Report on:

Final Coordination Meeting of project

RAF/7/011 *Integrated and Sustainable Management of Shared Aquifer Systems and Basins of the Sahel Region*

Accra, Ghana

28 November to 2 December 2016

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1. INTRODUCTION

1.1. Background

Project RAF/7/011 *Integrated and Sustainable Management of Shared Aquifer Systems and Basins of the Sahel Region* was initiated in 2012 by the International Atomic Energy Agency (IAEA) to respond to the critical issue of the lack of water resources in the Sahel region.

The Sahel region is subject to infrequent precipitation, ranging from 200 mm to 600 mm a year. Most rain falls in the summer during the movement of the inter-tropical convergence zone, a meteorological event that creates a monsoon type rainfall pattern. In some years, the Sahel receives a fair amount of rain; however, it may be isolated to one area or be so intense in magnitude that it is detrimental to crops. Much of the region depends on rain as its primary water source. In the late 1960s, the Sahel began to experience recurrent droughts that would last until the early 1980s. The droughts resulted in over a million deaths in the region. Sensitivity analysis has been carried out on the basis of historical observations (1901-2000) to identify regions with the largest difference in precipitation between drought and normal years. Three particularly sensitive regions have been identified: (i) the western-most part of the region (Senegal and Mauritania); (ii) the stretch between Mali and Niger; and (iii) the eastern fringe of Ethiopia, extending northward up to Sudan. Of the ten worst droughts since 1970, five occurred simultaneously in the eastern and western Sahel.

Many people in the Sahel region depend on groundwater as their main source of water supply. However, over the past few years the number of wells and irrigation systems in various aquifers in this region has increased with no or inadequate regulation of groundwater abstraction. This has resulted in overexploitation of groundwater resources and a subsequent decline in the quantity of available groundwater resources and lowering in groundwater levels. In addition, the deterioration of groundwater quality has been observed around urban areas, mining activities, the areas of intensive agriculture and along coastlines. High nitrate and arsenic levels as well as salinization are reported to be among the key water quality challenges. All these challenges come against the backdrop of climate change and variability which are already having an impact on groundwater recharge and demand for groundwater abstraction. Appropriate assessment of water resources is essential for assuring water supply and sustainable development and management of water resources. The lack of assessment of water resources in many developing countries including those in the Sahel region has already been recognized by the international community. Within the Sahel region, the major part of available fresh water is located in underground aquifers but the information on the aquifer geometry, groundwater availability (quantity and quality) and renewability is still inadequate. The lack of this information greatly affects sound decision making regarding sustainable development and management of this scarce resource. This information therefore needs to be generated if the challenges currently faced by the Sahel region are to be addressed to ensure integrated management and sustainable development of the shared groundwater resources.

The project responds directly to Sustainable Development Goal 6: *Ensure access to water and sanitation for all* and target 4: *By 2030, implement integrated water resources management at all levels, including through transboundary cooperation as appropriate.*

1.2. Envisaged Objectives, Outcomes, Outputs

The objective of the project is to provide a scientific basis for preparation of a Strategic Action Programme (SAP) for multipartite management of shared aquifers. Specific objectives are as follows:

- To provide evidence for establishing legal, policy and institutional framework for multi-partite management and rational use of shared aquifers;
- To enhance human capacity for the application of conventional and isotopic techniques on shared groundwater resources;
- To address and fill key methodological, data and knowledge gaps in the shared aquifer/basin systems of the Iullemeden Aquifer System, Liptako-Gourma-Upper Volta System, the Senegalo-Mauritanian Basin, the Chad Basin and Taoudeni Basin;
- To raise awareness and promote information sharing among key stakeholders on sustainable use and management of shared groundwater resources.

The outcomes of the project are envisaged as:

- Hydrogeological characterization of major trans-boundary aquifers/basins in the Sahel region;
- Updated water balance estimations of river basins and study of the interaction between surface waters and major trans-boundary aquifer/basin systems;
- Enhanced capacity of national and regional institutions to adopt sound water resources management policies of trans-boundary systems.

The major output of the project, to be achieved by December 2016, is a report including recommendations for improving the use and protection of each of the five major trans-boundary aquifers of the Sahel region based on new hydrological information acquired using nuclear techniques, among other research tools.

2. MEETING PROCEEDINGS

The list of participants is to be found in Annex 1 and the Agenda in Annex 2.

After presentations of a summary of the project's facts and figures, and the IAEA's IWAVE methodology, the Meeting considered national reports on work done in the thirteen participating countries (Algeria, Benin, Burkina Faso, Central African Republic, Chad, Cameroon, Ghana, Mauritania, Mali, Nigeria, Niger, Senegal and Togo).

Work done at the basin scale was then presented by five IAEA experts who had been given home-based assignments to produce reports covering the following transboundary aquifers or basins:

- Taoudeni;
- Liptako-Gourma/Upper Volta;
- Senegalo-Mauritanian;
- Lake Chad; and
- Iullemeden.

In order to identify possible synergies, representatives of the following river basin authorities and partners organizations made presentations on their work:

- Autorité du Liptako-Gourma;
- Volta Basin Authority;
- Lake Chad Basin Commission;
- Niger Basin Authority;
- UNESCO; and
- Bundesanstalt für Geowissenschaften und Rohstoffe (BGR).

Unfortunately, representatives of the Organisation pour la Mise en Valeur du fleuve Sénégal (OMVS) and Sahara and Sahel Observatory (OSS) were unable to attend the Meeting.

The experts then worked with the Project Counterparts to improve their reports. Focused presentations on national reports were then developed for submission to senior decision-makers in Ministries of Water who joined the Meeting for the final two days. These included the Minister of Water of CAF. The reports focused, in a less technical manner, on achievements, gaps, possible future work and recommendations to Governments, Partners and the IAEA.

The five experts then presented less technical, focused basin reports aimed at the decision-makers of the Ministries of Water.

Following discussions, the meeting identified several areas which could be contained in a possible phase two project.

3. PROJECT ACHIEVEMENTS

3.1. Project facts and figures

The project delivered the following:

- Eight Training courses on:
    - Isotope data interpretation;
    - Water quality aspects;
    - Groundwater age estimations using isotope methods;
    - Hydrogeological/Geochemical mapping.

- Nine Fellowships and Scientific Visits including three fellows trained at the Australian Nuclear Science and Technology Organization (ANSTO) through an in-kind contribution;

- 25 Expert missions including 22 technical Advisory Missions;

- One outreach mission;

- Five expert home based assignments for Basin result collation and interpretation;

- Eight technical meetings:

    - Five basin based meetings with experts (to update workplans and to facilitate information and data sharing)
    - Three coordination meetings.

- 88 professionals trained in sampling, analysis and interpretation of isotope hydrology related data (70 male + 18 female).

3.2. Sampling campaigns

National sampling campaigns are described in the national reports. In total, the project achieved the following analytical results:

- Over 2200 hydrochemical analyses (major ions and some trace elements);
- Over 2400 deuterium and oxygen-18 results;
- Over 1400 tritium results;
- Over 125 radiocarbon and carbon-13 results.

A map of the samples taken is found in Figure 1.

3.3. Project outputs

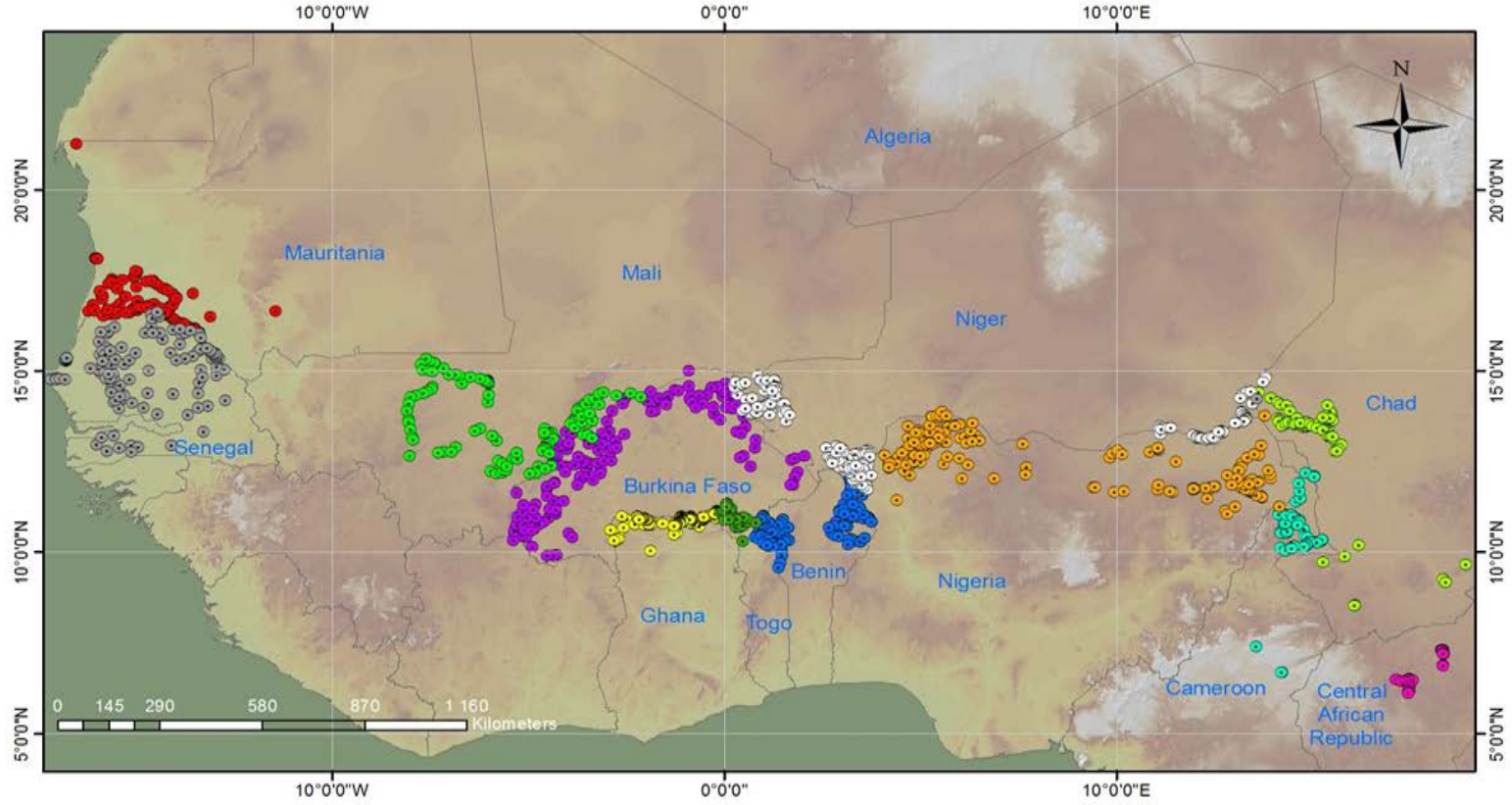
The project has produced the following outputs:

- Five basin reports on the hydrogeological, hydrochemical and isotopic assessment of the basins highlighting major findings, and recommendations on water management aspects, gaps identified in terms of required hydrogeological information and recommended future work;

- Thirteen national reports detailing main hydrological questions/aspects addressed highlighting major findings, and recommendations on water management aspects, achievements in terms of capacity building and development of analytical capacity;

- Enhanced national capability of thirteen Member States for sampling and acquisition of hydrological data through training and provision of equipment;

Figure 1: Sampling sites



- A functional isotope hydrology laboratory in Ghana;
- Laser spectroscopic isotope water analyzer equipment in Algeria and Nigeria.

A final report of the project can now be prepared. Arrangements for its production will shortly be made.

3.4. Financial Implementation Rate

The following table summarises funding received and used:

Donor	**Fund code**	**Amount provided (€)**	**Funds unused by 31 November 2016 (€)**
IAEA	TCF	540,000	926
USA	EBT-USA01-13-06:	184,493	681
USA	EBT-USA01-12-05:	201,630	939
Sweden	EBT-SWE08-13-01:	208,279	0
Sweden	EBT-SWE02-11-01:	328,206	0
New Zealand	EBT-NZL03-15-01:	50,000	169
New Zealand	EBT-NZL01-14-02:	31,056	49
Republic of Korea	EBT-KOR09-15-01:	180,800	971
Japan	EBT-JPN01-13-01:	113,250	6
Japan	EBT-JPN01-12-01:	80,400	189
USA	EBT-USA01-15-05	49,972	413
USA	EBT-USA07-16-02	80,000	40,887
USA	EBT-USA01-16-08	201,136	20,142
	Total:	**2,249,222**	**65,372**

Overall financial implementation rate = 97.1 %

3.5. Technical Findings

Below is a summary of key findings across the five basins:

3.5.1 Lake Chad Basin

- Groundwater from the shallow Quaternary aquifer of the Lake Chad Basin can provide important and relatively good quality waters to local populations;
- Groundwater flow patterns are still unclear concerning the Quaternary aquifer. However, groundwater interaction with the main river courses, and potentially Lake Chad, is a major phenomenon to consider;
- The southern boundary of the Lake Chad Basin appears to be the main source of water for all rivers and hence part of the groundwater within the Central basin;
- Groundwater quality is globally good enough as drinking water supply of local population but high mineralization levels can be an obstacle in some places;
- Contamination by nitrate and other components can be a problem in the most densely populated areas especially because of a lack of any protection of the wells or borehole from animals droppings and latrines;
- Even for the shallow aquifer levels of the Quaternary, residence time of groundwater can be important, locally exceeding the 60-70 years' time range;
- Mixing with evaporated water is a major characteristic of the isotopic signature of groundwater over most of the watershed area – supporting the hydraulic connection between surface and groundwater.

3.5.2 Iullemeden and Taoudeni Basins

Similar findings were made for these two Basins:

- The geochemistry and isotope hydrology of ground and surface water have provided useful insights into their origin, mineralization processes and recharge mechanisms;
- Some shallow groundwater samples show local pollution by nitrates mainly in Niger and Benin. This local nitrate contamination is detected in different aquifers and does not show any specific spatial pattern. This pollution could be linked with anthropogenic activities: mainly agricultural and domestic practices;
- The isotopic approach underlined the hydraulic interconnection between aquifers, palaeowaters, direct recharge of aquifers by surface waters in some areas, and recharge of aquifers by modern precipitation, which influence the groundwater geochemistry in both basins;
- The resources in the studied aquifers of the Iullemeden basin represent a significant reserve of good quality water which needs to be properly managed as high quality resources and as part of integrated plans for the basin's future supplies.

3.5.3 Liptako Gourma-Upper Volta System

- The stable isotopes are clear indicators of evaporation effects observed in groundwater bodies and have been used to demonstrate the relationships between groundwater and surface water. This feature is also observed in "old" groundwater, which was evaporated during recharge and has kept this isotope signature over time. The very old (hundreds of years) groundwater is isotopically depleted in stable isotope contents, indicating a paleo-recharge fingerprint;
- The system is dominated by hard-rock aquifers showing highly variable chemical and isotope contents, indicating that the hard-rock aquifers are composed of small and independent units;
- Nitrate, as indicator of human pressure on water quality, showed high spatial variability and, in some sectors, very high concentrations. The hard-rock type aquifers and more precisely the weathered zone is highly vulnerable to anthropogenic impact.

3.5.4 Senegalo-Mauritanian Basin

- New major findings have been obtained on recharge and flow patterns in the Eastern part of the Maastrichtian aquifer;
- New information on the geographical boundary of saline groundwater and the salinization process has been obtained in the Senegalese Maastrichtian aquifer;
- In the Quaternary and a part of the Continental Terminal aquifers, on the Northern side of the Senegal River, present day recharge from both rainfall and River water has been identified, as well as the two sources of salinization (ancient sea water intrusion and evaporites), by combining stable isotopes and chemical data.

4 CONCLUSIONS AND RECOMMENDATIONS

4.1. General conclusions

Project RAF/7/011 has provided a first, broad overview of groundwater in the Sahel Region. This can be considered a significant achievement given the vast area studied.

It was clear that of all UN agencies, only the IAEA has recently achieved actual results related to characterization of water resources, especially underground water in the Sahel region. BGR has worked mainly in the Lake Chad region and produced significant data which were incorporated into the Lake Chad Basin report by the IAEA expert. The IAEA and BGR should regularly communicate to avoid duplication of work and to share data.

It was gratifying to note that project RAF/7/011 has succeeded in developing capacity to a greater or lesser extent in all thirteen participating countries. All Project Counterparts attempted to use their training to develop their reports and interpret their data.

Whereas Governments and Partner Organizations tend to use external personnel and consultants to carry out field work, the IAEA has succeeded in developing capacity of local scientists to perform the actual work on the ground. This will enhance future sustainability.

An active and enthusiastic network of local counterparts now exists upon which future projects can be built.

4.2. Translating technical findings into policy and/or water management strategies

UNESCO reported that they will be hiring a consultant in 2017 to develop a large project on cross-border water management under the UN Integrated Sahel Strategy (UNISS). It is anticipated that the IAEA will be requested to be involved.

Some river basin authorities reported that they faced challenges in fulfilling their mandates. It is proposed that the IAEA should, however, maintain contact with regard to future work. Opportunities to strengthen collaboration should continue to be sought. In some cases (notably the Lake Chad Basin Commission), the authorities are issuing Policy Briefs on judicious water management to Member States. The IAEA may wish to use its similar modality ("IAEA Briefs") to recommend immediate follow-up actions to be taken by Governments to address the finding of project RAF/7/011.

The Meeting adopted the IAEA's IWAVE approach as the methodology to be used for the potential phase two project. This involves a comprehensive approach to characterization, management and monitoring of groundwater resources based on a thorough gap analysis of countries' needs and available capacity.

4.3. Recommendations

In the short term, the IAEA should prepare "IAEA Briefs" to recommend immediate follow-up actions to be taken by Governments to address the finding of project RAF/7/011. A further meeting at high level (even at Ministerial level) should be considered to convey important and urgent actions for follow up.

It is recommended that a phase two project be formulated with the facilitation of the IAEA and other donors. The IWAVE approach should be used. The follow-up project should be ambitious in nature and aim to make a decisive contribution to the characterization, management and monitoring of groundwater resources using isotope hydrology and other conventional techniques.

The phase two project will also address near term issues identified under RAF/7/011 such as:

- Translation of findings already made into policies (such as Strategic Action Plans or Briefs) especially for control of pollution and judicious development and management of good quality water resources. Development/consolidation of conceptual and numerical groundwater flow models of shared aquifer systems could help to define scenarios for the sustainable management of water resources;
- Better characterization of deep aquifers;
- Sampling in areas where important data gaps have been identified;
- Setting up of additional stations to sample rainfall and surface waters for isotope analysis;
- More ^{14}C and ^{13}C analyses are required to improve the current understanding of groundwater dynamics in various aquifers;

- Analysis of heavy metals is required in selected areas;
- Enhancing collaboration between the participating countries and the partner organizations involved in management of shared groundwater resources.

A report-back meeting should be arranged with the countries which provided funding under the Peaceful Uses Initiative of the IAEA.

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Togo	Mr Gounten Manouaba Ministère de l'agriculture, de l'élevage et de l'hydraulique Direction des Ressources en Eau 04 Ministries Bldg 01 B.P. 119, Lomé TOGO Tel.: 22890263671 Fax: 22822209047 EMail: gmanouaba@gmail.com
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ANNEX 2: MEETING AGENDA

Day 1: Monday 28th November 2016

TIME	ITEM	PRESENTER
09:00	Welcome Remarks by NLO for IAEA Affairs in Ghana	NLO Ghana Mr B. Nyarko
	Opening of Meeting by the Chairman	Prof. Francis Allotey
	Welcome by the Ministry of Water Resources	Dr. Ben Ampomah, Chief Executive Officer of Water Resources Commission
	Opening Remarks by IAEA TC	Neil Jarvis
	Choice of Facilitators/Rapporteur & Adoption of Agenda	NLO Ghana
	The Sahel Project – Status Update	Neil Jarvis
10:05 - 10:15	**COFFEE/TEA BREAK**	
10:15 -10:45	Presentation of the IWAVE Methodology	Luis Araguas
Presentation of National reports: Achievements, Outcomes, Gaps and recommendations: ~ 20mins per country		
10:50 – 11:10	ALGERIA	
11:10 – 11:30	BENIN	
11:30 – 11:50	BURKINA FASO	
11:50 – 12:10	CAMEROON	
12:10 – 13:30	**LUNCH BREAK**	
13:30 – 13:50	CENTRAL AFRICAN REPUBLIC	
13:50 – 14:10	CHAD	
14:10 – 14:30	GHANA	
14:30 – 14:50	MALI	
14:50 – 15:10	MAURITANIA	
15:10 – 15:30	NIGER	
15:30 – 15:50	NIGERIA	
15:50 – 16:00	**COFFEE/TEA BREAK**	
16:00 – 16:20	SENEGAL	
16:20 – 16:40	TOGO	
16:40 – 17:30	**Discussion on the National Presentations and closure for day 1.**	

Day 2: Tuesday 29th November 2016

09:00 - 09:10	**Summary and outcomes of Day 1 and Items for Day 2**	***Rapporteur/Facilitator***
	PRESENTATION OF AQUIFER BASIN REPORTS	
09:15 - 10:00	LAKE CHAD BASIN	*F. Huneau*
10:00 - 10:45	LIPTAKO-GOURMA-UPPER VOLTA	*L. Gourcy*
10:45 - 11:00	**COFFEE/TEA BREAK**	
11:00 - 11:45	IULLEMEDEN BASIN	*K. Zouari*
11:45 - 12:30	SENEGALO-MAURITANIAN	*Y. Travi*
12:30 - 13:30	**LUNCH BREAK**	
13:30 - 14:15	TAOUDENI	*J.D. Taupin*
	Presentation By River Basin Authorities and Partner organizations: Needs of the Sahel Region requiring further Scientific intervention	
14:20 - 14:40	Autorité du Liptako-Gourma	
14:40 - 15:00	Volta Basin Authority	
15:00 - 15:20	Lake Chad Basin Commission	
15:20 - 15:40	**COFFEE/TEA BREAK**	
15:40 - 16:00	Niger Basin Authority	
16:00 - 16:20	OMVS	
16:20 - 16:40	UNESCO	
16:40 - 17:00	Bundesanstalt für Geowissenschaften und Rohstoffe (BGR)	
17:00 - 18:00	**Discussion of the Basin reports, summary, achievements, outcomes and recommendations. Consolidation of Report by: Technical Officers, Resources Persons, Experts and Counterparts**	

Day 3: Wednesday 30th November 2016 -

09:00 - 10:30	**Interaction / work with Experts to fine tune National presentations and conclude on national highlights/recommendations to be presented on Thursday.**	
10:30 - 10:45	**COFFEE/TEA BREAK**	
10:45 - 12:30	Interaction / work with Experts to fine tune National presentations and conclude on highlights/recommendations to be presented on Thursday.	
12:30 - 14:00	**LUNCH BREAK**	
14:00 - 15:30	Discussion with partners on the overlaps, gaps, of their work in the Sahel region. What are the elements of a follow up project? Identification of the main components of a follow-up project using the IWAVE methodology.	Jarvis/Araguas
15:30 - 16:00	**COFFEE/TEA BREAK**	
16:00 - 17:30	Discussion with partners on the overlaps, gaps, of their work in the Sahel region. What are the elements of a follow up project? Identification of the main components of a follow-up project using the IWAVE methodology.	Jarvis/Araguas

Day 4: Thursday 1st December 2016

Rapporteur/Facilitator – TBD

09:00 – 09:10	**Opening Remarks**	Director –TCAF - IAEA
	Opening remarks from Min Water Resources, Central Africa Republic	Mr Leopold Mbolifatran
9:10 – 9:30	**The Sahel Project – Status Update 2.**	Neil Jarvis
9:30 - 10:10	Presentation of the opportunities for the future. Use of the IWAVE methodology.	Luis Araguas
Presentation of national highlights: Achievements, Gaps and recommendations		
10:10 - 10:20	ALGERIA	
10:20 - 10:30	BENIN	

10:30 - 10:40	BURKINA FASO	
10:40 - 10:50	CAMEROON	
10:50 - 11:00	CENTRAL AFRICAN REPUBLIC	
11:00 - 11:10	**COFFEE/TEA BREAK**	
11:10 - 11:20	CHAD	
11:20 - 11:30	GHANA	
11:30 - 11:40	MALI	
11:40 - 11:50	MAURITANIA	
11:50 - 12:00	NIGER	
12:00 - 12:10	NIGERIA	
12:10 - 12:20	SENEGAL	
12:20 - 13:30	**LUNCH**	
	Presentation of the synthesis of the Aquifer Basins: Implication for management, gaps, areas for future intervention.	
13:30 - 14:00	LAKE CHAD BASIN	*F. Huneau*
14:00 - 14:30	LIPTAKO-GOURMA-UPPER VOLTA	*L. Gourcy*
14:30 - 15:00	IULLEMEDEN BASIN	*K. Zouari*
15:00 - 15:30	SENEGALO-MAURITANIAN	*Y. Travi*
15:30 - 15:45	**COFFEE/TEA BREAK**	
15:45 - 16:15	TAOUDENI	*J.D. Taupin*
16:15 - 17:00	Discussion on the follow-up project using the IWAVE methodology.	

Day 5: FRIDAY 2nd December 2016

09:00 - 09:15	**Summary and outcomes of Day 4and items of Day 5**	***Rapporteur/Facilitator – TBD***
09:15 - 10: 00	Presentation of the synthesis of the project: Summary of the Sahel region identifying Key issues.	K. Zouari

10:15 - 11:00	Discussion on Project Recommendations & follow-up project using the IWAVE methodology.	
11:00 - 11:15	**COFFEE BREAK**	
11:15 - 12:30	*Project Business Meeting* : IAEA, River Basins, and Member States Discussion on Project Recommendations & follow-up project using the IWAVE methodology	
12:30 - 12:40	**CLOSURE**	
12:40 - 14:00	**LUNCH**	