurnal variations of 5^o-7^oC from the mean are observed in the basin.

The meteorological data also show that relative air humidity in the basin ranges from an average of 20%-30% in the driest months to about 80% in the rainy season. The mean annual potential evapotranspiration exceeds mean annual rainfall in the entire basin. It varies from about 1,950 mm in the northern part of the basin to about 1,650 mm in the south.

Climate change impact

In a study by the Environmental Protection Agency[10] the impacts of likely climatic changes on river discharges (runoffs) were analysed for the country. One of the basins included in the study was the White Volta River Basin. It is imperative that the impacts and consequences cited in that study report are duly recognised in future water resources planning activities for the basin. The main findings of relevance for the further water resources management planning in the basin are:

- There was an observed increase in temperatures of about 1°C over a 30-year period, and reductions in rainfall and runoff in the historical data sets.

[10] *Environmental Protection Agency (EPA): Climate Change Vulnerability and Adaptation Assessment on Water Resources in Ghana (February 2000).*

- Simulations using realistic climate change scenarios (10-20% change in rainfall and a 1-2°C rise in temperature over the respective values for the base period 1961-1990) indicated reduction in runoffs of about 15%-20% over the coming 20-year period.
- The climate change scenarios also showed a reduction in groundwater recharge at a rate of some 25% during the same period.
- Irrigation water demand would be affected considerably by the simulated climate change scenario, and indications are that the present water requirement per unit area under irrigation could increase by a factor 2, i.e. double up during the coming 20-30 years.

2.2.2 Surface water availability

The White Volta River and its main tributaries – Red Volta, Kulpawn/Sissili, Nasia, Nabogo and Mole rivers – constitute a relatively evenly distributed surface water drainage network nested in the basin's relative flat terrain. The main White Volta water course became "more perennial" after 1995 due to the introduction of the Bagré dam in Burkina Faso. However, most of its main tributaries dwindle to hardly any or no flow in the dry season with only pockets of stagnant water remaining.

Water (hydrological) balance of the basin

Considering the flow generated within the Ghana section of the White Volta River Basin, a simplified annual water (hydrological) balance has been set up aimed at estimating the basin's annual runoff Q as follows:

$$Q = RF - AET - GWR$$

where RF is rainfall, AET is actual evapo-transpiration, and GWR is groundwater recharge – all parameters expressed in mm and calculated on an annual basis to be representative of the basin as a whole.

In the simplified annual water balance calculations, it is assumed that contributions from groundwater to river flow (base-flow) and vice-versa is negligible, and thus, not included, and likewise that long-term fluctuations (year-to-year) basin storage volumes are not taken into consideration either.

The parameters have been estimated based on a number of criteria and assumptions as outlined in the following:

- The average annual basin rainfall has been calculated based on the rainfall distribution as depicted on Map 6 weighted according to representative size of basin area, and found to be 1,050 mm.
- The actual evapo-transpiration has been derived from study findings made available by the Northern Ghana Hydrogeological Assessment Project (HAP)[11], which used the Penman-Monteith equation to estimate the AET at 5 meteorological stations fairly well distributed in and around the basin. Subsequently, an area-based weighting of the 5 discrete values was applied to arrive at a representative value for the entire basin as shown in Table 2.5.

[11] *Final workshop to present results obtained during first phase (2006-2008) of the Northern Ghana Hydrogeological Assessment Project (HAP), CIDA/HAP-WRC, April 2008*

- The groundwater recharge rate for the basin was estimated as a weighted average of recharge rates also obtained from HAP, which applied the Soil Moisture Balance method at the same five 5 stations. These values are also shown in Table 2.5.
- The total area of the White Volta River Basin is 50,000 km^2.

Table 2.5: Estimates of annual actual evapo-transpiration (AET) and groundwater recharge (GWR), White Volta River Basin

Station location	Representative area (km^2)	AET (mm)	AET weighted average (mm)	GWR (mm)	GWR weighted average (mm)
Navrongo (UER)	11,000	798	878	65	70
Wa (UWR)	9,000	866		15	
Tamale (NR)	8,000	913		34	
Yendi (NR)	17,000	910		133	
Bole (NR)	5,000	908		27	

Table 2.6 provides a summary of the elements in the water balance. Taken as an average for the entire basin within Ghana, it is found that some 83%-84% of the rainfall goes back to the atmosphere as evapo-transpiration, 6%-7% infiltrates down to the aquifers to recharge the groundwater resources, and the remaining nearly 10% ends up as surface water runoff.

It should be reiterated, though, that this water balance calculation presents a simplified situation incorporating rather crude assumptions. For instance, calculations are made directly at the stations without spatial data interpolation, and upper soil layers are assumed to act as a single reservoir and also that variations in the hydraulic properties of the different soil classes are not considered. Further, a constant (uniform) runoff coefficient has been applied at all 5 locations. Nevertheless, it is judged that the presented water balance provides a realistic measure as to the relative size of the elements of the basin's hydrological cycle.

From Table 2.6 it can be seen that on an annual basis, the average "yield" of the White Volta River Basin (surface water availability) amounts to 5,100 million m^3. By using this basin runoff, the annual flow volumes at various points along the river and for some of the main tributaries have been estimated (calculated on the basis of sub-basin area) as listed in Table 2.7. It should be noted that these runoffs pertain to flows generated in the country only and do not include external cross-border flows entering from Burkina Faso.

Table 2.6: Annual water balance for White Volta River Basin

Water balance component	Specific value	Volume	Proportion

	(mm)	(million m^3)	of rainfall
White Volta Basin, total area: 50,000 km^2			
Annual mean rainfall (RF)	1,050	52,500	-
Annual actual evapo-transpiration (AET)	878	43,900	83.6%
Annual recharge to groundwater (GWR)	70	3,500	6.6%
Surface runoff (Q=RF-AET-GWR)	102	5,100	9.8%

Table 2.7: Mean annual flow volume, White Volta River system (runoff generated in Ghana only)

Locality/sub-basin	Area of sub-basin (km^2)	Mean annual runoff (million m^3)
White Volta at Pwalugu	4,130	420
White Volta at Nawuni	34,500	3,520
White Volta at Daboya	38,900	3,970
Red Volta sub-basin	420	43
Nasia sub-basin	5,400	550
Nabogo sub-basin	2,730	280
Kulpawn sub-basin	9,310	950
Sissili sub-basin	5,220	530
Mole sub-basin	6,020	610
Total White Volta River Basin	**50,000**	**5,100**

Runoff statistics

Recorded flow data and information on runoffs are obtained from the Hydrological Services Department, which operates a number of river gauging stations in the basin. The locations of these monitoring stations are indicated on Map 6. Though there are many gaps in the existing hydrological data, their quality is still good enough for extracting general information on the flow characteristics of the White Volta River.

The flow regime of the river exhibits a marked variability in the seasonal runoff within the year as well as in the annual flows. These features are highlighted below using streamflow data from the Daboya gauging station in the downstream section of the White Volta River. The discharge record used represents the flow regime after commissioning of the Bagré Dam in Burkina Faso in 1995.

Table 2.8 depicts the average monthly runoff as well as the average monthly maximum and minimum values, whereas Figure 2.1 presents a graph based on the daily flows as recorded in 2006 (as an example). The distinct, skewed temporal distribution of the White Volta River runoff within a year is clearly detected from these presentations. It is worthwhile noting that statistically about 80%-85% of the total annual runoff occurs during a span of only 3 months, i.e. from August to October.

Furthermore, it can be mentioned that the mean dry season flows have increased appreciably and with hardly any variability following introduction of the Bagré Dam. For the low-flow period covering the months of January to April, the mean monthly flows was 8.9 m^3/sec before 1995, whereas the value for the same period after the dam was built is found to be 27.1 m^3/sec (figure derived from Table 2.8), i.e. a tripling in the average low-flow runoff.

Table 2.8: White Volta River mean monthly flows (1997-2007) at Daboya (m^3/sec)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean	26.8	25.4	24.7	31.5	42.6	84.6	151.1	469.2	910.8	518.0	71.2	35.1
Max.	48.7	52.7	37.5	45.6	89.0	189.2	309.9	903.8	1612.4	1028.5	151.8	56.1
Min.	6.8	7.2	5.5	19.3	19.7	43.7	59.0	182.3	479.3	168.5	36.9	18.2

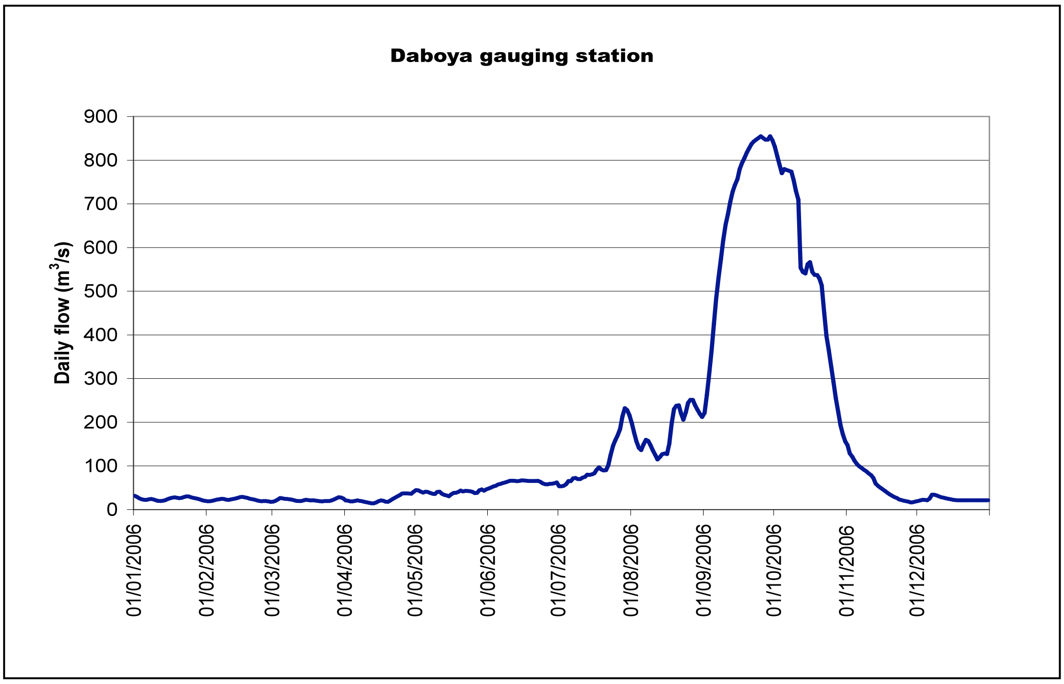


Figure 2.1: White Volta River daily flows (2006), Daboya gauging station

Figure 2.2 provides a graphical representation of the annual runoff as recorded at Daboya. The average annual volume of flow at Daboya during the 1997-2007 period is recorded as 6,335 million m^3, equivalent to 201 m^3/sec. It can be derived from the graph that widespread flooding in the White Volta River system occurs when the annual runoff approaches 10,000 million m^3, as it happened in 1999 and 2007.

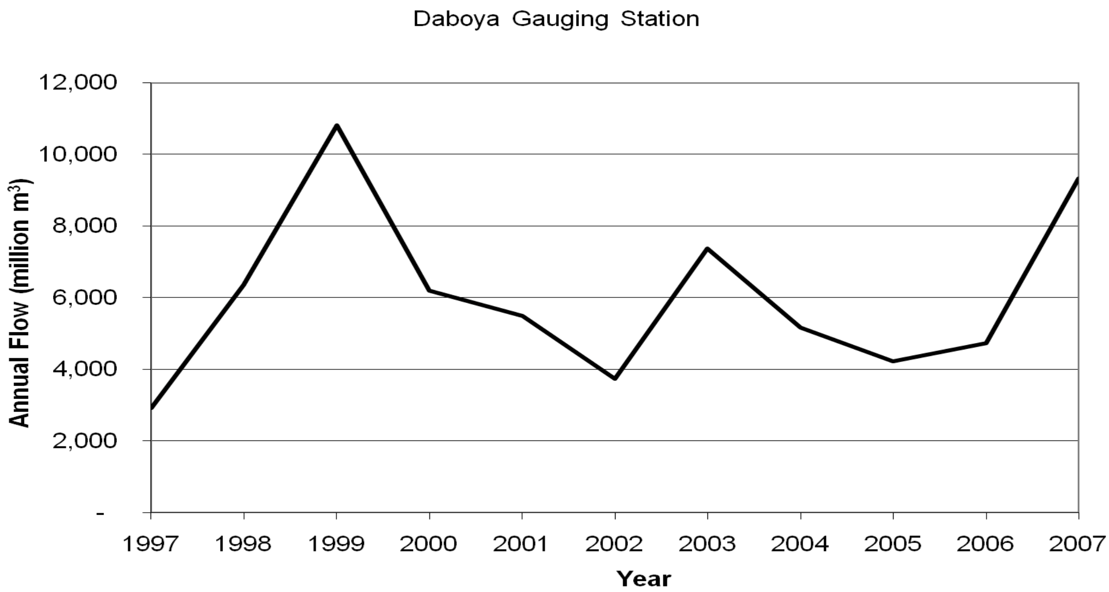


Figure 2.2: White Volta River annual runoff (1997-2007) at Daboya

Flow reserve for downstream uses

Hydropower generation at Akosombo Dam and Kpong power stations:

It must be recognised that any abstractions from the White Volta River system – in particular the purpose of irrigation due to its potential magnitude – will have an impact on the inflow into the Volta Lake and cause a reduction in the hydro-electric output from the Akosombo Dam and Kpong power stations. It is evident, therefore, that in the future a balance has to be struck between further development of irrigated-based agro-industries upstream and the role of the White Volta water resources in the generation of hydropower as a contributor to the Volta Lake.

It can be argued that the water resources of the White Volta system as defined in this document are constraint to the north by the water uses and management practices in Burkina Faso, and to the south by requirements for downstream flow to maintain the river as an important element of the water balance of the Volta Lake and the national economic implications by virtue of the hydropower generation at the power stations downstream.

Environmental flow requirements:

The low-flow regime of the White Volta River itself has improved as a result of the upstream Bagré Dam operations. This should have a marked positive impact on the flora and fauna associated with this part of the surface water system. However, the increased low-flow regime is also seen by people as a good opportunity for an accelerating expansion of the dry season irrigation activities along the banks of the White Volta River. If not checked, this development could eventually lead to quite serious consequences on the dry season flows and, hence, on the aquatic ecosystems associated with the river if not properly managed.

Guided by the IWRM principles and using well targeted procedures in the assessment and evaluation of applications for water abstraction permits (particularly dry season abstractions), WRC should be able to safeguard that the requisite environmental flows both in quantity and quality for aquatic ecosystems maintenance are available also in the future.

2.2.3 Cross-border flow

Considering the trans-boundary character of the White Volta Basin, it is of interest to know to which extent Burkina Faso and Ghana, respectively, contribute to the total annual runoff of the river as recorded at its downstream section before Volta Lake.

For this purpose recorded flows at the following 4 gauging sites have been utilised:

- Yarugu on White Volta close to the national border;
- Nangodi on Red Volta close to the national border;
- Nakong on Sissili close to the national border; and
- Daboya on White Volta before the Mole tributary confluence (being the last gauging station with reliable runoff data recorded before Volta Lake).

The flow records show that the last four years, i.e. 2004-2007, provide an unbroken data series for all the stations, and hence this period is used below.

The mean monthly and annual flows calculated for the downstream Daboya station and the combined cross-border flow from Burkina Faso contributed by the White Volta (Nakanbé in Burkina Faso), the Red Volta (Nazinon in Burkina Faso) and the Sissili rivers are presented in Table 2.9. Additionally, the contribution expressed as a percentage of the flow recorded at Daboya is also given in the table.

Table 2.9: Cross-border flow compared to Daboya (2004-2007)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Daboya flow (m^3/sec)	26.9	23.4	25.2	30.4	52.9	84.2	161.4	458.3	905.3	364.6	58.2	33.0	185.3
Cross-border flow (m^3/sec)	10.3	11.4	10.8	22.6	33.1	47.9	116.4	154.5	150.3	33.4	21.9	19.1	52.6
Cross-border flow (%)	38%	49%	43%	74%	63%	57%	72%	34%	17%	9%	38%	58%	28%

As seen in the table, the average annual runoff at Daboya gauging site during 2004-2007 was 185.3 m^3/sec, equivalent to an annual flow of 5,840 million m^3, and the cross-border flow was 52.6 m^3/sec, equivalent to a volume of 1,660 million m^3. This means that 4,180 million m^3 was generated in the Ghana part of the White Volta Basin on an annual basis (2004-2007), excluding the current water supply abstractions (irrigation, livestock and domestic demand), which are some 70 million m^3 per year. In conclusion, the internally generated amount of water as measured at Daboya is rather some 4,250 million m^3 per year.

It can be noted that this figure matches well with the value of 3,970 million m^3 given for Daboya catchment in Table 2.7, which was calculated "theoretically" using a (hydrological) water balance method with rainfall statistics and estimated values for actual evapo-transpiration and groundwater recharge providing the parameters in the equation.

Another interesting feature in the pattern of the cross-border flow is the fact that the percentage contribution (28% on an annual basis) shows marked differences between the seasons. During the high-flow months of August-September-October the contribution is at around 20% in average, whereas during the dry-period, i.e. the rest of the year, it is at 60% in average. This latter characteristic is to a large extent attributed to the steady release of water for hydropower generation at Bagré Dam in Burkina Faso.

Finally, it can be mentioned that of the three trans-boundary rivers, the White Volta (Nakanbé) river is by far the most important in terms of its contribution to the flow from Burkina Faso. It provides around 80% of the total cross-border flow, and this is in spite of the fact that the catchment areas of the Red Volta (Nazinon) and Sissili in Burkina Faso combined is about half the size of the Nakanbé catchment. Similarly as above, this feature can primarily be explained by the augmented low-flow regime created downstream of the Bagré Dam.

2.2.4 Groundwater resources

Geology and aquifer systems

The geology of the White Volta Basin is composed of about 45% crystalline rocks of the Birimian system and its associated Granitic intrusives, and isolated patches of Tarkwaian formations, and 55% Voltaian systems consisting of the Upper Voltaian sandstone, Obosum and Oti beds and Basal sandstone. Map 7 (inserted at the end of the chapter) depicts in summary form the geology of the White Volta River Basin.

The Birimian system or crystalline basement complex occurs mainly in the western and north-eastern parts and are the oldest rock units in the basin. The series occurs in two stratigraphic successions – the Upper and Lower Birimian. The Upper Birimian is the dominant rock formation and consists of metamorphosed lavas and pyroclastic rocks. The Lower Birimian consists of phyllites, schists, tuffs and greywackes, and is dominant in the western part of the basin. The Birimian system is intruded by Granitoids of uncertain age, but which are believed to be of post-Birimian and pre-Tarkwaian age. These Granitoids occur mainly in the northern and western parts of the basin.

The Voltaian systems comprise of sandstones, shales and mudstone beds, and rest on the Birimian, the Granite and Tarkwaian formations. They extend over a large part of the central, eastern and southern portions of the basin and are considered to be of late Precambrian to Paleozoic age. Three main stratigraphic subdivisions of the Voltaian systems occur in the basin - the Basal sandstone, the Upper Voltaian and Obosum beds. The Basal sandstone is mainly a quartz sandstone formation about 75 m thick occurring at the northern and western peripheries of the Voltaian system. It overlies the Upper Birimian in the north and the Lower Birimian in the west. The Upper Voltaian consists of thin bedded quartzitic and micaceous sandstones. These occur mainly towards the northern and western margins of the Voltaian system and form approximately 30% of the system within the Basin. Obosum beds comprise of argillaceous sandstones, arkose, siltstones, interbedded mudstone, sandy shale and conglomerates. They form about 55% of the Voltaian system within the basin and occur mainly to the south, south-east and the central parts of the basin.

Both the Birimian formation and its associated granite intrusions as well as the Voltaian formation are characterised essentially by little or no primary porosity. Therefore, groundwater occurrences are associated with the occurrence of secondary porosities caused by fracturing, faulting, jointing and weathering. The development of secondary porosity has given rise to two distinct types of aquifers in the White Volta River Basin, viz. the weathered zone aquifers and the fractured zone aquifers.

The weathered zone aquifers usually occur at the base of the thick weathered layer and are either phreatic or semi-confined to confined depending on the permeability of the upper weathered layer.

The fractured zone aquifers tend to be more localized in nature, and groundwater occurrences are controlled by the degree of fracturing and the nature of groundwater recharge. Borehole yields within the fractured zone are determined by the extent and degree of fracturing. A formation which combines a thick weathered zone with a well fractured bedrock zone provides the most productive aquifer situation.

Hydrogeological data from existing boreholes

Based on data and information available from the existing boreholes in the basin as compiled by HAP (2008)[12], Table 2.10 below summarises the statistical evidence related to occurrence and potential rate of groundwater abstraction in the basin.

The mean yield as calculated from a total of more than 1,400 existing boreholes with yield data available in the White Volta River Basin is 3.7 m^3/hour.

Furthermore, the available borehole records also show that the drilling success rate, i.e. the chances of striking water of sufficient quantity and quality, in average is around 70% in the Crystalline Basement Complex and around 50% in the Voltaian formations.

It has been estimated that in most parts of the basin, current groundwater production is less than 1% of estimated recharge. Production is still less than 5% of recharge even in areas such as the north-eastern part of the basin, where groundwater abstraction is relatively high (Martin and van de Giesen, 2005)[13]. Bawku municipality and environs are served by the largest groundwater-based supply scheme in the basin

[12] *Derived from results obtained during first phase (2006-2008) of the Northern Ghana Hydrogeological Assessment Project (HAP), CIDA/HAP-WRC, April 2008*

[13] *Martin, N. and van de Giesen, N. Spatial Distribution of Groundwater Production and Development Potential in the Volta River basin of Ghana and Burkina Faso. Water International, Volume 30, Number 2, Pages 239–249, June 2005.*

with close to 1,400 m^3/day supplied from a total of 5 boreholes currently in operation.

Table 2.10: Borehole characteristics in White Volta Basin

Geological zone	Depth of borehole (m)		Depth to aquifer top (m)		Borehole yield (m^3/hour)	
	Range	Mean	Range	Mean	Range [(i)]	Mean
Birimian Formation	10 – 104	43.6	1 – 81	24.5	0.6 – 12.0	3.1
Voltaian Formation	6 – 180	54.2	1 – 72	17.3	0.5 – 18.0	4.1

(i) Yield range given as probable (95%) of occurrence, i.e. the interval excludes the 5% lowest and highest recorded yields to avoid "outliers".

It can be concluded that considerable groundwater reserves are available for domestic water supplies and other uses. To obtain optimal utilization of the basin's groundwater resources, it is imperative that groundwater schemes are based on state-of-the-art hydrogeological assessment methods, efficient borehole siting techniques as well as proper design, construction and development (including hydro-fracturing) of the boreholes.

2.3 Utilisation of water resources in the basin

2.3.1 General overview of water supply situation

The White Volta River and its tributaries constitute a major source of water supply to communities within the basin. However, most streams in the basin, including major tributaries, either dry up or have very little flow in the prolonged dry season. During this period, the bigger irrigation dams, and numerous small reservoirs and dugouts, which exist in the basin, become an (unprotected) source of water for many people.

Groundwater resources also serve as an important source of supply for the basin's population, particularly in the rural areas, but some piped urban water supply schemes also rely on groundwater.

Table 2.11 provides an overview of the existing water supply situation and shows for each district within the basin, the main source of drinking water as derived from the 2000 Census, i.e. with the quoted percentages representing the entire district.

Table 2.11: Main source of drinking water (in % of households)

District	Pipe-borne supply	Well	Borehole	Spring/rain water harvesting/ river/stream	Dugout	Other
Builsa	7.7	50.4	28.0	11.5	1.8	0.6
Kasina-Nankana	10.5	23.0	47.8	16.2	1.8	0.7

Bongo	6.1	22.8	47.4	18.2	4.8	0.7
Bolgatanga	22.3	21.8	38.2	13.7	3.2	0.8
Bawku West	9.7	48.6	26.6	12.7	1.6	0.8
Bawku East	11.3	38.0	30.0	16.9	2.6	1.2
Wa	22.3	13.1	34.9	20.7	7.8	1.2
Sissala	15.5	6.9	53.4	21.3	2.1	0.8
Jirapa-Lambusie	9.4	12.8	58.2	15.8	3.2	0.6
Nadawli	5.9	6.7	60.7	23.9	2.4	0.4
Bole	10.5	6.4	48.6	24.7	9.0	0.8
West Gonja	10.8	10.5	8.1	42.1	28.0	0.4
Gushiegu-Karaga	2.3	9.2	25.5	27.3	35.2	0.5
Savelugu-Nanton	10	3.7	15.4	19.3	50.6	1.1
Tamale	78.9	1.7	0.6	2.8	11.6	4.5
Tolon-Kumbungu	21.5	7.1	2.1	13.7	54.6	0.9
West Mamprusi	3.2	28.8	21.6	42.1	4.0	0.4
East Mamprusi	0.9	70.6	9.0	14.6	4.5	0.4
Overall for basin	**15.1**	**22.9**	**28.7**	**18.4**	**10.8**	**4.0**

To assess the existing water supply situation for the White Volta Basin as a whole, by means of a weighted average figure for each water source category (last row in Table 2.11), the percentages for the districts have been applied against the proportion of the respective district population living within the basin boundary.

The figures in Table 2.11 show that about 44% of households in the basin (2000 Census data) have access to potable water (combining piped and borehole supplies), though pipe-borne water reaches only 15% of households.

There are marked contrasts between the 3 regions in the basin as to the levels of coverage of potable water supply. While on the average the UWR has more than 63% coverage, the UER has about 50% and the NR only 39% coverage. If wells are included in the potable water category, the basin's water supply coverage becomes 67% while the regional coverage is 74%, 81% and 52% for the UWR, UER and NR, respectively. Lastly, the figures in the table reveal the well known fact that pipe-borne water supply in the basin is available more to the urban than to the rural households.

2.3.2 Urban water supply

Pipe-borne schemes with abstractions in the basin

Presently, in the White Volta River Basin a total of 19 pipe-borne systems are in operation serving urban communities utilising water from abstraction points within the basin. The schemes have a total installed capacity of 32,000 m^3/day or 11.7 million m^3/year. Table 2.12 provides a list of these schemes including information about source, intake, treatment capacity (where available) and abstraction rates as obtained from the individual water plants' statistics and from abstraction licences issued by the WRC in 2007. The water supplied is used mainly for domestic, industrial, commercial and institutional purposes.

Table 2.12: Piped water supply schemes with abstractions in White Volta Basin (2007)

Water supply scheme	Source	Intake	Treatment capacity m^3/day	Abstraction	
				m^3/day	million m^3/year
Pusiga	Groundwater	1 borehole		164	0.06
Garu-Tempane	Groundwater	1 borehole		65	0.02
Bawku	Groundwater	5 boreholes		1,363	0.50
Binduri	Groundwater	1 borehole		60	0.02
Bolgatanga	Surface water	Dam	7,400	2,777	1.01
Zuarungu	Groundwater	2 boreholes		120	0.04
Nalerigu	Groundwater	1 borehole		100	0.04
Gambaga	Groundwater	1 borehole		360	0.13
Gushiegu	Surface water	Weir	180	153*	0.06
Sirigu	Groundwater	1 borehole		82	0.03
Paga	Groundwater	1 borehole		130	0.05
Navrongo-Doba	Groundwater	10 boreholes		759	0.28
Chiana	Groundwater	1 borehole		40	0.01
Chuchuliga	Groundwater	1 borehole		200	0.07
Sandema	Groundwater	1 borehole		90	0.03
Tumu	Groundwater	3 boreholes		380	0.14
Tamale	Surface water	Weir	19,450	17,450**	6.37
Daboya	Surface water	Weir	180	153*	0.06
Walewale	Surface water	Weir	220	187*	0.07
Total				24,543	9.00

* *actual abstraction assumed to be 85% of treatment capacity*
** *it is estimated that about 10% of this abstraction is supplied to the part of Tamale's population living within the White Volta Basin boundary*

The figures in the table reveal that presently about 82% of the total abstraction of water for the urban supply schemes is for the Tamale and Bolgatanga water systems alone. In contrast, the groundwater supplied piped schemes of which there are 14 have a combined abstraction rate of 3,913 m^3/day equivalent to 16% of total piped-borne water abstractions.

By comparing the figures in Table 2.7 and Table 2.12, it can be concluded that on an annual basis utilisation of the surface water resources of the basin through abstractions for urban schemes presently amounts to less than 0.2% of the mean annual basin runoff.

Having pointed this out, it should also be emphasised that it is the low-flow regime of the river network, which determines its viability as a source for year-round water supplies (run-of-the-river scheme), i.e. direct abstraction without in-stream (or off-stream) storage capacity established. These important aspects are looked into in Chapter 3, where water demand projections and future water availability are assessed through analyses of future development scenarios.

Pipe-borne schemes with abstractions outside the basin

In addition to the schemes with abstractions located within the basin, a number of urban communities in the fringe portions of the basin are supplied by pipe-borne systems that take water from outside the basin boundary. These supply schemes are listed in Table 2.13. For instance, in the West Gonja District there are schemes with water sources in both the White Volta (the Daboya water scheme) and Black Volta (the Damongo water scheme) basins. On the other hand, the entire Tamale metropolitan area has its water supply system based on abstraction from the White Volta River, but only some 10% of Tamale's population resides within the basin boundary.

Furthermore, parts of the Tolon-Kumbungu District are also served by the Tamale water supply system. Therefore, the urban population of this district is added to that of the Tamale metropolitan area to determine the percentage urban coverage of the Tamale pipe-borne system.

Table 2.13: Piped water supply schemes with abstractions outside the White Volta Basin, but serving populations in the basin

Water supply scheme	Source	Intake	Treatment capacity m^3/day	Abstraction	
				m^3/day	million m^3/year
Bole	Groundwater	3 boreholes		490	0.18
Tinga	Groundwater	1 borehole		100	0.04
Damongo	Surface water (dam on tributary to Black Volta River)	Weir	220	127	0.05
Lambusie	Groundwater	1 borehole		110	0.04
Nandom	Groundwater	1 borehole		220	0.08
Hamile/Hapa	Groundwater	1 borehole		220	0.08
Jirapa	Groundwater	2 boreholes		150	0.05
Nator	Groundwater	1 borehole		137	0.05
Daffiama	Groundwater	1 borehole		150	0.05
Wa	Groundwater	10 boreholes		111	0.04
Total				1,816	0.66

Population served by pipe-borne schemes

By applying the GWCL used criteria for unit consumption figures, which are differentiated according to settlement sizes, as shown in Table 2.14, the number of people served by the schemes can be estimated. Adding the abstractions in Table 2.12 and 2.13, the piped water supply schemes can be found to serve a population of about

265,000 mainly in urban communities, i.e. people living in settlements larger than 5,000.

Table 2.14: Criteria for unit consumption figures for urban communities

Size of settlement	Less than 15,000	Between 15,000 and 50,000	Over 50,000
Unit consumption (l/capita/day)	55	85	105

However, if the "export" of water pumped to people living outside the basin is excluded, i.e. primarily the 90% of Tamale supply scheme's abstraction from the White Volta River, it implies that of the urban population residing within the basin itself some 115,000 are served by a piped water supply scheme. This number is equivalent to about 34% of the urban population of 341,300 in the basin (ref. Table 2.1).

It should be noted, though, that in the above estimation of the number of people being served, the un-accounted-for water, i.e. leakage and other distribution losses, has not been duly incorporated in the figures. This would imply that the proportion of the population served as given here is somewhat over-estimated.

The reasons for not being able to cater for the rather large "unmet" urban demand (66%) are attributable more to factors such as technical-economic and financial aspects in expanding the systems' capacities as well as the distribution network (the outreach) of the schemes than to scarcity of the water resource. Even the current low-flow regime of the White Volta River is not a limiting factor to the capacity of the surface water source. Under climate change conditions with envisaged reduced flows in the basin, storage facilities through construction of dams could provide enough surface water sources for urban water supply schemes. These aspects are elaborated further on in Chapter 3.

2.3.3 Rural water supply

As can be seen in Table 2.11, a sizeable proportion of the rural population of the White Volta Basin depend on the river system as the water source. However, through the implementation of accelerated programmes to improve the water supply situation of rural communities, groundwater is increasingly being exploited as better sources of rural water supply.

Estimates from available data at the CWSA indicate that as at 2006, there were about 3,600 boreholes and 800 hand-dug wells constructed in the basin to provide potable water to the rural communities. While most of these boreholes and wells are fitted with hand pumps and serve small communities, a number of mechanized boreholes with motor-driven pumps are also in operation to serve larger communities or clusters of small communities.

If it is assumed that a hand pump typically is used by the community members during a day equivalent to 8 hours of continuous pumping and that hand pumps in average have a design capacity of 10 litres/min, the abstraction rate at a water point can be estimated at 4,8 m^3/day. If it further is assumed that some 80% of the water points, i.e. 3,520, are operational with functioning hand pumps etc, it implies that these water points provide a total groundwater abstraction of some 17,000 m^3/day. Based on CWSA borehole design of 200 persons per water point, it means that some 700,000 people are being served at present, equivalent to about 45% of the basin's rural population of 1,570,100 (ref. Table 2.1).

2.3.4 Water for agriculture

Irrigation

As indicated earlier, the water resources of the White Volta is being used increasingly for irrigation, mainly for farming of rice and vegetables. The most prominent of the existing irrigation schemes in the basin are:

- Tono irrigation project in the Kasina-Nankana District (UER) with an irrigable area of up to 2,500 ha and a total annual water requirement of 40 million m^3;
- Vea irrigation scheme in the Bongo District (UER) with an irrigable area of up to 1,000 ha and a total annual water requirement of 8 million m^3;
- Bontanga irrigation scheme in the Tolon Kumbugu District (NR) with an irrigable area of up to 500 ha and a total annual water requirement of 11 million m^3;
- Integrated Tamale Fruit Company (ITFC), mango plantation, in the Savelugu-Nanton District (NR) with an irrigable area of up to 1,000 ha and a total annual water requirement of 4 million m^3.

Although adequate documentation on all existing irrigation schemes is not readily available, it is estimated that the above schemes make up the majority of water abstractions for irrigation in the basin presently. In realistic terms, it is assumed that the above schemes have included 80% of their respective irrigable areas for crop production, which implies that the actual water use of the 4 schemes combined is some 50 million m^3/year.

By adding to this abstraction an estimated 10% for the various "unaccounted-for" small irrigation systems, a total of 55 million m^3/year is estimated to represent the present utilisation of water for irrigation in the basin.

In this connection it can be noted that the Ghana Sugar Development Company proposes establishing a large-scale sugarcane irrigation scheme in the basin to abstract water directly from the White Volta River between the Nasia and Nabogo tributaries in the NR. In the first phase of the proposed project, direct water abstraction from the White Volta River up to a maximum of 9 m^3/sec during the low flow period would be made to irrigate 7,500 ha of sugarcane. The company is further planning for an additional abstraction of 10 m^3/sec to irrigate up to 15,000 ha of sugarcane in a second phase, which only can be realised in conjunction with the establishment of a storage facility[14].

Livestock

[14] *The Ghana Sugar Development Company has submitted (2007) to WRC a preliminary application for a water use permit, but further processing of the application is pending results of technical feasibility and environmental impact studies relating to the dam/ reservoir construction.*

For the purpose of defining the livestock (primarily cattle, sheep and goats) water use, information available in the EPA publication[15] has been used. It is indicated that the livestock population in the three northern regions was about 2.2 million in 1996. If it is assumed that this number now is 2.5 million and the unit water consumption per livestock head is 10-15 litres/day, it would imply that the present total livestock water requirement is about 31,000 m^3/day, equivalent to 11.3 million m^3.

2.3.5 Industrial water use

Within the supply areas of the urban pipe-borne schemes the water demand by industries, manufacturing and other commercial activities is included in the schemes' production figures and hence, in future expansion plans. It is further assumed that the water requirements for food processing etc. in connection with agro-industrial activities listed in Section 2.3.4 above are included in the agriculture (irrigation) demand.

2.3.6 Summary of water resources utilisation

Table 2.15 provides an overview of the existing utilisation (actual abstractions) of the water resources located within the White Volta Basin as derived from the above description.

Table 2.15: Water resources utilisation (2008), White Volta Basin

Category	Present (actual) abstraction		Source
	m^3/day	million m^3/year	
Potable (domestic, industrial and institutional):			
- urban water supply	24,540 $^{(i)+(ii)}$	9.0	surface water and groundwater
- rural water supply	17,000	6.2	mainly groundwater
Agriculture:			
- irrigation	458,330$^{(iii)}$	55.0	mainly surface water
- livestock	31,000	10.3	mainly surface water
Total for White Volta Basin	**-**	**80.5**	

(i) of this amount 15,700 m^3/day is "exported" and used outside the White Volta Basin (Tamale water supply).
(ii) an additional amount of 1,816 m^3/day is used within the basin, but "imported" from outside the basin.
(iii) daily abstraction figure calculated based on a 4-month irrigation season per year

It is evident from the table that the main water use is for irrigation purposes, which counts for close to 70% of all present abstractions, whereas abstractions for the domestic, industrial and institutional user categories together amount to a little less than 20%. The remaining good 10% is for livestock upkeep.

2.4 Water quality and pollution

[15] *Environmental Protection Agency (EPA): National Action Programme to Combat Drought and Desertification (April 2002).*

2.4.1 Water quality monitoring

The first regular water quality monitoring of the White Volta River started in 1974 at the beginning of the Onchocerciasis Control Program of the World Health Organisation (WHO). The programme continued until the biological monitoring programme ended in 2000. The programme monitored pH, conductivity, temperature, and infrequently, dissolved oxygen. The results showed that pH was slightly acidic and fluctuated around 6.6.

The Global Environmental Resources Management Programme (GERMP) also initiated a programme for monitoring the quality of the Volta River in the 1990s. However, the programme could not be sustained because of funding problems.

Recently, Goes[16] tested quality of the White Volta in both Ghana and Burkina Faso. In Ghana, the monitoring incorporated eight stations from Yapei at the inlet of the river into Volta Lake and upstream to the Bawku (at the Burkina Faso border road bridge). However, the laboratory analyses included only four physico-chemical parameters (pH, nitrate-nitrogen, electrical conductivity and water temperature), which all were comfortably below or inside the WHO recommended values. This monitoring effort was followed up by PAGEV in February 2008[17] with another monitoring exercise, which incorporated 9 parameters from 11 well water and 3 river water samples.

In the previous exercises the sampling sites were visited once and, thus, the results could only provide a "snapshot" picture of the water quality situation in the basin as it prevailed at that time. However – although initially only carried out for groundwater – a regular (continuous) water quality monitoring programme was initiated by WRC in 2005 through Danida support and subsequently amended through CIDA support in 2007. A total of 25 dedicated monitoring boreholes have been established in the three northern regions and are now included in the programme with water samples collected and analysed on a quarterly basis. Furthermore, as far as groundwater is concerned, a wealth of water quality information is also available from the water sampled and analysed as part of the previous drilling campaigns for various rural water supply programmes.

Against this background, HAP[18] has created a database in which all available – but thoroughly assessed and judged reliable – groundwater quality information is collated and presented thematically in table form and on GIS-based maps. So far under the HAP activities, the following data material (parameters) and area distribution maps have been produced:

- Arsenic (based on 60 samples)
- Chloride (based on 1,249 samples)
- Conductivity (based on 805 samples)
- Fluoride (based on 985 samples)

[16] *Goes, J.M.: Pre-Audit Report for the Volta River Basin, West Africa. PAGEV Project (2005)*
[17] *CSIR Water Research Institute: Physico-Chemical, Microbiological and Pesticides Analyses on Water Samples from the PAGEV Pilot Zone in Burkina Faso and Ghana. PAGEV Project (April 2008)*
[18] *Final workshop to present results obtained during first phase (2006-2008) of the Northern Ghana Hydrogeological Assessment Project (HAP), CIDA/HAP-WRC, April 2008*

- Iron (based on 1,091 samples)
- Manganese (based on 984 samples)
- Nitrate (based on 1,025 samples)
- pH (based on 1,375 samples)

It can be noted that this new WRC-HAP groundwater database includes data from a considerable number of boreholes, and hence provides a well documented basis for assessing regional trends/differences in the groundwater quality of the basin. The database is being updated regularly when new information becomes available.

It should also be mentioned that Ghana Water Company Limited conducts regular monitoring of the White Volta River water at the abstraction point at Dalon for the purpose of quality assurance of the potable water supplied.

2.4.2 Surface water quality

General overview

The White Volta River system has remained reasonably clean over the years. However, this may not continue to be so with the increasing usage of the surface water sources for irrigation purposes with the inherent risk of effluents containing likely pesticide residues to be discharged into the water courses.

Chemically, there are no "hot spots" detected from the more recent monitoring exercises that indicate trends towards eutrophication of the river. It is expected, though, that promotion of fertilizers in improved agronomy within the basin and the reactivation of the Pwalugu Tomato Factory among other developments will affect the quality coupled with increasing abstraction for irrigation as mentioned above.

Water Quality Index

The Water Quality Index (WQI) adopted by WRC in 2003, is used to facilitate comparison and to classify the extent to which the natural water quality is affected by human activities. The index is used to describe the state of water quality as a whole instead of looking at individual parameters and can provide indications as to the suitability of the water for various purposes. In the Ghanaian context, the methodology incorporates 10 selected key physical, chemical and microbiological determinants, and aggregates them to calculate a WQI value at specific water quality monitoring/sampling site. For obtaining a reliable "representative" WQI value of the water sample, it is advisable not to apply the methodology if the number of analysed parameters is below 8.

Based on the WQI value, the index classifies water quality into four categories as presented in Table 2.16, with a descriptive note given concerning the pollution level of the water body. The aim is to protect natural waters from pollution such that the water falls at least in the upper portion of Class II – and more desirably in Class I.

Table 2.17 presents as an example the result of WQI calculations carried out for the most recent water quality data available, which were sampled at three sites along the White Volta River in February 2008 (as given in the CSIR-WRI monitoring report cited above). All the required parameters were analysed in these samples except for suspended solid, i.e. the total maximum score is therefore 93 instead of 100 as also indicated in Table 2.17.

Table 2.16: Criteria for classification of surface waters

Class	WQI - range	Description
I	> 80	Good - unpolluted water
II	50 – 80	Fairly good quality
III	25 – 50	Poor quality
IV	< 25	Grossly polluted water

Table 2.17: Calculation of WQI at three sites, White Volta River (Feb. 2008)

Parameter	Laboratory analysis results			Maximum score
	Bagré Irrigation Intake site	Bagré irrigation Exit site	Hydro Kobore site	
Dissolved oxygen (% saturation)	95	91	91	18
BOD (mg/l)	2.1	2.8	2.6	15
Ammonia-nitrogen (mg/l)	0.022	0.094	0.068	12
pH	7.72	8.04	7.32	9
NO_3-N (mg/l as N)	0.741	1.31	0.314	8
Faecal coliform (counts/100 ml)	4	100	8	12
PO_4-P (mg/l as P)	0.087	0.034	0.048	8
Suspended solids (mg/l)	-	-	-	(7)
Elec conductivity (µS/cm)	58	61	76.2	6
Temperature (°C)	21.3	22.9	23.5	5
Total Score - S (%)	85	84	87	93
WQI = S^2 / 93	**77.7**	**75.9**	**81.4**	

The WQI values calculated for the sites along the White Volta River reflect the fact that the surface water source can be classified as mostly good (upper part of Class II) to even good/unpolluted (Class I). Not surprisingly, the lowest WQI value in these samples is obtained from the water just downstream of the Bagré irrigation scheme, whereas the river water apparently "recuperates" as the water flows downstream and is subject to some self-purifying effect.

Trace metals and micro-organic pollutants

Apparently, no screening of trace metals in the surface waters of White Volta is currently ongoing. The same may be said for organic pollutants. Thus, it is necessary that a structured programme for monitoring of micro-organic pollutants and trace metals be undertaken to trace these compounds in sediments and biota of the river.

2.4.3 Groundwater quality

As noted in section 2.4.1, the recently established WRC-HAP groundwater database provides a tool for obtaining an overview at the basin level, in this case of the groundwater quality situation, which has not been possible before. In summary it can be stated that the quality of the groundwater is good with some exceptions as outlined below:

- Chloride levels of above 250mg/l (WHO "aesthetic" guideline value) are found in some groundwater samples in the Voltaian formation in the Northern Region, particularly in Tolon-Kumbungu, West and East Mamprusi, and Gushiegu districts. Of the sampled 1,249 boreholes 3.5% had chloride level above this value.
- Generally for the basin, the pH level falls within an acceptable range of 6.5 to 8.5, with only a few cases, e.g. in the northern part of West Gonja District, where groundwater of acidic character is found.
- The concentration of nitrate in borehole water is used as an indicator of groundwater pollution. The nitrate levels in most parts of the basin fall within the WHO recommended level of 50 mg/l with a tendency of higher nitrate concentrations in the groundwater found in the Birimian formation, particularly in the south-western part of the Upper West Region. However, only 0.2% of the 1,025 sampled boreholes had nitrate contents above the guideline value.
- Of a total of 60 boreholes, arsenic of elevated concentrations above the 0.01 mg/l WHO guideline value was found in only 3 water samples located in West Mamprusi and Gushiegu districts.
- The fluoride concentration is in quite many boreholes too high and in some instances even grossly elevated compared to the WHO guideline value of 1.5 mg/l, particularly in boreholes located in Gushiegu, Karaga and Savelugu-Nanton districts underlain by the Voltaian formation. The statistical evidence shows that in total 12.2% of the 985 boreholes sampled for fluoride exceeds the guideline value, i.e. some 120 boreholes. The prevalence of fluoride in certain of the groundwater occurrences is the biggest concern in relation to further groundwater development in the basin.
- In general, turbidity, taste and discolouration due to the content of iron and manganese in the groundwater are not conceived problematic.

2.4.4 Sources of pollution and sanitary condition

Causes of water pollution

Degradation of the water quality in the White Volta River Basin poses a range of concerns, including eutrophication, de-oxygenation, increased turbidity and BOD loadings because of improper use of agro-chemicals, illegal fishing methods, and unauthorised gold mining operations. Furthermore, indiscriminate disposal of waste and the impact of devastating floods also pose risks to the water quality.

The soils of the basin is generally suitable for agriculture; hence there is growing interest in damming the tributaries to store water for dry-season irrigated agriculture. The reactivation of the Pwalugu Tomato Factory, for example, will increase the use of fertilizers and agro-chemicals that will ultimately end in the river. Effluent discharge from the factory is also likely to affect water quality if not properly handled. Another example is the impact of the proposed large-scale sugar plantation in the Savelugu-Nanton District.

The collective impacts of these adverse effects result in:

- escalating water treatment cost;
- loss of biodiversity;
- loss of livelihoods and income;
- high disease prevalence rate and associated high medical cost;
- diminishing water availability; and
- water use conflicts.

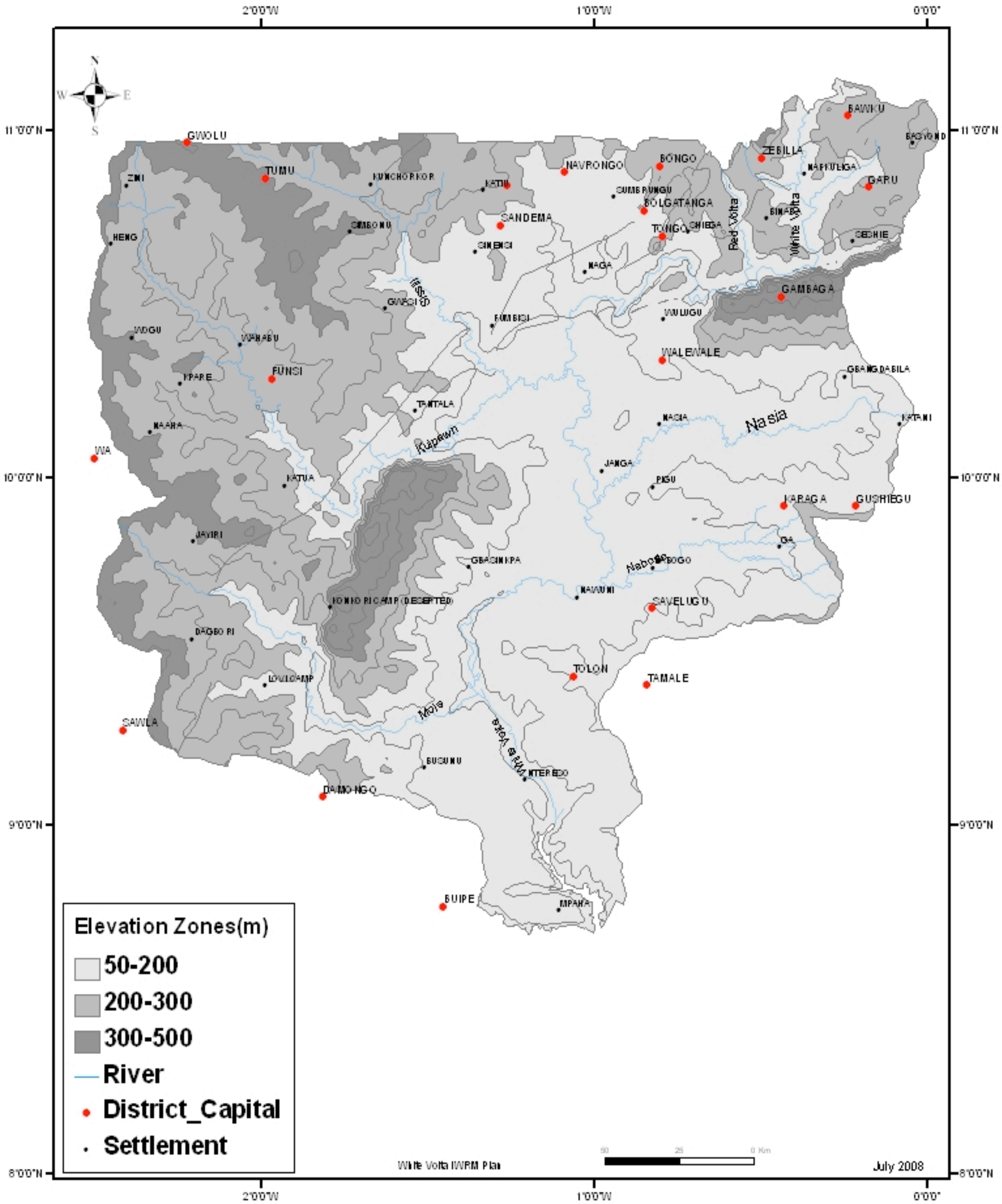
Overview of sanitary situation at basin level

The sanitary and waste disposal facilities are inadequate for the population living in the basin. When inhabitants with toilet facilities are considered, it is observed that only about 8%, 3% and 4% of the population in the Northern, Upper East and Upper West Regions, respectively, have access to toilets[19]. Furthermore, the collection and disposal of garbage is poor and there are pile-ups of garbage in the urban communities throughout the basin.

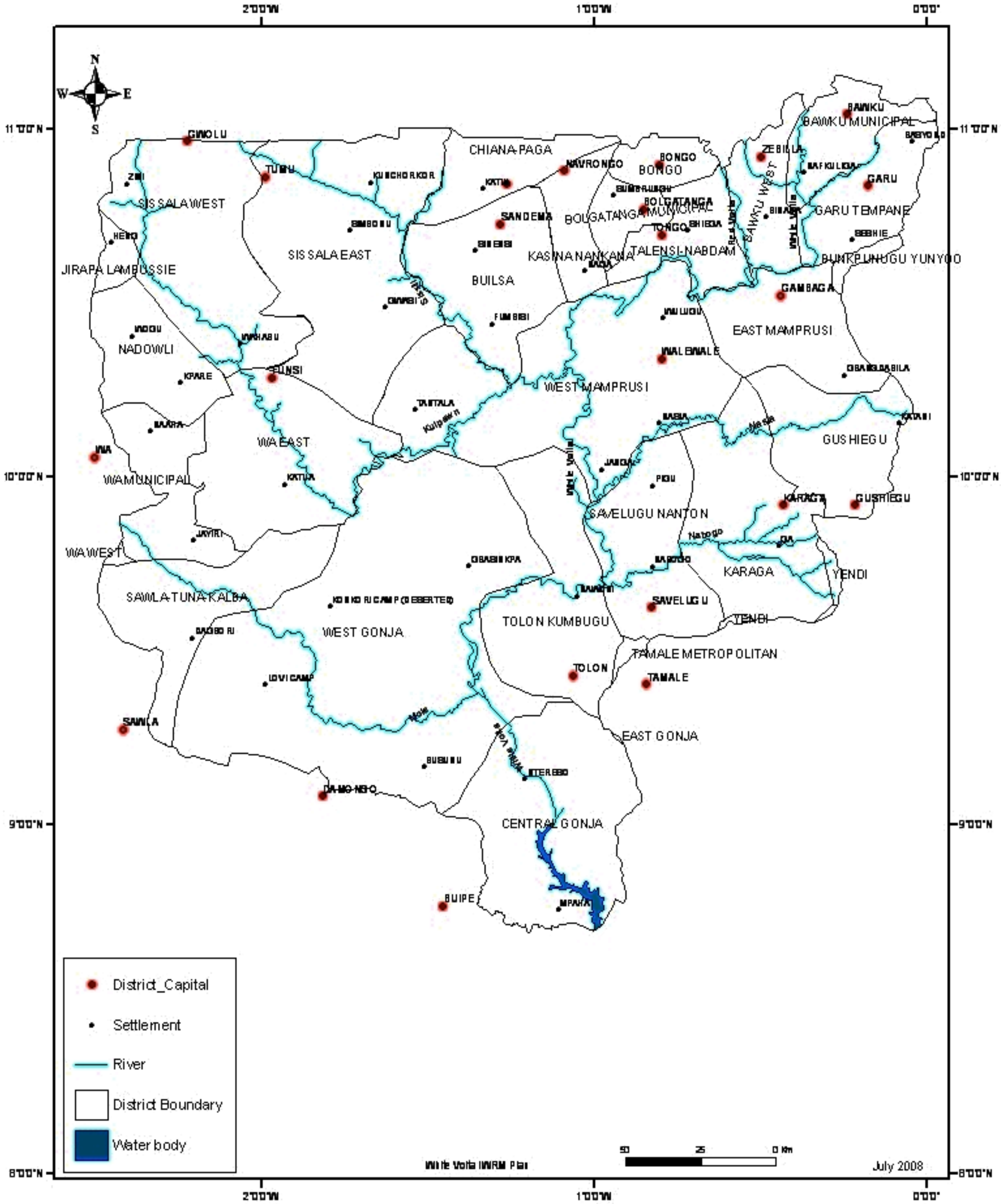
2.4.5 Trends in pollution load

The occurrence of floods in the basin, coupled with the gradual industrialisation and large-scale irrigated agriculture will become the more important pollution factors that will impact on surface waters. The use of water for irrigation also can lead to "salination" of the soils rendering them harmed for further agriculture. In step with further urbanisation, industrialisation and expansion in agriculture, the likely pollution load and its impact on the water quality is bound to increase.

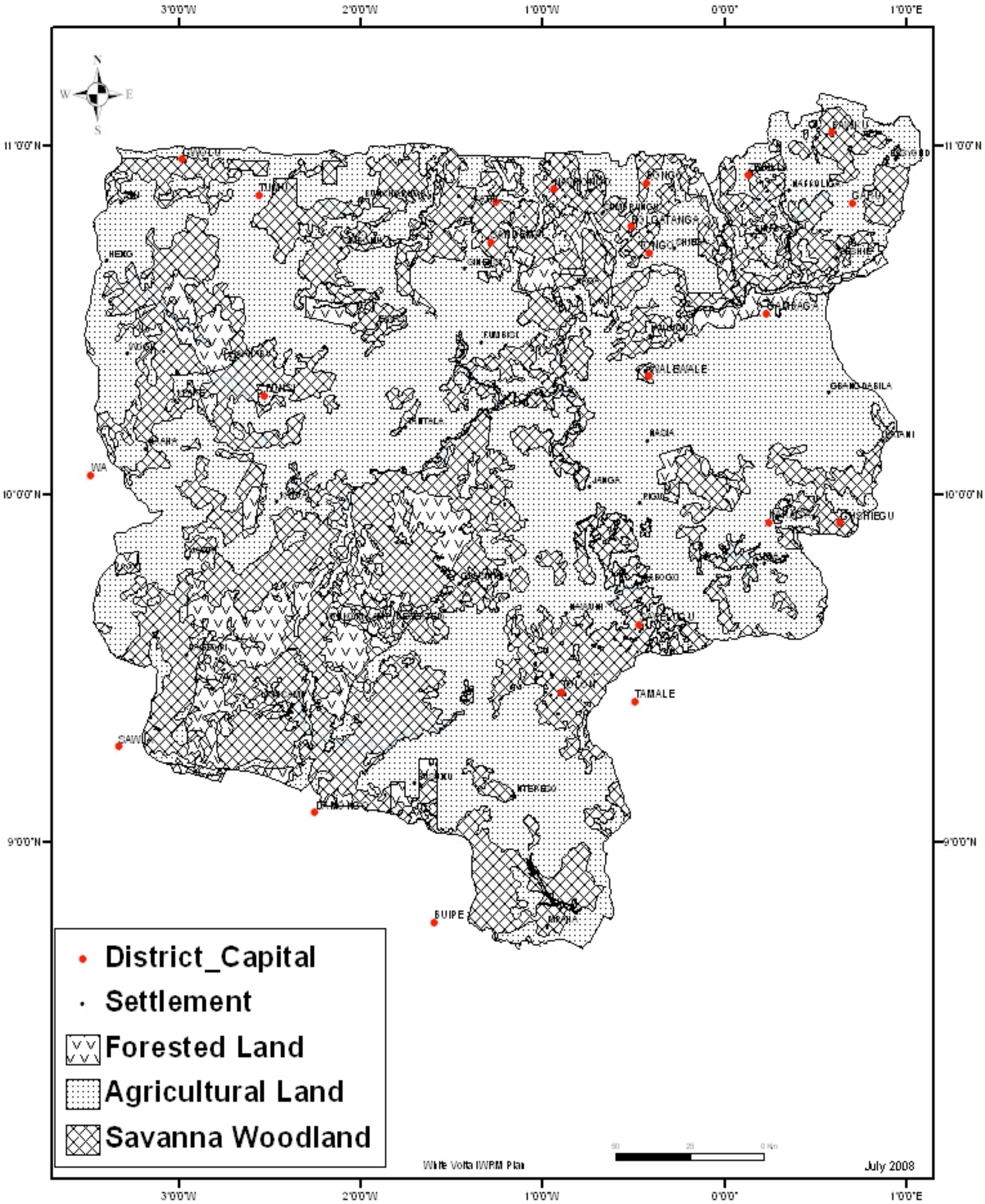
[19] *Community Water and Sanitation Agency data (2006)*



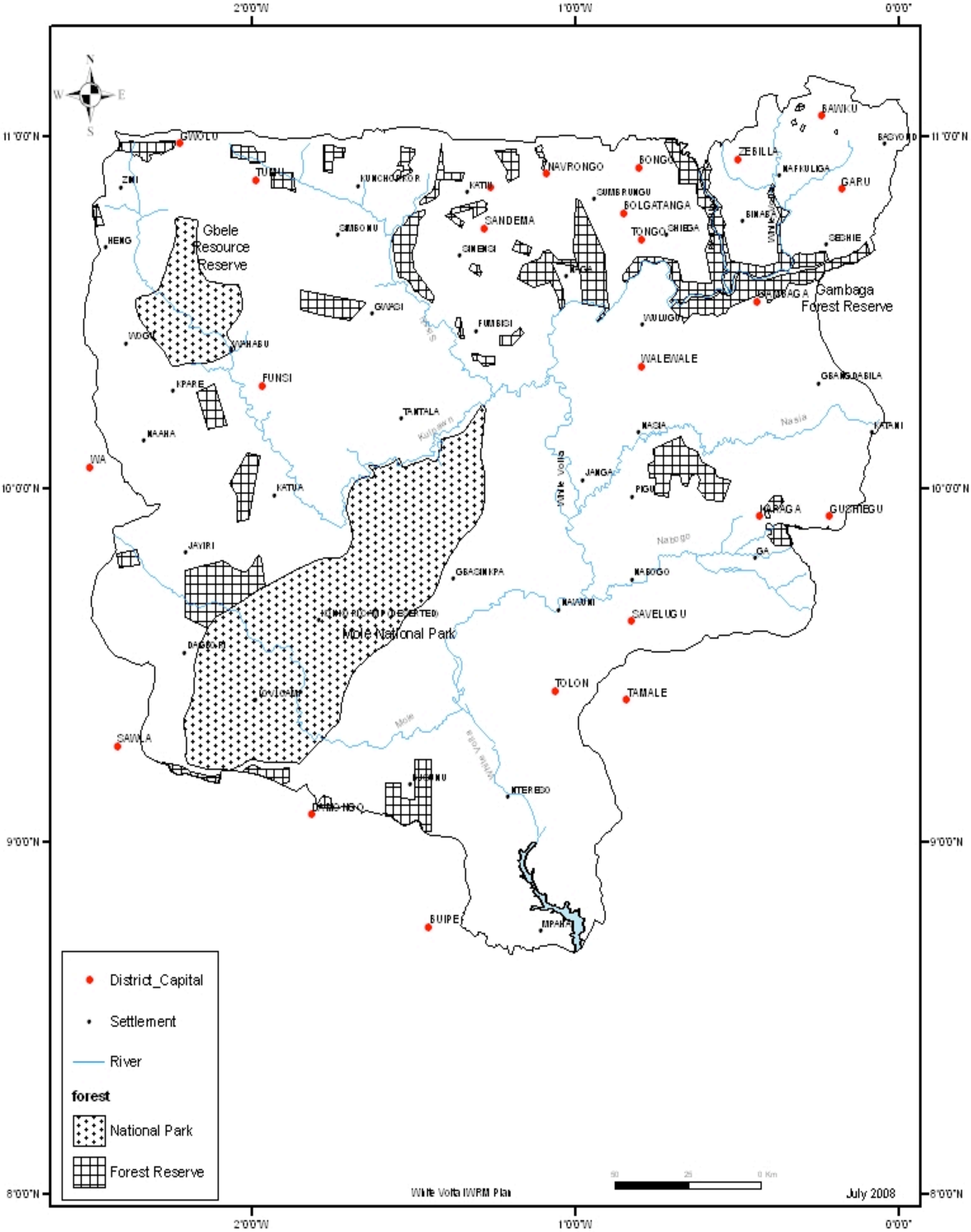
Map 1: Topography of White Volta River Basin



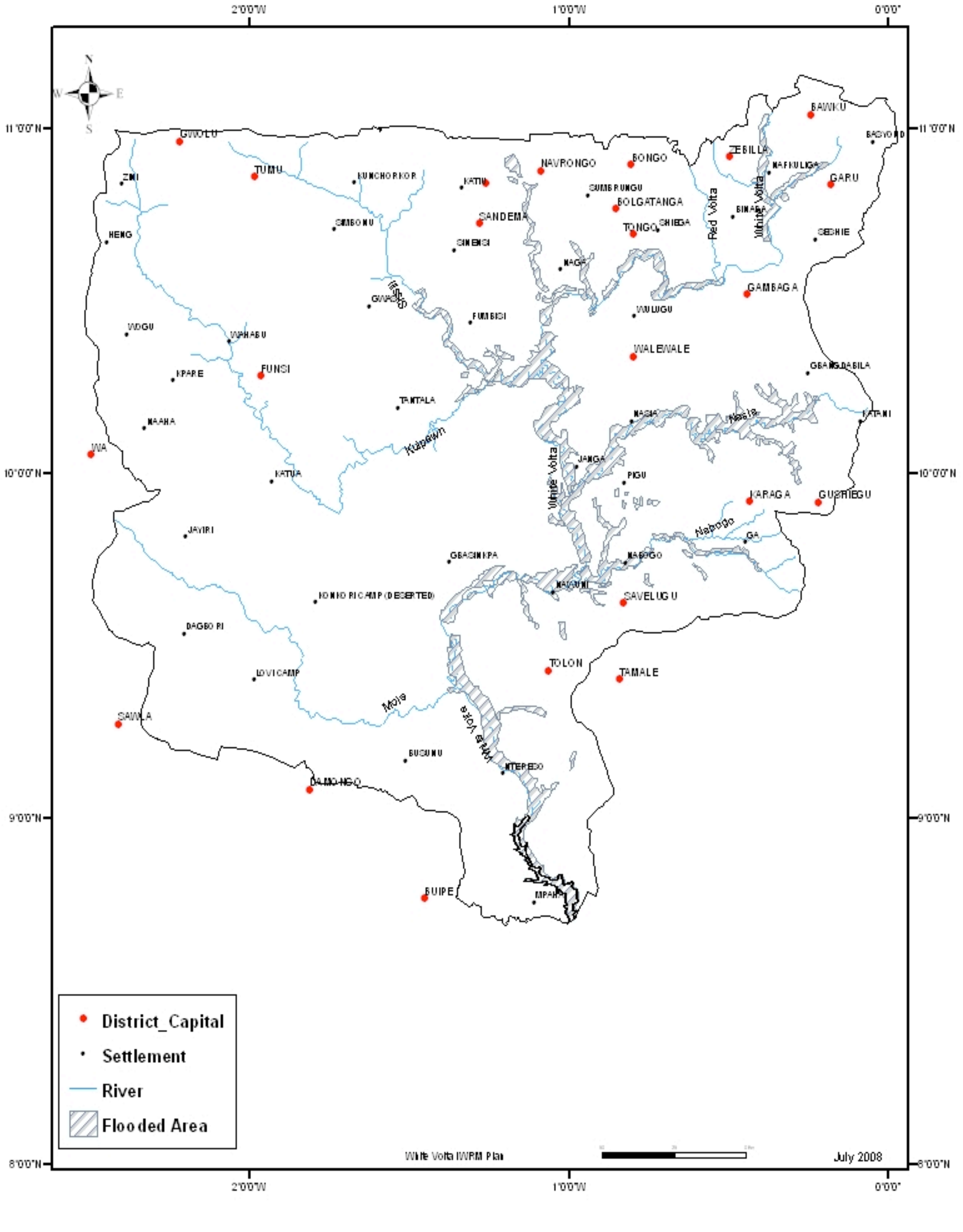
Map 2: Districts and towns/settlements in White Volta River Basin



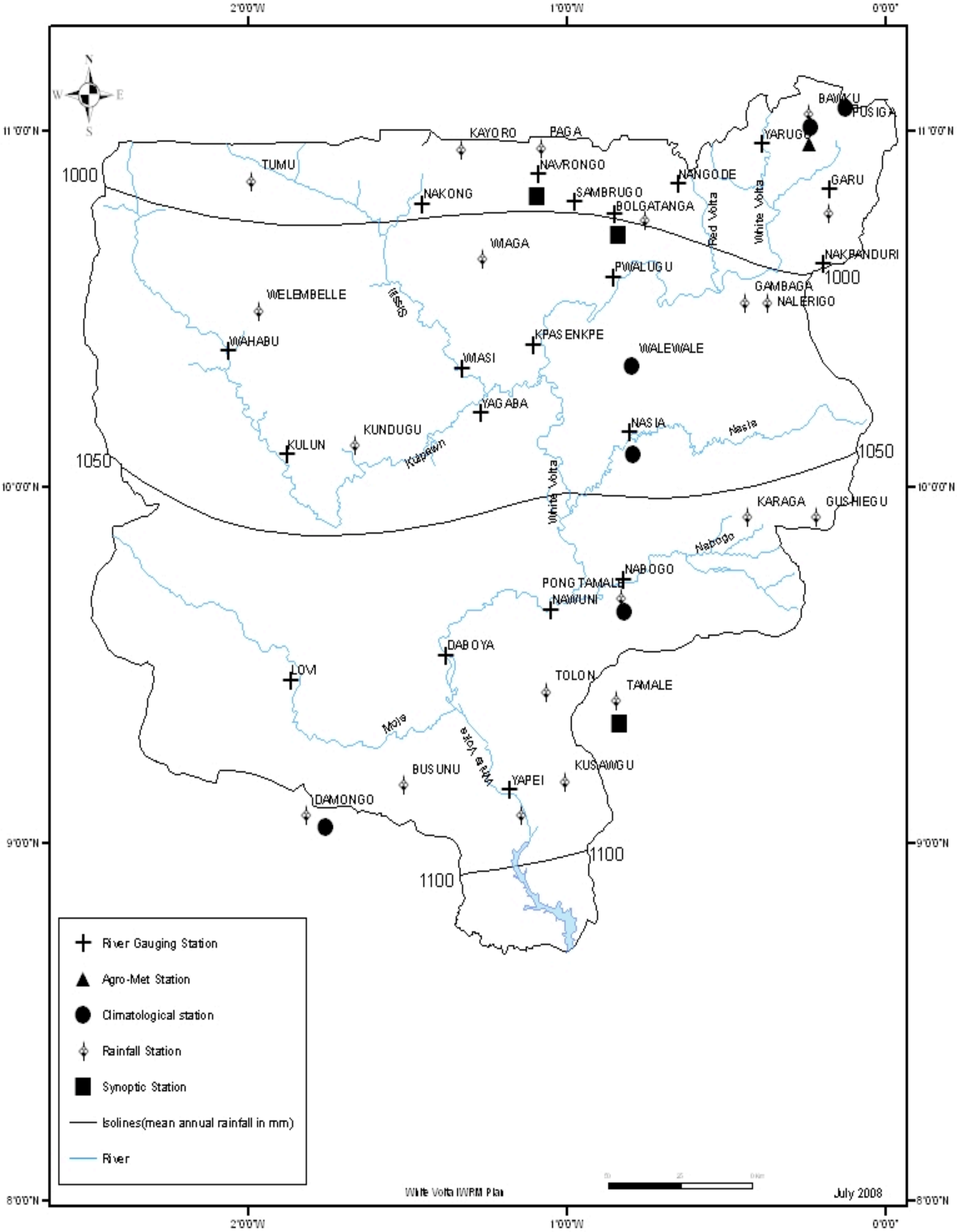
Map 3: Land use/cover (2000) of White Volta River Basin



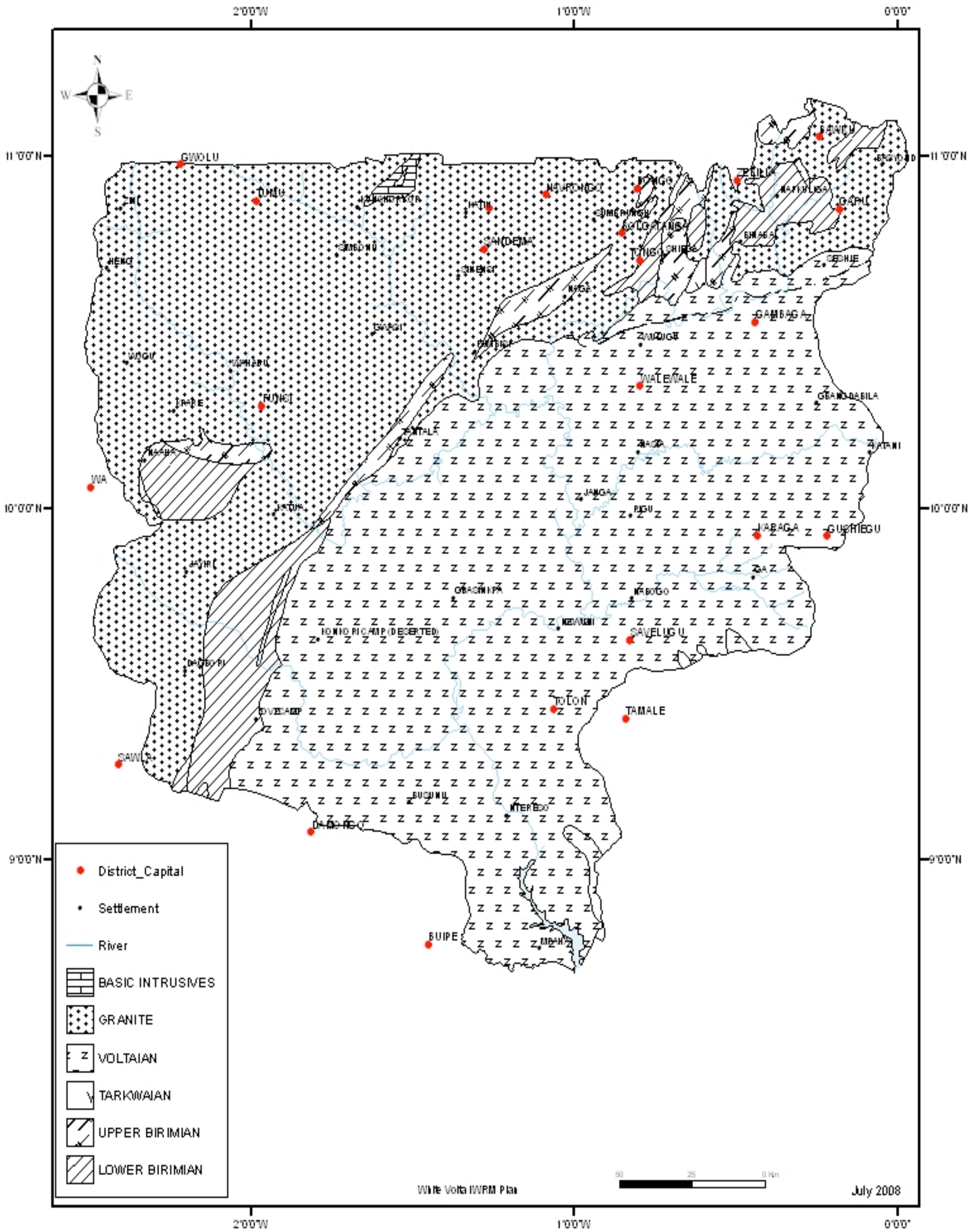
Map 4: Forest reserves and national parks of White Volta River Basin



Map 5: Inundated areas in White Volta River Basin in September 2007



Map 6: Meteorological and hydrological stations in White Volta River Basin



Map 7: Geological map of White Volta River Basin

3. WATER DEMAND PROJECTIONS AND WATER AVAILABILITY

Based on the demographic and socio-economic conditions, findings related to the overall water balance of the basin, the river flow regime (floods/droughts) and other data given in the baseline description in the previous chapter, this part of the IWRM plan provides information on projected water demands and assesses the balance between future requirements and water availability.

The demand projections versus future availability of water is addressed by presenting a number of scenario analyses, which highlight various options related to utilisation and management of the water resources. The water demand projections are made covering a plan period ending by year 2025.

The scenario analyses capture some of the key “quantitative” water resource planning issues associated with the White Volta River Basin in meeting future demands, namely impacts of diminishing water availability particularly during the low-flow season due to climate change and variability, and possible changes in the cross-border flow from upstream Burkina Faso.

The consequences related to the establishment of major irrigation schemes both concerning the need to create reservoir facilities and changes in the inflow regime to Volta Lake are included in the analyses. Furthermore, the result of meeting environmental flow requirements to protect the ecosystems of the riverine environment is also accounted for in the scenario analyses.

3.1 Demographic and socio-economic development trends

The assumptions used in calculating water demand for the supply of potable (municipal/domestic) water and to meet water requirements for the main socio-economic activities, notably agriculture (irrigation), are outlined below.

3.1.1 Assumptions for projection of potable water demand

The requirement for potable water for domestic, institutional and industrial purposes is determined based on estimates of per capita water demand figures, which are inclusive of these various categories of water use, and future population growth. The unit water demand (daily per capita demand) figures applied are adapted from the design values generally used by GWCL, which are differentiated according to settlement size and time horizon as depicted in Table 3.1.

The unit consumption rate of 35 litres/capita/day indicated for the rural communities is set relatively high to reflect the fact that some water from the point sources (boreholes/wells) also is used for subsistence farming and cattle watering purposes.

Table 3.1: Unit water demand (litres/capita/day)

Settlement size	Category	2008	2015	2020	2025
< 5,000	rural	35	35	35	35
5,000-15,000	urban	55	65	75	85
15,000-50,000	urban	85	85	90	95
> 50,000	urban	105	110	115	120

With departure point in the 2000 Census population figures presented in Table 2.1, annual population growth rates as given in the individual District Poverty Profile reports[20] have been guiding to arrive at the 2008 population sizes for each district represented within the White Volta Basin. In some cases, when the district population growth rates were not readily available, the regional growth rates were adopted. The annual growth rates used in the population projections are given in Table 3.2.

The latest inter-censual period (i.e. between 1984 and 2000) indicates that the three northern regions – or rather the part of the population living within the White Volta Basin – recorded an average annual growth rate of 2.1%. As can be seen in Table 3.2, the similar figure which has resulted from this study is 2.4% as an average for the whole basin, still less than the national average of 2.7% recorded during the last inter-censual period. Apparently, the development in the size of the population, expressed by the annual growth rate figure, seems rather constant – although showing a certain upward trend – when comparing the past eight years to the previous inter-censual period. Against this background, it is not expected that the growth rates given for the past recent years leading up to 2008 will change much (if at all), and in the context of this study are assumed to be valid throughout the whole plan period.

It can also be noted that the population growth rates for the districts do not make a distinction between municipalities/urban areas and rural settlements/villages, which means (it must be assumed) that the indicated growth rates represent "average" values combining both the rural and the urban settlements of the respective district. In the context of the IWRM planning these compounded figures provide sufficient detailing for overall water demand estimation, water balance analysis etc. Further details in this regard are only required, e.g. in connection with actual design of specific water supply schemes.

With these basic assumptions in mind, Table 3.2 presents the population forecasts per district and accumulated for the entire White Volta River Basin. As mentioned in connection with Table 2.1, the districts of East Gonja and Yendi contribute hardly anything both in population and area to the basin, and thus have not been included in Table 3.2 and in the further analysis.

[20] *As part of the second generation Ghana Poverty Reduction Strategy (GPRS II) activities (2004), the National Development Planning Commission (NDPC) directed each District Assembly to prepare poverty profiling and pro-poor programming reports – the documentation is available on www.ghanadistricts.com*

Table 3.2: Population projections for the White Volta Basin (2000-2025)

Region	District	Settle-ment category	Annual growth rate (in %)	Population 2000 Census	2008	2015	2020	2025
Upper East	Builsa	rural	1.0	75,400	81,600	87,500	92,000	96,700
		urban		0	0	0	0	0
	Kasina-Nankana	rural	1.1	125,700	137,200	148,100	156,400	165,200
		urban		23,800	26,000	28,000	29,600	31,300
	Bongo	rural	2.8	77,900	97,200	117,900	135,300	155,400
		urban		0	0	0	0	0
	Bolgatanga	rural	2.0	179,700	210,800	242,100	267,300	295,200
		urban		49,100	57,500	66,100	73,000	80,600
	Bawku West	rural	1.5	72,500	81,700	90,700	97,600	105,200
		urban		8,100	9,100	10,100	10,900	11,800
	Bawku East	rural	2.0	244,700	286,700	329,300	363,600	401,600
		urban		63,300	74,200	85,200	94,100	103,900
Upper West	Wa	rural	2.0	110,200	129,100	148,300	163,800	180,800
		urban		46,600	54,600	62,700	69,300	76,500
	Sissala	rural	1.7	76,600	87,700	98,600	107,300	116,800
		urban		8,800	10,100	11,300	12,300	13,400
	Jirapa-Lambusie	rural	1.7	19,400	22,200	25,000	27,200	29,600
		urban		0	0	0	0	0
	Nadowli	rural	1.5	41,400	46,600	51,800	55,800	60,100
		urban		0	0	0	0	0
Northern	Bole	rural	3.6	28,000	37,200	47,600	56,800	67,800
		urban		3,800	5,000	6,500	7,700	9,200
	West Gonja	rural	3.1	72,000	91,700	113,500	132,200	154,000
		urban		11,800	15,100	18,700	21,700	25,300
	Gushiegu-Karaga	rural	3.0	89,800	112,700	138,700	160,700	186,400
		urban		23,800	30,200	37,100	43,000	49,800
	Savelugu-Nanton	rural	3.0	54,500	69,000	84,900	98,400	114,100
		urban		31,000	39,300	48,300	56,000	64,900
	Tamale[(i)]	rural	3.5	9,100	12,000	15,200	18,100	21,500
		urban[(i)]		197,200	259,700	330,400	392,400	466,000
	Tolon-Kumbungu	rural	2.8	112,000	139,700	169,500	194,600	223,400
		urban		20,900	26,100	31,600	36,300	41,700
	West Mamprusi	rural	2.8	101,500	126,600	153,600	176,300	202,400
		urban		13,600	17,000	20,600	23,600	27,100
	East Mamprusi	rural	3.0	82,400	104,400	128,400	148,800	172,500
		urban		13,800	17,500	21,500	24,900	28,900
White Volta Basin, total		rural	2.4	1,572,800	1,874,100	2,190,700	2,452,200	2,748,700
		urban		515,600	641,400	778,100	894,800	1,030,400

(i) The entire Tamale Metro urban population is included for the purpose of water demand projection since its water supply relies on abstraction from the White Volta River at Nawuni.

From the figures in Table 3.2 it can be concluded that the total population of the White Volta Basin (including the whole of Tamale Metro population residing at the fringe of or just adjacent to the basin boundary) is expected to increase from the 2000 Census figure of about 2.1 million to nearly 3.8 million in 2025.

3.1.2 Assumptions for projection of agriculture water demand

Irrigation

Irrigation water requirements are in various documents, for instance the WARM study[21], reported to vary from an annual amount of about 10,000 m^3/ha for vegetable produce to around 25,000 m^3/ha for rice fields. An average value of 15,000 m^3/ha/year is adopted for the irrigation water demand in the White Volta River Basin (equivalent to approximately 3.5 litre/sec/ha in average assuming a 4-month irrigation season with 12 hours of pumping per day). It can be mentioned that this amount matches well with a similar figure which can be derived from the State of Environment Report[22], indicating an amount of 14,300 m^3/ha/year in average for the country. In the context of this IWRM plan it is further assumed that the irrigation efficiency factor is embedded in the above given average water requirement per unit area under irrigation.

Undisputable, the potential irrigable area in the White Volta Basin is sizeable. According to the above cited reports it is assessed that 300,000 ha or more can be classified as "potential irrigable land". Hence, it is to be expected that the basin is likely to attract large-scale irrigated agro-industrial ventures in the future. The limiting factor in developing this potential is the future low-flow regime of the river system coupled with the possibilities (feasibility) of constructing suitable storage facilities (dams).

In realistic terms, therefore, it will only be possible to develop a certain (much smaller) land area for irrigation compared to the size of total potential irrigable land indicated above. Rather, it will be the consequences of these future irrigation development schemes on the availability of water resources for other purposes, including an obligation of not altering (reducing) the annual inflow to Lake Volta too drastically, which eventually will determine to which extent irrigation-dependable agriculture can be introduced in the White Volta Basin.

As part of a 1992 pre-feasibility study[23] carried out for the Volta River Authority and the Ghana Irrigation Development Authority an indication as to the likely total area in realistic terms to be developed for gravity-based irrigation in the alluvial plain of the entire White Volta valley is given as 84,000 ha. To assess the impact of this possible development in the context of this IWRM plan, the scenario analyses presented in this chapter include a "modest" development in the irrigated area of up to15,000 ha (including the existing irrigation schemes), and an accelerated development whereby a total area under irrigation will reach 50,000 ha by the end of the plan period.

---

[21] *Ministry of Works and Housing: Water Resources Management (WARM) Study, Information "Building Block" Study, Part II, Vol. 2: Information on the Volta Basin System (May 1998)*

[22] *Environmental Protection Agency: State of Environment Report 2004. EPA (April 2005)*

[23] *Volta River Authority: White Volta Development Scheme, Pre-feasibility Study, Coyne et Bellier, Consulting Engineers, France (November 1992)*

Additionally, the analyses also need to incorporate the effect of climate change and variability, which besides having an effect on the river flow regime also has a pronounced bearing on the water requirement per unit area under irrigation.

Livestock

The livestock water demand as calculated in Section 2.3.4 is assumed to increase in step with the development in the rural population's domestic water demand and maintaining the same percentage of this demand as valid for year 2008.

3.2 Water demand projection on a basin basis

By applying the various assumptions and figures given in the preceding section, the future water demand for the whole White Volta Basin as a unit has been calculated with results given in Table 3.3. To account for the fact that some of the communities presently classified as "rural" eventually will move into the "urban" category, i.e. when they grow to exceed 5,000 people, it is assumed that 15% of the 2025 calculated rural water demand will be part of the urban water demand – this aspect is also imbedded in the water demand figures given in Table 3.3. Furthermore, it should also be emphasised that the figures in the table represent the "ultimate" water demand as required by the whole population of the basin, i.e. assuming 100% service coverage both in the rural and urban settings.

The irrigation demand shown in the Table 3.3 is based on a gradual development, whereby the irrigated land will increase to 15,000 ha towards the end of the plan period – this area is chosen as an example for the purpose of the table presentation.

Table 3.3: Water demand projections, White Volta Basin (2008-2025)

User category	2008 values represent current abstractions		2015		2020		2025	
	m^3/day	$10^6 m^3$/yr	m^3/day	$10^6 m^3$/yr	m^3/day	$10^6 m^3$/yr	m^3/day	$10^6 m^3$/yr
Urban(i) population	24,600	9.0	83,000	30.3	105,000	38.3	132,000	48.2
Rural population	17,000	6.2	72,000	26.3	77,000	28.1	82,000	29.9
Irrigation(ii) (15,000 ha)	458,300(ii)	55.0	875,000(ii)	105.0	1,375,000(ii)	165.0	1,875,000(ii)	225.0
Livestock	31,000	11.3	33,800	12.3	36,200	13.2	38,500	14.1
White Volta Basin, total	-	81.5	-	173.9	-	244.6	-	317.2

(i) the entire Tamale Metro urban population is included in the water demand projection since its water supply relies on abstraction from the White Volta River at Nawuni.
(ii) daily water demand figures for irrigation calculated based on a 4-month irrigation season per year

Not surprisingly, from the figures in the table it can be concluded that the agriculture (irrigation) sector will be by far the largest demand category, which under the assumption that a total of 15,000 ha of land is being irrigated in 2025 will constitute about 70% of the total water demand, whereas the combined domestic (urban and ru-

rural population) categories make up 25%. The remaining 5% is water for upkeep of livestock.

3.3 Scenario analyses of water availability vs. requirements

3.3.1 Introduction to scenario analyses and model assumptions

It is a well known fact, that the low-flow regime of the White Volta River system determines its viability to sustain a year-round (run-of-the-river) supply for larger schemes designed for direct abstraction without storage (reservoir) capacity provided. Therefore, to examine the consequences and extent of future water shortages in step with increased demand, the low flow regime – as reflected in runoff records from a number of river gauging stations in the basin – is introduced as requisite input in the water accounts analyses.

The WEAP water accounts model tool

The computer-based Water Evaluation and Planning (WEAP) model is used to carry out scenario analyses to facilitate the understanding and description of different water resource development choices, and to establish their consequences. It operates on the principles of water balance accounting and examines alternative water development strategies in form of scenario analyses to provide answers to various "what if" questions.

For each model run (scenario), the various water requirements covering the whole river system are taken into consideration, and the induced upstream-downstream interactions are being accounted for and results shown in a number of optional ways to be chosen by the user, such as graphs, in table form or as histograms. Also the percentage of requirements met (coverage rate) at each demand site is calculated with increments of one month throughout the plan period.

The WEAP model has a built-in "priority" facility, whereby the domestic water requirements are met as first priority and water for e.g. irrigation has a lower priority. This optional facility is important in situations when there is "competition" for water due to scarcity in the supply.

It should be noted that conclusions reached, based on results of the scenario analyses, only consider coverage in term of water availability as a source for meeting the requirements, and does not take into consideration the various technical aspects as precondition for attaining the coverage, e.g. appropriateness and efficiency of water intake structure, expansion of transmission mains and distribution outreach.

The starting point of the basin modelling is to establish and define the basic water related elements of the basin and their relations as they currently exist. This overview of the existing situation is called the "current accounts". The "current accounts" includes the specification of supply, demand and resource data, including information on dams and reservoirs, as extracted from the information and figures presented in the previous chapters/sections and other sources.

Figure 3.1 below provides a schematic overview of the White Volta River system and the basic set-up of the WEAP model components. The set-up depicts the main elements such as abstraction/demand sites (urban water supplies, irrigation schemes, etc), dam sites, and other main features used in the scenario analyses.

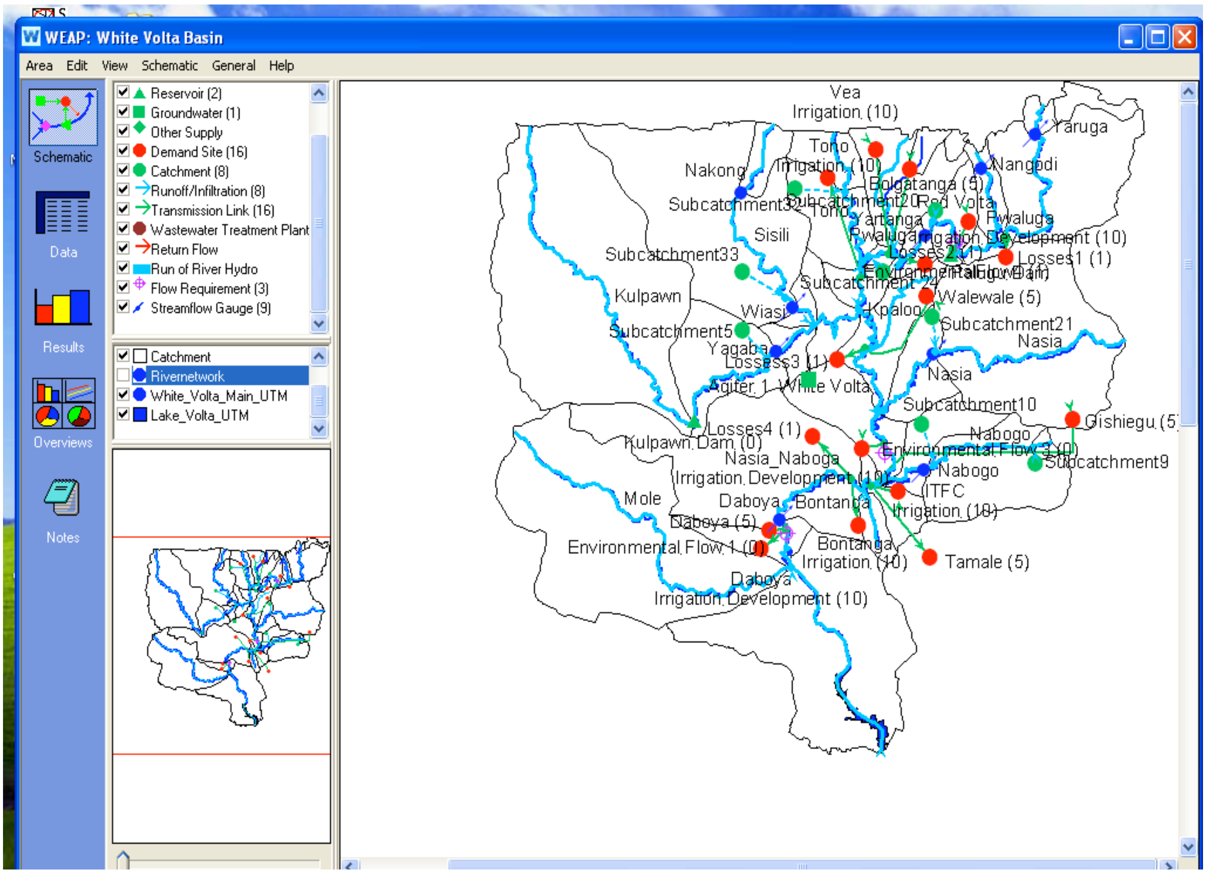


Figure 3.1: WEAP model configuration for White Volta River Basin

Location of urban water abstraction/demand sites and water requirements

The following urban demand sites, which at present are supplied through piped systems relying on the White Volta River system, are assumed to continue to be supplied by surface water from schemes to be expanded in step with increase in water requirements in and around these supply areas:

- Bolgatanga,
- Gushiegu,
- Tamale,
- Daboya, and
- Walewale.

In the future, other urban settlements located in the vicinity of the above urban areas or along the main transmission lines leading from the abstraction points can be assumed to be included in the expansion of the "old" schemes to cater for these additional urban water requirements.

Against this background and utilising the projected urban population figures (ref. Table 3.2) and the unit consumption rates as given in Table 3.1, the 2025 water demand situation for these urban demand sites is summarised in Table 3.4.

Table 3.4: Projected surface water demand of main urban piped schemes

Demand site	2025 population to be served	2025 water demand (m^3/day)
Bolgatanga (entire urban pop. in Bolgatanga district)	80,600	9,672
Gushiegu (incl. half of urban pop. in Gushiegu-Karaka district)	24,900	2,988
Tamale (entire Tamale Metro pop. also outside basin boundary)	466,000	55,920
Daboya (incl. half of urban pop. in West Gonja district)	12,650	1,518
Walewale (incl. half of urban pop. in West Mamprusi district)	13,550	1,626

As pointed out previously, undoubtedly the basin's groundwater resources have a potential to be utilised much more than at present. Therefore, the part of the urban population residing in the basin, and which is not included in the demand figures given in Table 3.4 – notably the urban population of the Bawku Municipality and its environs and the eastern parts of Wa Municipality – is assumed also in the future to be served from groundwater sources.

It should be reiterated, that within the supply areas of the urban pipe-borne schemes, the water usages by industries, manufacturing and other commercial activities as well as institutions are included in the schemes' production figures, and hence in the forecasted water demand figures in Table 3.4.

System losses (un-accounted for water)

It is a fact that the existing piped water supply systems in Ghana generally suffer from unacceptable high rates of un-accounted for water, i.e. physical losses, notable in the transmission mains and distribution network. At present, it is estimated that for certain schemes in average some 40% of water produced can be categorised as un-accounted for water. It should be noted that a high rate of un-accounted for water not only implies a non-efficient way of using the available water sources, but also results in extra costs related to water treatment, pumping (energy) and other operational aspects.

As part of the analyses presented below, it is opted in this plan to assume that system losses will (and must) gradually be brought down at least to a 25% level in average, which also is considered realistically to be achieved over the plan period. This un-accounted for water percentage figure is added to the demand figures as presented in Table 3.4 to arrive at the actual water requirements at the various abstraction points.

Rural population water requirements

In the context of this plan, it is assumed that the rural population also in the future to a large extent will continue to be supplied from groundwater through non-piped hand pump equipped boreholes or through piped (mechanised) borehole supply schemes.

Location of irrigation schemes and their water requirements

The existing larger irrigation schemes are Tono located in Kasina-Nankana District, Vea in Bongo District, Bontanga in Tolon Kumbugu District and the ITFC scheme in Savelugu-Nanton District. In the scenario analyses, the proposed new irrigation developments are represented at three locations along the White Volta River (as per the previously cited pre-feasibility study, ref.[23]), i.e. one in the upper section upstream of Pwalugu, one in the middle section between the Nasia and Nabogo confluences, and one in the lower section in the Daboya area.

The future water requirements envisaged for irrigation developments, currently at about 4,000 ha, are established and introduced in the scenario analyses as explained in Section 3.1.2 above, i.e. two possible scenarios in the expansion of the area to be under irrigation in the basin are analysed. Firstly, a “modest” development of 15,000 ha by the end of the plan period, and secondly, a much accelerated development of up to 50,000 ha under irrigation by 2025.

Livestock water requirements

Due to its small size in the overall water balance (< 5%) and mode of usage, the livestock water requirement is not accounted for explicitly in the scenario analyses, but rather included as an integral part of the irrigation (agriculture) water demand.

Environmental flow requirements

As explained in Section 2.2.2, the low-flow regime of the White Volta River is nowadays basically “controlled” with a relatively steady flow due to the operations of the Bagré Dam in Burkina Faso. In that respect White Volta’s minimum flow situation has improved, whereas the major tributaries in the system, i.e. the Red Volta, Sissili and Kulpawn, to a large extent seize to flow during the dry season.

To sustain a reserve of the river flow for environmental “maintenance”, a minimum flow requirement has been introduced in the calculations downstream of the main water abstraction points and dam sites on the White Volta River proper. Bearing in mind the “controlled” low-flow condition, the environmental flow requirement is calculated as a simple percentage (10%) of the average dry-season flow recorded since 1996, i.e. after commissioning of the Bagré Dam. In other words, the flow should never fall below this value in any of the scenario analyses throughout the whole plan period. The reason for not introducing an environmental flow requirement in the other parts of the river system is that the various tributaries in their “natural” stage already seize to flow in the dry season.

3.3.2 Results from the scenario analyses

Introduction

A number of scenarios, comprising various assumptions related to availability of water and different development options for the utilisation of the basin's water resources have been analysed with results presented in this section. It must be emphasised that the presented scenarios and associated water resource development options should be regarded as a "point of departure" from which the basin modelling coupled with requirements for detailing can be further developed as the need for planning and decision-making at various levels (basin-wide or project specific) arises.

As mentioned previously, it must be recognised that any abstractions from the White Volta River system – in particular for irrigation due to its potential magnitude – will have an impact on the inflow into the Volta Lake and could cause a reduction in the hydro-electric output from the Akosombo Dam and Kpong power stations. Therefore, in the future, a balance has to be struck between how much development of irrigated-based agro-industries can be accommodated upstream in the White Volta River system and the role of the river in the generation of hydropower with its 20%-25% contribution to the water resources of the Volta Lake.

In the context of this plan, the results from the scenario analyses are reported on and compared with each other by highlighting the level of coverage (% of requirement met) as calculated at the different demand sites towards the end of the plan period. The demand sites include the urban population abstraction points, the existing irrigation sites and the identified three new irrigation schemes as explained above.

In the following, a total of 5 scenario analyses are presented. The first 3 model runs (Scenarios 1, 2 and 3) provide information about the existing situation and assess to which extent external factors such as climate change and alterations in the cross-border flow from Burkina Faso during the low-flow season may impact on the availability of water towards the end of plan period. Against this background, the last 2 model runs (Scenarios 4 and 5) provides a "sensitivity analysis" to highlight the interdependency between development in irrigated agriculture and the need for introducing in-stream or off-stream storage/reservoir capacities to be established within the basin.

For each model run the total flow of the White Volta River downstream of the last abstraction point, i.e. after the Mole River confluence, is also calculated. On this basis the changes (reductions) in annual inflows to the Volta Lake caused by the increase in the water supplied to meet future requirements in the basin can be assessed.

Scenario 1: Water resource capacity without effects of external factors

This scenario assumes a future *status quo* situation regarding the resource capacity, which implies that no new dams or additional sources will be introduced. In this scenario the existing water abstraction and other facilities will be expanded in step with the increased water requirements to cater for the growing population and socio-economic activities up to the limit of the present source capacity. As far as the existing irrigation schemes are concerned, it means that they will be developed to their envisaged capacities, i.e. adding 25% to the land currently under irrigation during the plan period (ref. Section 2.3.4), but with no new major schemes to be introduced.

This model run provides a "reference point" against which the effects of climate change/variability and altered cross-border flow from Burkina Faso can be assessed.

Result:

The results of this scenario show that the water requirements can be met 100% almost entirely during the 18-year plan period (2008-2025) at all demand sites whether for the urban water supply schemes, including Tamale Metro, or the irrigation schemes currently in operation. The model run, however, indicates that in one year only, the Tono and Vea irrigation schemes would realise a modest shortfall in the supply of water to the extent that only about 50% of the requirements are met during a 2-month period in that specific year.

Scenario 2: Impact of climate change

As explained in Section 2.2.1, the effects of a likely climate change can be quantified in terms of an anticipated decrease in surface water runoff. The study referred to in that section indicates that a climate change scenario considered realistically to occur, i.e. 10-20% decrease in annual rainfall and a 1-2°C rise in temperature, will reduce surface runoff by about 15% over the plan period.

Furthermore, irrigation water demand would be affected considerably by the simulated climate change, not only because of the increase in temperature causing higher evapo-transpiration, but also due to the expected change in the distribution of the rainfall with longer dry spells and a more erratic rainfall pattern to be realised in the future. To accommodate these compounded effects in the WEAP model runs, the irrigation water requirements per unit area has been increased by 75% compared to the present average figure of 15,000 m^3/ha/year, and hence, gradually will increase to 26,250 m^3/ha/year towards the end of the plan period.

The changed runoff regime caused by climate change has been imposed on the data series used in the calculations, and an alternative model run was made for the "*status quo*" situation (Scenario 1) to compare and assess the "order of magnitude" of a climate change impact on meeting the future water requirements.

Result:

The result of this model run comes out quite similar to Scenario 1. By and large all water requirements at the various demand sites can be fully met except for the Tono and Vea irrigation schemes, which also in this case will realise a shortfall in one year, although it is more pronounced with only around 25% of the water requirements met.

Scenario 3: Reduction in cross-border flow from Burkina Faso

By virtue of being the downstream country in the Volta Basin, the water resources of the White Volta River in Ghana are to some extent constraint to the north by the future utilization and water management practices in Burkina Faso. Besides peak runoff releases from Bagré Dam, which occasionally cause flooding problems along the banks of the White Volta River during the high-flow season, in the context of this plan it is alterations, i.e. decreases, in the low-flow regime, which would compound the effect of likely climate change impacts.

Therefore, in addition to the factors imposed on the runoff regime and the changed unit area irrigation water requirement due to climate change effects (ref. Scenario 2), this scenario also includes a certain reduction in the low-flow of the White Volta River as it enters Ghana from Burkina Faso. For the purpose of assessing this impact, it is in the model calculations assumed that the low-flows will reduce gradually by 30% towards the end of the plan period. Reduced low-flow conditions could for instance be caused by further expansion of the irrigation schemes downstream of the Bagré Dam in Burkina Faso.

It should be reiterated that Scenario 3 reflects the *status quo* situation as outlined under Scenario 1, implying that new larger-scale irrigation developments are not to be established under this scenario.

Result:

In this scenario most demand sites will be affected to a varying degree, and shortfalls in meeting water requirements start occurring more frequently during the latter part of the plan period. Specifically, it can be noted that the abstraction at Nawuni for the greater Tamale water supply scheme will be impaired to some extent in as much as the supply can not meet the demand during the low-flow season at two occasions during the latter part of the plan period.

This model run highlights the rather obvious fact that in case the otherwise quite steady dry season runoff in the White Volta River attributed to the Bagré Dam operations is to be curtailed in the future, it would affect the capacity of the source to meet future water requirements of schemes relying on direct abstractions ("run-of-the-river" schemes).

Scenarios 4: Development of irrigated agro-industrial schemes

This scenario attempts to highlight to which extent the irrigation water requirements can be met if/when new larger-scale agro-industrial ventures are to be established relying on water from the river system. Scenario 4 includes the assumptions used in Scenario 3, namely that the effects of both climate change and reduction in the White Volta minimum flow are imbedded in the model run.

As an example, it is assumed that a total of 15,000 ha of irrigated land (including the existing irrigation schemes) will be established gradually from the start to the end of the plan period. As explained in Section 3.3.1 above, the new irrigation developments will be represented by three sites along the White Volta River, and the expansion of the irrigated areas will be distributed equally among the new sites.

Result:

With reference to Figure 3.2, it can be concluded that for this scenario all demand sites will be affected with shortfalls realised every year in meeting water requirements towards the end of the plan period, and often with no water supplied at all. It can be noted that even during the first part of the plan period, the water requirements can only be met partially for some of the irrigation schemes.

The result of this model run implies that for more sizeable irrigation developments to be sustained based on the surface water of the White Volta River system, in-stream or off-stream reservoir facilities will be required to store water from the high-flow season to the low-flow season.

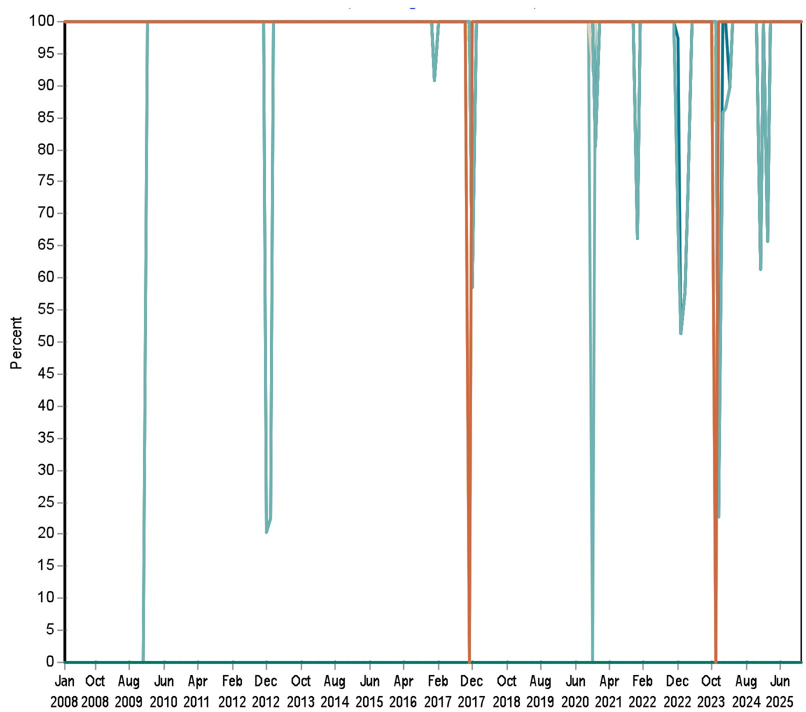


Figure 3.2: Demand site coverage (in %) with 15,000 ha irrigated area

Scenarios 5: Introduction of storage facility/dam on the White Volta River

In the previously cited White Volta Development Scheme Pre-feasibility Study (VRA 1992, ref [23]) three reservoir/dam sites along the White Volta River were assessed. The study was directed towards identifying a dual-purpose scheme for hydropower and irrigation development. The most attractive site from a technical-economic viewpoint was identified to be located some 20 km upstream from the Pwalugu road bridge across the White Volta River - dubbed the Pwalugu Hydroelectric Scheme[24]. In the pre-feasibility study a large dam structure was envisaged creating a reservoir capacity of 4,200 million m^3. The dam height above the river bed would be about 40 metres and the crest length some 1,600 metres. The large size dam was proposed to enable generation of a financially viable output of power of 50 MW.

In Scenario 5, the findings of the cited pre-feasibility study have been used concerning specific design features of the structure, specifically the reservoir's water

[24] *In early November 2008, Parliament approved an externally negotiated loan agreement aimed at ensuring financing to pursue the 1992 pre-feasibility study and move the Pwalugu Hydroelectric Scheme into a fully fledged design phase for subsequent construction. The overall goal of creating a multi-purpose scheme is still intact.*

level/storage relationship. However, in this scenario focus is on the water balance in connection with the envisaged "accelerated" development in the irrigated areas in the White Volta alluvial plains to a sizeable area totalling 50,000 ha by the end of the plan period. As above, it is assumed in this model run that three sites, i.e. one below the Pwalugu dam, a second along the reach between the Nasia and Nabogo confluences, and a third downstream from the Daboya road bridge, will be established with a equal share of the land areas to be put under irrigation. Furthermore, in the WEAP model calculations, the Pwalugu dam/reservoir is assumed to be brought into operation by year 2015, and sized to serve all three agro-industrial development sites along the river as well as the domestic and industrial water requirements, notably the population concentrations in and around the greater Tamale Metro area.

Result:

The aim of this scenario analysis is to provide an estimate of the optimal (smallest) size of the Pwalugu dam/reservoir which will able to meet the total water requirements in 2025 when the irrigation developments are fully established, i.e. the reservoir must ensure that no water shortages will occur at any of the demand sites by the end of the plan period. Figure 3.3 depicts one of the WEAP model runs in which the reservoir size was set at 3,200 million m^3.

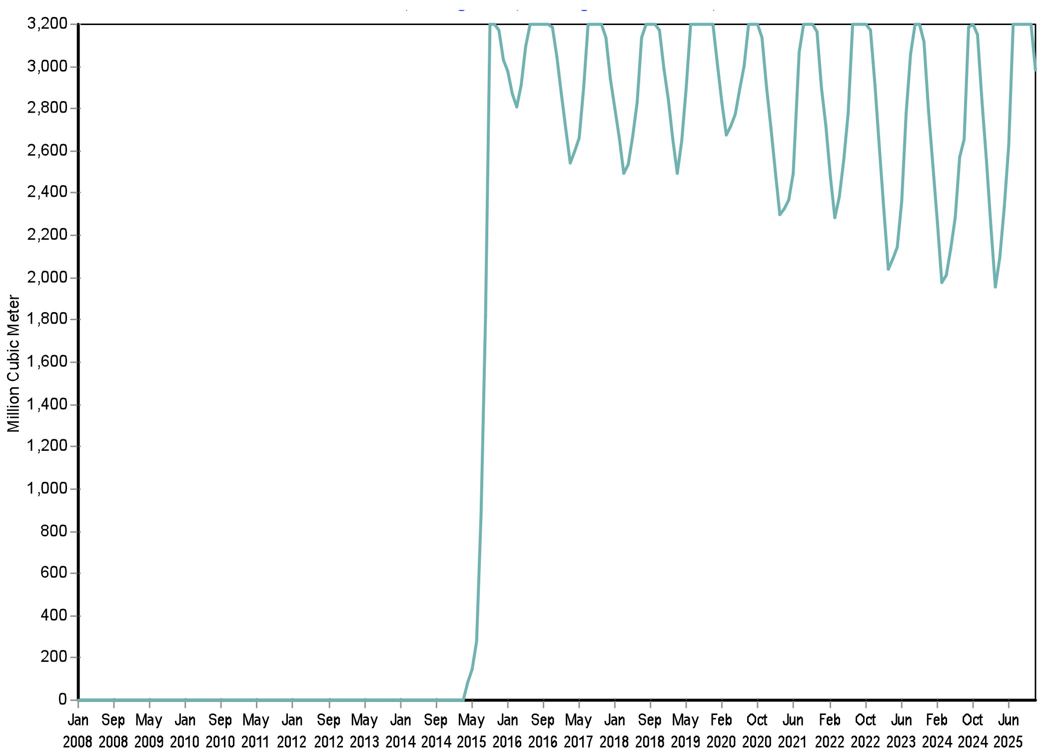


Figure 3.3: Pwalugu reservoir storage volume in million m^3 (2015-2025)

The graph highlights the fluctuations of the storage volume and how the reservoir capacity is utilised increasingly over the plan period. Furthermore, it can be read from the graph that the required storage fluctuates within a range of 1,900 million m^3 and 3,200 million m^3, equivalent to a reservoir volume of 1,300 million m^3. To this volume should be added a certain "dead" storage estimated[25] at 300 million m^3 as an allowance primarily set aside for sediment accumulation during the lifetime of the dam. In other words, to meet the total water requirements by 2025, including an assumed development in irrigated agriculture of up to 50,000 ha as well as satisfying the other demand categories, would require a reservoir capacity of 1,600 million m^3. In this case, the dam height would be reduced to around 27 metres measured from the deepest point in the river course, and the crest length would be about 900 metres.

Figure 3.4 shows the percentage of water requirement met throughout the plan period provided that the Pwalugu scheme is constructed and put into operation by 2015. The graph below clearly depicts the impact of the dam with frequent water shortages before 2015 and 100% coverage at all demand sites in the remaining part of the plan period.

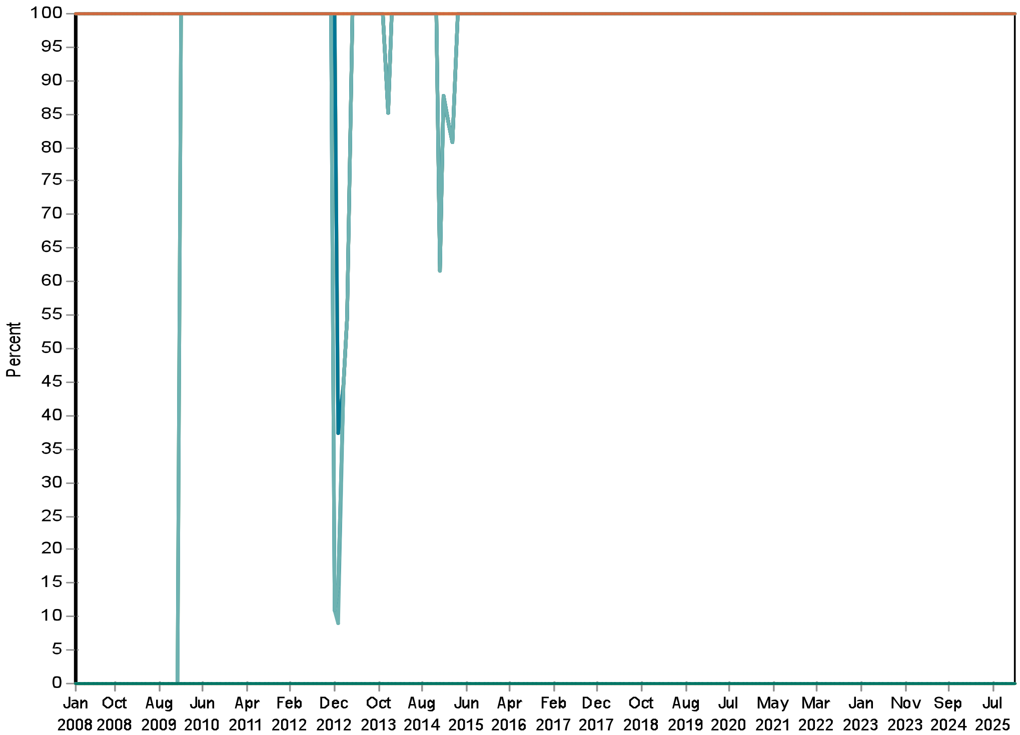


Figure 3.4: Demand site coverage (in %) with Pwalugu reservoir built by 2015

Impact on inflow to the Volta Lake

As mentioned, the WEAP model also gives the flow at pre-defined sections of the river system with due consideration to meeting the various water requirements and incorporating the upstream-downstream interactions. Of specific interest in this regard is the impact on the inflow to the Volta Lake caused by the above analysed expansion in the irrigation requirements.

From the model runs presented for Scenario 3 and Scenario 5, the mean annual inflows to the Volta Lake emanating from the White Volta River system towards the

[25] *Agrasi, S.A. (2005). Assessment of suspended sediment inputs to Volta Lake. Lakes & Reservoirs: Research and Management 10, pp. 179-186.*

end of the plan period are found to be about 6,500 million m^3 and 5,150 million m^3, respectively. That means, a development of up to 50,000 ha of irrigated lands would reduce the inflow to Volta Lake by about 1,350 million m^3 annually. To this volume should be added evaporation losses imposed by the establishment of the Pwalugu reservoir estimated at 450 million m^3 annually[26].

This reduction of 1,800 million m^3 annually is equivalent to about 27% of the White Volta's inflow, which in turn contributes in average about 23% to the water resources of the Volta Lake (the other main contributions come from the Oti River, the Black Volta River and the many, smaller inflows directly to the lake). In conclusion, the water requirements of the envisaged irrigation developments (50,000 ha) are found to account for approximately 6% of the total inflow to the Volta Lake[27].

For comparison, it can be noted that the WEAP model runs for Scenario 1 and Scenario 3 indicate that the combined effect of climate change and reduction in dry-season flow from Burkina Faso accounts for a reduction annually of about 800 million m^3 towards the end of the plan period, i.e. about half of the amount to be used in a fully developed irrigation scenario.

It should also be noted, that construction of a dam at this location will also provide a certain degree of flood retention measure for the benefit of the downstream reaches of the White Volta River valley, which normally are quite prone to be flooded during these recurrent events.

3.3.3 Overall assessment and concluding remarks on scenario analyses

The scenario analyses have highlighted that storage facilities sooner or later need to be included in the further expansion of the various water supply schemes that be for the major urban schemes (Tamale) or new irrigation ventures. Specifically, the looming risk of a reduced low-flow regime in the White Volta due to further expansion of the irrigated areas downstream of Bagré Dam in Burkina Faso compounded with impacts of climate change necessitates such considerations.

Considering availability of water only, i.e. without taking into account the various technical infrastructure requirements in abstracting and transmitting and distributing the water to consumers and the irrigation schemes, and not the least the economic and financial consequences, an attractive solution would be to construct a dam in the upstream section of the White Volta system with a reservoir capacity large enough to safeguard the future water demands through the required within-year storage.

Scenario 5 includes a proposed 1,600 million m^3 reservoir with its dam located midway between the Pwalugu road bridge and the Red Volta confluence with the White

[26] *The surface area of the reservoir is estimated to be 300 km^2, which with an annual "open surface" evaporation rate of 1,500 mm translates into an evaporation of 450 million m^3 per year.*

[27] *Consequently, the hydroelectric output generated at the Akosombo and Kpong power stations will be reduced proportionally, which amounts to some 50-60 MW. That means, although the new multi-purpose Pwalugu scheme will only just barely compensate for the loss in hydroelectric output generated at the existing Akosombo and Kpong power plants, water security, and hence realisation of the agro-industrial development potential, is safeguarded in the White Volta Basin if the Pwalugu scheme is to be constructed.*

Volta. This storage facility would be able to augment the dry season flow downstream in the entire stretch of the White Volta River to the extent that future projected water demands of e.g. an expanded greater Tamale water supply scheme and large-scale irrigation developments (up to about 50,000 ha) can rely on direct (run-of-the-river) abstractions from the river.

Alternatively – or rather in conjunction with the Pwalugu reservoir – a dam site on the Kulpawn River could also be considered, but this alternative has not been pursued further in the context of this IWRM Plan.

It should also be reiterated that the full development in the irrigation potential as proposed here combined with 100% coverage of the other surface water based supply schemes in the basin, by the end of the plan period accounts for 27% reduction in the annual flow in the lower section of the White Volta River, equivalent to a reduction of about 6% of the total inflow into the Volta Lake.

Although meant as a remedy for augmenting the low-flow regime of the White Volta, and hence as a measure towards addressing the impact of climate change, to ensure continued socio-economic development in this part of Ghana, it should be reiterated that the proposed Pwalugu dam also would serve as a flood retention reservoir, which to some extent will alleviate the devastating effects of the recurrent floods in the downstream reaches of the White Volta flood plains.

Undoubtedly, the results of the scenario analyses particularly related to the future irrigation water demand, is sensitive to how much the effect of climate change and accompanying inter-annual variability in rainfall distribution eventually will increase the irrigation water requirement per unit area (m^3/ha/year). In the scenario analyses the estimated present amount is increased gradually by 75% at the end of the plan period. In this connection it should be mentioned that a direct proportionality exists between changes in this figure and the total area in hectares, which can be irrigated for a certain amount of water made available.

Considering the size and importance of the water requirements for irrigated agriculture, it is paramount to improve irrigation techniques by adopting practices that use water more efficiently, e.g. introducing lined canals instead unlined, preventing seepage from the main transmission canals by piping the water, and applying efficient methods like drip and micro-spray irrigation. Furthermore, diversification of harvest pattern by shifting to more drought resistant and less water demanding crops will also release some pressure on the water resources.

As far as meeting the irrigation water requirements it is also important to look at possibilities of using groundwater or sub-surface water contained in the dry river beds for irrigation conjunctively with the traditional surface water sources.

In parallel to these developments, efforts should also be made more vigorously to bring down the unacceptable high rate of un-accounted for water (water supply system losses) in the urban schemes. A number of measures exist to assist towards the reduction of physical losses, some of which can be implemented by the service provider (GWCL), e.g. leakage detection/repair and renovation of old distribution network, and other measures which direct themselves more to the consumers, that be industrial, institutional and individual users.

The introduction of water demand management measures is also an important aspect in curtailing the otherwise ever increasing demand. In the water demand projections presented above, the departure point in the calculations is a list of pre-set unit consumption figures (ref. Table 3.1). The aim must be to halt the continuously increasing trend as reflected in the table values through measures, including public awareness raising, which should address, e.g. behavioural changes towards being “water-wise” individually and collectively, and being conscious about water (ab)uses.

Other measures which should be considered include changes to building codes to make it mandatory to install water-saving devices (self-closing taps, low-flush toilets etc) particularly in public institutions, boarding schools and military barracks. Additionally, the introduction of rainwater harvesting from roofs and other surfaces, and extraction of water from dry river beds should all be promoted.

4. CONSULTATIVE PROCESS

4.1 Application of SEA in the IWRM planning process

This IWRM plan is based on hydrological and other technical data, socio-economic trend analysis, and population census information that only partly has been presented earlier and not as an integrated assessment with the purpose of describing the present and future situation within the White Volta Basin concerning the availibility and quality of the water resources.

In parallel with the technical assessments and description of the water resource-related challenges as presented in the previous chapters, a consultative process has been carried out to involve basin-based stakeholders with the aim of capturing the local knowledge on water resources problems and actions required in addressing the identified water management issues and problems.

In the Ghanaian context, well anchored procedures exist where plans and programmes are elaborated and vetted following a participatory approach allowing for thorough public discussions – often in workshop settings – guided by principles which form part of the concept of Strategic Environmental Assessment (SEA). SEA procedures and tools[28] have been applied in the process of developing the White Volta Basin IWRM plan.

A SEA approach for planning is defined as:

"*A systematic process of evaluating the environmental effects of a policy, plan or programme and its alternatives, including documentation of findings to be used in publicly accountable decision-making"*.

Furthermore, the application of SEA procedures in IWRM planning means that the evaluation of environmental effects has an additional social dimension, viz.:

"…to safeguard the future sustainable use of water resources aimed at maintaining the economic and social welfare within a basin without compromising the preservation of vital aquatic ecosystems".

The district-based planning by District Assemblies is the cornerstone of the decentralised governmental approach for which the overall legal framework and institutional delegation of responsibilities are proven and understood - although gaps in legislation, overlapping responsibilities, lack of capacity/resources and enforcement still exist.

---

[28] *Support and Capacity Building to apply SEA Principles and Tools in preparing IWRM Plans at River Basin Level. WRC (October 2006).*

An IWRM plan for a basin addresses the basin-wide water management problems to achieve future sustainable management of the basin's water resources, and as such provide a framework for local water management planning at the district level.

Consequently, the effects of the IWRM plan should not be restricted to a description of broad existing and projected future environmental and social impacts, but should also try to describe the effects of the IWRM plan on other existing plans and programmes. The IWRM plan may entail legal and institutional consequences that may cause conflicting management structures, which then need to be coordinated and adjusted to ensure an efficient implementation of the plan.

In adherence with the SEA principles of embracing a participatory approach, stakeholders with specific interest/knowledge of the basin, including planners from District Assemblies, governmental departments, members of the White Volta Basin Board, NGOs and water user organisations were gathered at two occasions in workshop settings convened by WRC at Bolgatanga.

The objective of the first workshop was twofold, namely (i) to identify and rank water resource management issues and problems within the White Volta Basin as perceived by the stakeholders, and (ii) to identify and prioritise actions and interventions, which in a realistic way can address and mitigate the various identified problems.

At the second workshop the action programme was subjected to a test aimed at assessing the overall sustainability of the IWRM plan by the concerned decision-makers and other stakeholders.

The outcome of this consultative process with specific results emanating from the tool applications are reported in the following Sections 4.2 to 4.6.

4.2 Water resources management issues as identified by stakeholders

Table 4.1 presents the result of the exercise carried out as part of the first workshop aimed at identifying what are considered the important water resource issues and problems prevailing in the basin. The information in the table reflects the answers as provided by five working groups, which the workshop's 25 participants were divided into. Each group was asked to agree on a list of the 10 most important water resource related problems based on the result of an identification (scoping) exercise carried out by all participants on individual basis, which preceded the group work. It should be mentioned that the listings of problems in Table 4.1 are not prioritised or ranked as such.

It can be seen from the listing that -

- although a diversity in opinion exists among stakeholders as to the main problems to be addressed, there are also quite coinciding views and similarity in water resources management problems listed by the five groups;

- the issues identified to a large extent have their background in individual perceptions of problems in everyday life without a direct view concerning implications for the basin looked at as a unit and hardly any attention given to the transboundary character of the river system; and
- Cost implications and other resource requirements as well as lack of institutional capacity for implementation of the various proposed water resources management activities and mitigating measures are not listed explicitly among the issues/problems to be addressed.

Due to the rather marked similarity among quite many of the 50 problems, a careful scrutiny provided the basis for reducing the number of issues to 15 distinct different problems.

As mentioned above, the scoping exercise by the stakeholders did not list economic (cost) and financial aspects as a specific issue/problem. These aspects, nevertheless, are considered important and, subsequently, a specific problem area was added to the list.

Furthermore, for compilation and description of the findings from the identification of water resource management issues/problems, the problem areas were grouped into the following categories in accordance with commonly used criteria for describing the sustainable development in Ghana, viz.:

- natural resources,
- socio-cultural conditions,
- economic and financial aspects, and
- regulatory, administrative and institutional aspects.

Table 4.2 reflects the above described criteria for listing the identified issues and problem areas.