THE REPUBLIC OF THE SUDAN
MINISTRY OF WATER RESOURCES,
IRRIGATION AND ELECTRICITY
WATER RESOURCES TECHNICAL ORGAN

THE REPUBLIC OF THE SUDAN
PROJECT FOR ENHANCEMENT OF INTEGRATED WATER RESOURCES MANAGEMENT

FINAL REPORT

May 2023

JAPAN INTERNATIONAL COOPERATION AGENCY
(JICA)

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RECS INTERNATIONAL INC.

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23-061

THE REPUBLIC OF THE SUDAN
PROJECT FOR ENHANCEMENT OF
INTEGRATED WATER RESOURCES MANAGEMENT

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Abbreviation

Abbreviation	Official name
ACZ	Agricultural Climatic Zone
AfDB	Africa Development Bank
AgWA	agricultural water for Africa
AQUASTAT	FAO's Global Information System on Water and Agriculture
AU	Administrative Unit
BADC	British Atmospheric Data Centre
BCM	billion cubic metres
COMESA	Common Market for Eastern and Southern Africa
CBO	community-based organization
COP21	Conference of Parties 21
C/P	counterparts
CRU-TS	Climatic Research Unit Time Series
DFID	Department for International Development
DIU	Dam Implementation Unit
DPs	development partners
DWSTC	Drinking Water and Sanitation Unit Training Centre
DWSU	Drinking Water and Sanitation Unit
EFS	environmental feasibility study
EIA	environmental impact assessment
EPA	Environmental Protection Act
FAO	Food and Agricultural Organization
GDP	Gross Domestic Product
GDNRWD	General Directorate for Nile River Water and Dams
GERD	Grand Ethiopian Renaissance Dam
GIS	geographical information system
GW	Groundwater
GSMP	Global Satellite Mapping of Precipitation
GWWD	Groundwater and Wadies Directorate
HAZ	hyper arid zone (in Agricultural Climatic Zone)
HCENR	Higher Council for Environment and Natural Resources
HRC	Hydraulic Research Centre
ICAD	The Interagency Coalition on AIDS and Development
IDP	internally displaced persons
IEE	initial environmental examination

Abbreviation	Official name
IFAD	International Fund for Agricultural Development
INDCs	intended nationally determined contributions
IOM	International Organization for Migration
IWRM	Integrated Water Resources Management
JAXA	Japan Aerospace Exploration Agency
JCC	Joint Coordination Committee
JICA	Japan International Cooperation Agency
JPT	JICA Project Team
LCD	litres per capita per day
ME	monitoring and evaluation
MM	minutes of meetings
MCM	million cubic metres
MDGs	millennium development goals
MIC	Ministry of International Cooperation
MAF	Ministry of Agriculture and Forestry
MARF	Ministry of Animal Resources and Fisheries
MENRPD	Ministry of Environment, Natural Resources and Physical Development
MFA	Ministry of Foreign Affairs
mil.US$	million US dollars
MIWR	Ministry of Irrigation and Water Resources
MLFR	Ministry of Livestock, Fisheries and Rangeland
MWIE	Ministry of Water Resources, Irrigation and Electricity
NASA	National Aeronautics and Space Administration
NBI	Nile Basin Initiative
NGO	non-governmental organization
Nile-COM	Nile Council of Ministers
Nile-SEC	Nile Basin Initiative Secretariat
Nile-TAC	Nile Technical Advisory Committee
NRMC	Natural Resources Management Committee
NRN	Nile River Flow North Zone (in Agricultural Climatic Zone)
NRS	Nile River Flow South Zone (in Agricultural Climatic Zone)
NWC	National Water Corporation
NWRC	National Water Resources Council
OCHA	United Nations Office for the Coordination of Humanitarian Affairs
OECD	Organization for Economic Co-operation and Development

Abbreviation	Official name
OJT	on-the-job training
PCM	project cycle management
PDM	project design matrix
PET	potential evapotranspiration
PWC	Public Water Corporation
PWCT	Public Water Corporation Training Centre
RD	record of discussions
RWC	Rural Water Corporation
SC	Steering Committee
SCE	State Council for the Environment
SDGs	sustainable development goals
SEA	strategic environmental assessment
SMA	Sudan Metrological Authority
(S)MIUD	State Ministry for Infrastructure and Urban Development
SMP	State Ministry of Production
SMS	short message service
SMWREM	State Ministry of Water Resources, Energy and Mining
SRZ	Southern Rain Fed Zone (in Agricultural Climatic Zone)
SW	surface water
SWAT	soil and water assessment tool
SWC	State Water Corporation
SWRC	State Water Resources Council
TC	Technical Committee
TMPA(3B42RT)	Tropical Rainfall Measuring Mission (TRMM) Multi-Satellite Precipitation Analysis
TOR	terms of reference
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNICEF	United Nations Children's Fund
URC	Urban Water Corporation
VCO	village development committees
VHF	viral haemorrhagic fever
WASH	water, sanitation and hygiene
WC	Water Council

Abbreviation	Official name
WES	Water, Environment and Sanitation
WMO	World Meteorological Organization
WRA	Water Resources Act
WRTO	Water Resources Technical Organ
WTO	World Trade Organization
WUC	Water Users' Committee
WUM	Water Users' Meeting

Chapter 1 Project Background, Objective and Structure

1.1 Background of the Project

Sudan has suffered from limited water resources, such as low annual rainfall of less than 300mm across most of the country, which constrains economic development and the daily life of its people. The "Water and Sanitation Policy of Sudan", prepared by the National Water Corporation in 2010, analysed that the water demand of 32.1BCM per year has already exceeded the water resources' volume of the whole country, which is between 29.5 and 31.5BCM per year. Moreover, increasing national population, with an annual growth rate of 3.2%, is putting further pressure on the water balance.

Water resources exist unevenly in regions in Sudan; the Non-Nile area has suffered from water shortages compared to the Nile area. It is one of the main reasons why there is a low access rate of safe water, namely 55%, in Sudan. Another challenge is the water allocation to each water-use sector; 90% of water is consumed for agriculture and only 3% for drinking water. Another issue is the improvement of water resources management, such as a hydrological observation system for groundwater and dam operation.

In relation to these aforementioned serious water conditions, Sudan needs to update its water use strategy at national level as well as its water resources' development plans, based on scientific data. Water resources management with an improved coordination mechanism among stakeholders will reduce the conflict surrounding water allocation and will enhance water use efficiency.

1.2 Outline of the Project

Objectives of the Project

The objectives of the Project are "to make recommendations for a practical strategy and establish an institutional and organizational framework to improve the policies, strategies and plans of the IWRM, which will contribute to the improvement of related projects".

Expected Outputs

Output 1: Water balance evaluation

Output 2: Analyses of issues on water resources management

Output 3: Implementation of IWRM in specific regions (pilot activities)

Output 4: Recommendations for a strategy, a legal framework and implementation arrangements

Subject Area

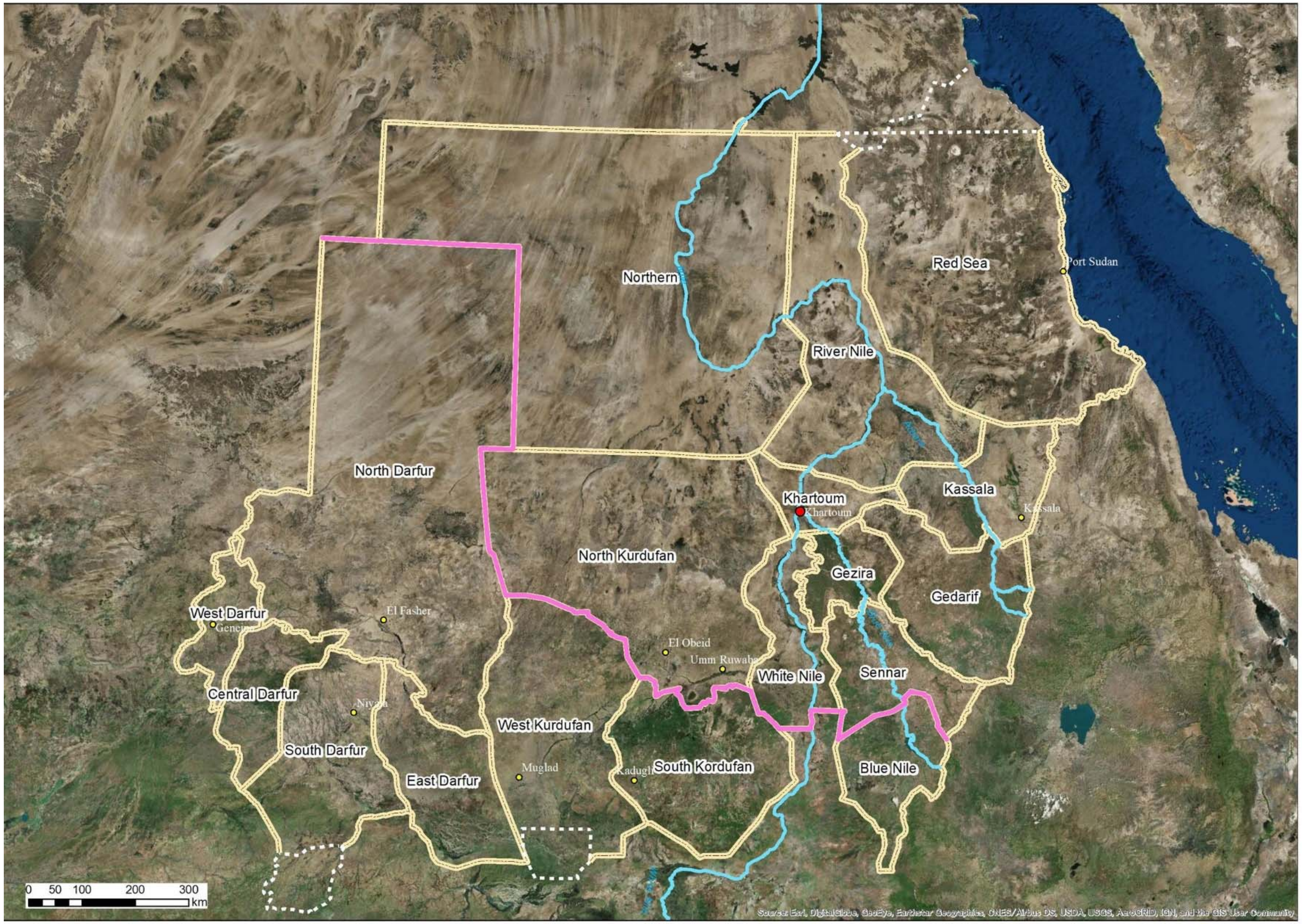


Figure 1.2-1 Location Map of Sudan

Main Government Offices and Organizations

These are the Water Resources Technical Organ (WRTO) of the Ministry of Irrigation and Water Resources (MIWR), the departments of the MIWR related to water resources such as Groundwater and Wadies Directorate (GWWD), ministries related to water use (Ministry of Agriculture, Livestock etc.) and the associated organizations in state governments (Ministry of Infrastructure, Urban Development, State Water Corporation (SWC), etc.).

Implementation Period

From August 2016 to March 2023.

Basic Policy for Project Implementation

The relationship between the objectives of the Project and four outputs are below.

As mentioned above, the objectives of the Project are "to make recommendations for a practical strategy and establish an institutional and organizational framework to improve the policies, strategies and plans of the IWRM, which will contribute to the improvement of related projects (Output 4)". Output 4 will be accomplished utilizing the results of the water balance analysis, based on scientific evidence and identifying water resources and water issues at national level (Outputs 1 and 2), reaching a participatory consensus with a wide range of stakeholders on water resources (Output 3) and implementing the IWRM in a practical manner (Outputs 1, 2 and 3).

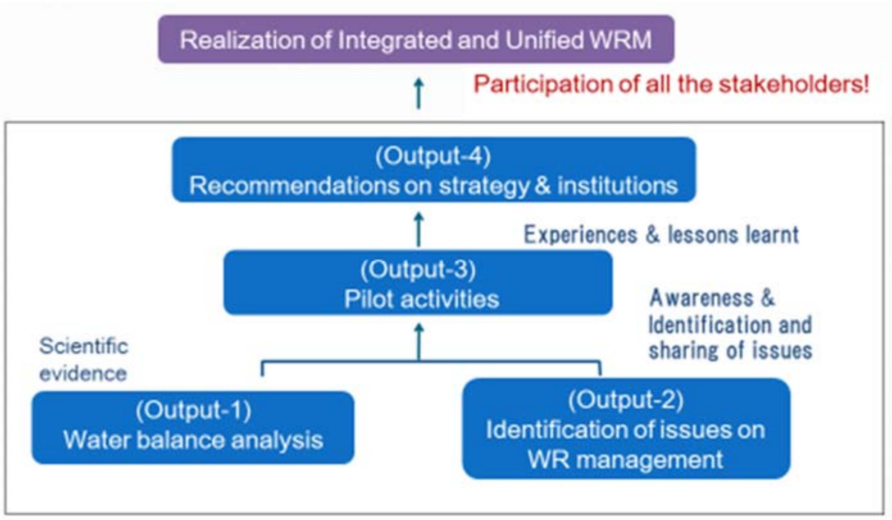
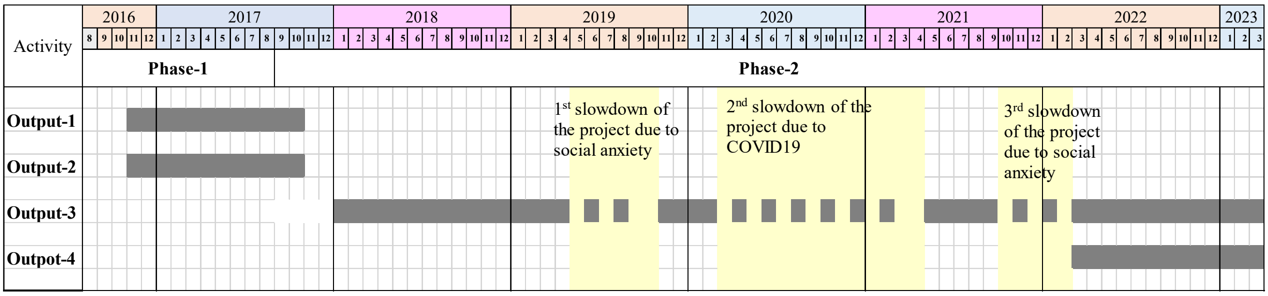


Figure 1.2-2 Relationship Between Project Objectives and Outputs

Activities

The Project began in 2016 and was scheduled to end in August 2018, but ultimately lasted until March 2023. During the course of the Project, activities were suspended three times, in 2019, 2020 and 2021-2022 (see Table 1.2-1). Accordingly, the Project was extended three times: the first extension was in October 2019, the second in March 2021 and the third in March 2022.

Table 1.2-1 Project Period and Activity



During the period of the slowdown, Japanese experts were unable to travel to Sudan, and from April 2020 onward, regular remote meetings were held weekly to allow the Japanese experts to exchange information with the counterparts (C/Ps), while continuing to strengthen the C/Ps' capacity. Even after the Japanese experts resumed their trip to Sudan, regular remote meetings continued with all the C/Ps. This enabled the Japanese experts and the Sudanese C/Ps to keep in touch throughout the year. The number of regular remote meetings increased 110 times. In addition to the regular meetings, group meetings were held weekly. The Joint Coordination Committee (JCC), the Steering Committee (SC), the Technical Committee (TC) and the Water Users' Committee (WUC) meetings were also held remotely during certain periods of the slowdown.

Important Meetings

The overall progress of the Project was reported by the JICA Project Team (JPT) to the Sudanese side at the JCCs. For the pilot activities in North Kordofan State, the SC and the TC were established in March 2018 and the WUC in November 2020. The dates of the JCC, SC, TC and WUC meetings are shown in Table 1.2-2. The JCC, SC, TC and the WUC acted as forums for consensus-building regarding the purpose of the pilot activity, the explanation of the content/progress of the activity, the discussion of issues relating to the implementation of the activity and the planning of the schedule.

Table 1.2-2 Dates of the JCC, SC, TC and WUC Meetings

No.	JCC	SC	TC	WUC
No.1	7th September, 2016	12th July, 2018	29th August, 2018	18th-19th November, 2020
No.2	17th April, 2017	28th November, 2018	25th September, 2018	15th July, 2021
No.3	19th October, 2017	14th February, 2019	11th December, 2018	23rd May, 2022
No.4	3rd April, 2018	26th November, 2019	10th February, 2019	20th December, 2022
No.5	29th November, 2018	25th August, 2020	3rd April, 2019	28th October, 2022
No.6	28th November, 2019	18th March, 2021	25th November, 2019	28th February, 2023
No.7	27th August, 2020	26th May, 2022 (State Water Resources Council (SWRC))	6th February, 2020	-
No.8	25th March, 2021	25th December, 2022 (SWRC)	27th August, 2020	-
No.9	1st June, 2022	9th March, 2023	9th November, 2020	-
No.10	20th March, 2023	-	9th December, 2020	-
No.11		-	16th March, 2021	-
No.12	-	-	28th July, 2021	-
No.13	-	-	26th May, 2022 (SWRC-TC)	-
No.14	-	-	7th Mar, 2023	-

C/Ps

The project activities were led by the Sudanese C/Ps, with Japanese experts providing technical support to the C/Ps. The Sudanese C/Ps consisted of the Federal C/Ps and the State C/Ps. The list of C/Ps is shown in Table 1.2-3. Ten members of the federal C/Ps worked on a full-time basis on this Project. Ten state government C/Ps also worked on a near-full-time basis. When working on the Project, the C/Ps were divided into six groups as Table 1.2-3. The purpose of the grouping system was to facilitate the exchange of information among the C/Ps and to strengthen cooperation among them. The C/Ps had limited experience of discussion, therefore, a group system was introduced to overcome this situation. Since July 2020, group-based online meetings have been the main activities ensuring the progress of the Project, and each group has been active in their duties. It is believed that the reason for this may be that individual C/Ps became aware that they are responsible for their own group activities.

Table 1.2-3 C/P Group

Group		Group No.	Leader	Sub-Leader	Members[1)]
1		Surface Water	El Tag	El Mohsen	M. Eldou, Suzan, Awad, Osman
2		Groundwater	M. Yousef	M. El Tayeb	Safaa, Sahar, Ibrahim, Mona
3		Irrigation	Farah	Agban	Zohaira
4		GIS/Database	Suzan/Sahar	Awad	Zohaira, Mona, Ibrahim, M. Yousif, Osman
5		Environment and WUC	Marwa	Mozamil	Marwa, Hind, Sahar, Abdalla, Mozamil
6	a	SWRC Management	Saffa	-	M.Yousif, Mona, Mozamel
	b	Law and Regulation	Ibrahim	Safaa	Siddig El Khatee
	c	NCWR Preparation	Marwa	-	Suzan, Sahar, Zohaira, Hind

1) Members of each group are duplicated

Chapter 2 General Situation Related to Water Resources in Sudan

2.1 Water Resources

(1) Topography

Sudan is the third largest country in Africa. Its terrain is generally flat with an elevation ranging from 200m to 600m. There are several mountain ranges. In the west, the Marrah Mountains rise to around 3,000 m while the Red Sea Hills exist in the east.

(2) Geology

Sudan's geology ranges from Precambrian crystalline basement rocks to Quaternary unconsolidated alluvial deposits as shown in Figure 2.1-1. The geological history witnessed a long period of erosion from the end of the Precambrian to the late Paleozoic, removing most of the previously deposited sedimentary cover with the exceptions of a few isolated outcrops.

During the Mesozoic, Nubian Sandstone deposits were laid down, and survived particularly in basins within the basement and the Paleozoic cover. The tectonic movements of the Rift system in the middle and late Tertiary led to the formation of vast structural basins. A volcanic phase throughout the late Tertiary and into the early Quaternary produced the basaltic bodies. In the Plio-Pleistocene period, these Tertiary basins received thick alluvial and lacustrine deposits, of the Um Ruwaba formation.

A major shear zone, the Central African Shear Zone, runs through the central part of Sudan.

Table 2.1-1 Geology of Sudan

Period	Lithology
Quaternary	The youngest sediments in Sudan include alluvial silts and clays with occasional sands, deposited in the valleys of the Nile and other rivers.
Tertiary	They are dominantly Tertiary in age and are formed of continental gravels, sands, silts and clays, and marine coral limestones. Their thickness can exceed 2 km.
Late Tertiary To Quaternary	The Um Ruwaba Formation occurs in two large trenches in the center and south of Sudan: the Bara and the Blue Nile/Rahad/Dinder area. The Um Ruwaba Formation comprises unconsolidated alluvial and lacustrine sands, silts and clays. It is between 150 m and 500 m thick.
Tertiary Volcanic Rocks	Basic volcanic rocks.
Upper Jurassic to Lower Cenozoic	The Nubian Sandstone covers almost one third of Sudan, and comprises largely horizontal or gently dipping, well stratified sandstones with layers of conglomerate and siltstone.
Cambrian to Carboniferous	Outcrops of un-metamorphosed sandstones occur in the west of the country, along the Chad border. Argillaceous sedimentary strata overlie the basement complex in central Kordofan.
Precambrian (Basement)	Undifferentiated basement rocks are exposed over almost half of the area of Sudan, composed of metamorphosed igneous, sedimentary and metamorphic rocks. Rocks include acid gneisses, quartzite and schists. They are intruded by igneous rocks and ring complexes, mainly granites.

Source; British Geological Survey HP

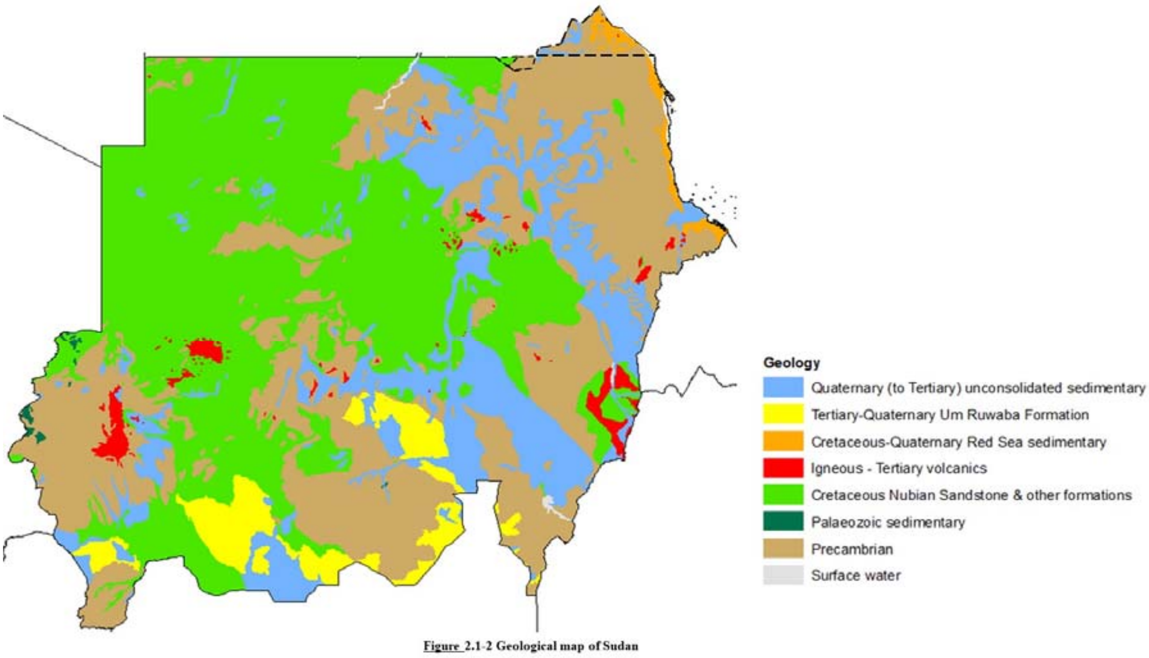


Figure 2.1-1 Geological Map of Sudan

Source: British Geological Survey

(3) Meteorological Conditions

Sudan is located at approximately 8-23° N and 21-39° E. Most national land is classified as having a "warm desert climate". The Nubian Desert spans between the Nile and the Red Sea, while the Bayuda Desert is located in the western area of Khartoum and spans between north of Omdurman and south of Korti. Haboobs (sandstorms) occur in the dry regions. Southern parts of Sudan, such as the Sennar, Blue Nile and some Darfur areas, are classified as having a "warm semi-arid climate", while a "tropical savanna climate" can be found in a very limited area near the borders with Ethiopia and Central African.

In general, the rainy season lasts for around three months (July to September) in the north and six months (June to November) in the south. The monthly average temperature and rainfall in the main cities are shown below in Figure 2.1-2 and Figure 2.1-3.

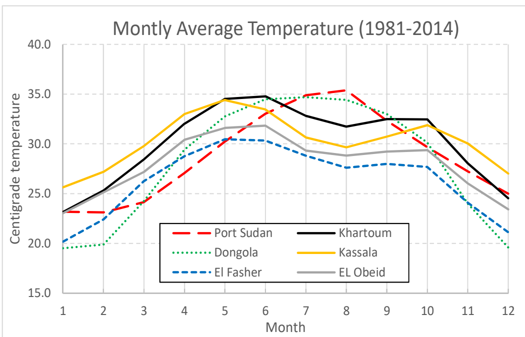


Figure 2.1-2 Average Monthly Temperature

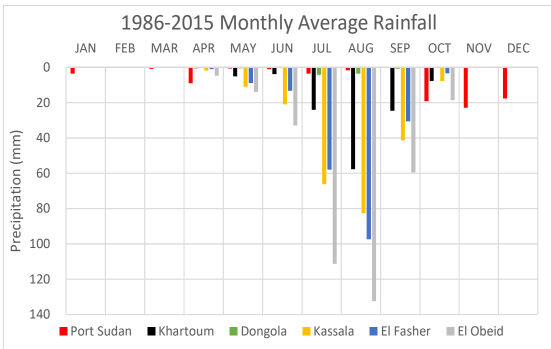


Figure 2.1-3 Average Monthly Rainfall

(4) Hydrological Conditions

The Nile River runs through Sudan from south to north. Blue Nile joins the White Nile in Khartoum. The flow discharge of the Blue Nile during the rainy season becomes extremely high, even though it is relatively less than that of the White Nile during the dry season. Due to the Grand Renaissance Dam in the upstream of the Blue Nile in Ethiopia, it is estimated that the flow discharge of the Blue Nile will be fairly constant over time in the near future. The average monthly flow of the Nile River is shown in Figure 2.1-4.

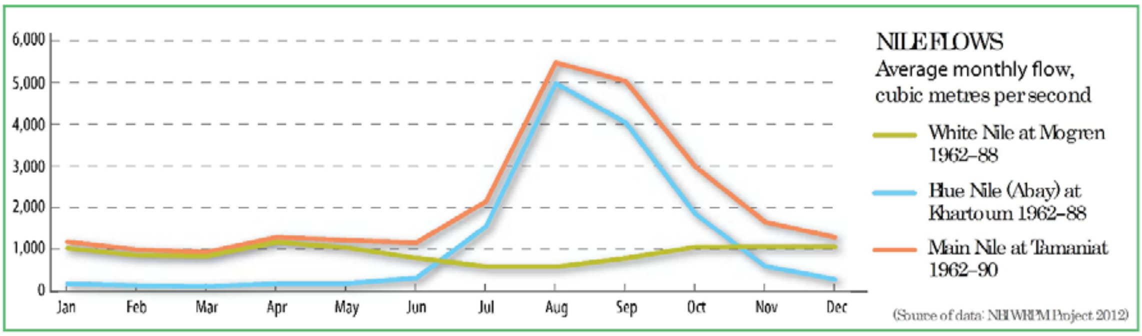


Figure 2.1-4 Average Monthly Flow of the Nile River

Source: State of the River Nile Basin 2012

(5) Hydrogeology

Major GW aquifers in Sudan cover about 50% of the surface area of the country as shown in Figure 2.1-5. These aquifers fall under the following five (5) categories based on aquifer type and productivity.

1) The Basement Complex.
2) Consolidated Sedimentary - Intergranular Flow.
3) Consolidated Sedimentary - Intergranular & Fracture Flow.
4) Igneous Volcanic - Fractured Aquifer.
5) Unconsolidated.

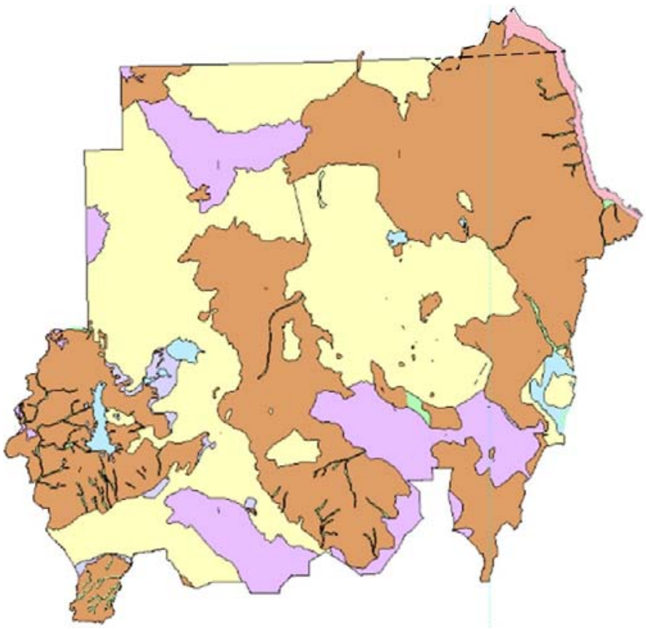


Figure 2.1-5 Hydrogeological Map of Sudan

Source: Hydrogeology of Sudan, British Geological Survey

Source: Hydrogeology of Sudan, British Geological Survey

(6) Existing Water Intake Facilities

a) Dams

Big Dams Along the Nile River

The number of existing dams in the Nile system in Sudan is 6, and their total storage capacity is 26.5BCM. Out of the total storage capacity of 26.5MCM, 12.5BCM is that of the Merowe dam in the Main Nile, a large hydropower dam. The 14BCM is mainly used for irrigation and hydropower.

There are other large dams along the Blue Nile River namely Sennar, Roseires and Khashm el Girba dams. Sediment ratio of Sennar, Roseires and Khashm el Girba dam is 15%, 30% and 50% respectively. Regarding the sedimentation of dams, countermeasures such as dredging sediment or heightening of dams will be necessary to secure their storage capacity in the future.

Small Dams and Weirs

Both DIU and state governments were responsible for the design and construction of small dams. DIU have designed and constructed small dams in the Water Harvest Project since 2010. The number of small dams constructed in that project is 36 including 6 which are still under construction with a total storage capacity of 122MCM. The average storage capacity of reservoirs is about 3.4 MCM. Water resource facilities such as small dams and hafirs are constructed in accordance with the policy of DIU.

Operation and Maintenance of Facilities

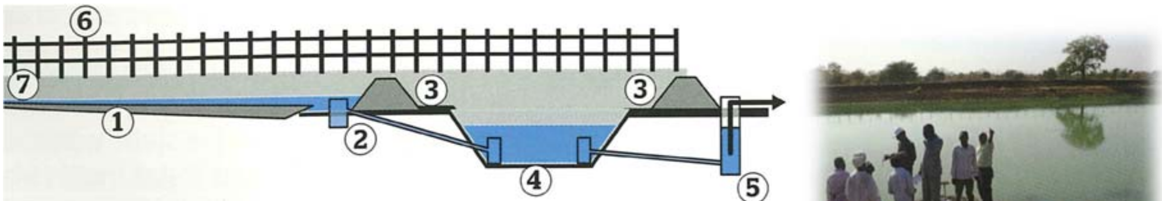
State governments and their locality are responsible for operation of small dams. On the other hands, DIU is mainly responsible for maintenance of small dams depending on facility scale and maintenance cost.
Small dams have staff gauge to monitor water level, which is measured in rainy season. Periodic water-quality inspections of small dams are implemented by state governments.

b) Hafirs

Hafirs are ponds to store SW for human and livestock drinking in the non-Nile areas. Water in hafirs is stored by collecting water from "wadis" during the rainy season. DIU have designed and constructed hafirs in the Water Harvesting Project since 2010. The number of existing hafirs in non-Nile areas constructed in the water harvesting project from 2010 to 2015 is 325, and their total storage capacity is 19Mm3. The average storage capacity is about 60,000m3.

Operation and Maintenance

SWC in each state is responsible for the operation and maintenance of hafirs. Monitoring equipment such as water level gauges are not usually installed in the hafirs. On the other hand, the number of existing hafirs in the non-Nile areas constructed before 2000 is 739, and their total storage capacity is 18.2Mm3. The average storage capacity is about 25,000m^3. The general structure of a hafir is shown in Figure 2.1-6.



Source: Community Watershed Management Guidelines (2015)

Figure 2.1-6 Schematic Figure of a Hafir Structure and its Construction

b) Wells

Well information was stored by GWWD and DIU. The distribution of wells is shown in Figure 2.1-7.

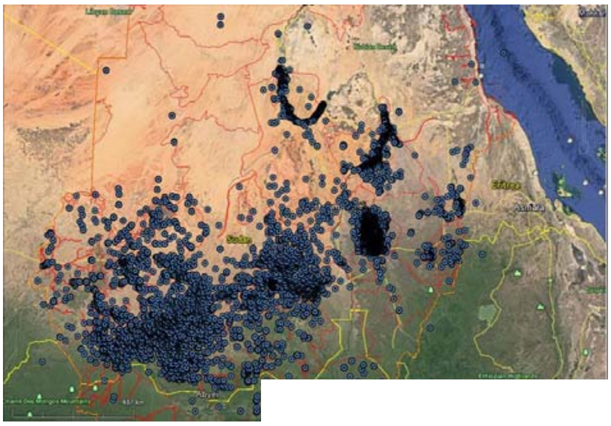


Figure 2.1-7 Distribution of Wells

Source: DIU

According to Figure 2.1-7, across Sudan, the distribution of wells is highly uneven. It is governed by rainfall, population and aquifer distribution. Based on these three factors, the area of well drilling is determined. The information is recorded in 17 files, including position, unified number, depth, water level, condition, pumping method, owner, usage purpose and water quality, etc. However, this data is just part of the Well Database that is owned by the Information Center of GW & W, and there are many items that are left unknown in the collected files. The total number of data/information on the existing wells is 8,958.

2.2 Organizations and Institutions

(1) Ministry for Water Resources at the Federal Level

The organizational structure of the current Ministry of Irrigation and Water Resources (MIWR) changed during the project period after the revolution.

As of 2017, the ministry name was the Ministry of Water Resource, Irrigation and Electricity (MWRE). MWRE was entrusted with monitoring, assessing, planning and developing water resources (i.e., SW, GW, and sewage and sanitation) at a national level. Provision of drinking water at the state level was and is the responsibility of each state under the State Water Corporation (SWC). The organizational structure of the MWIE is as follows.

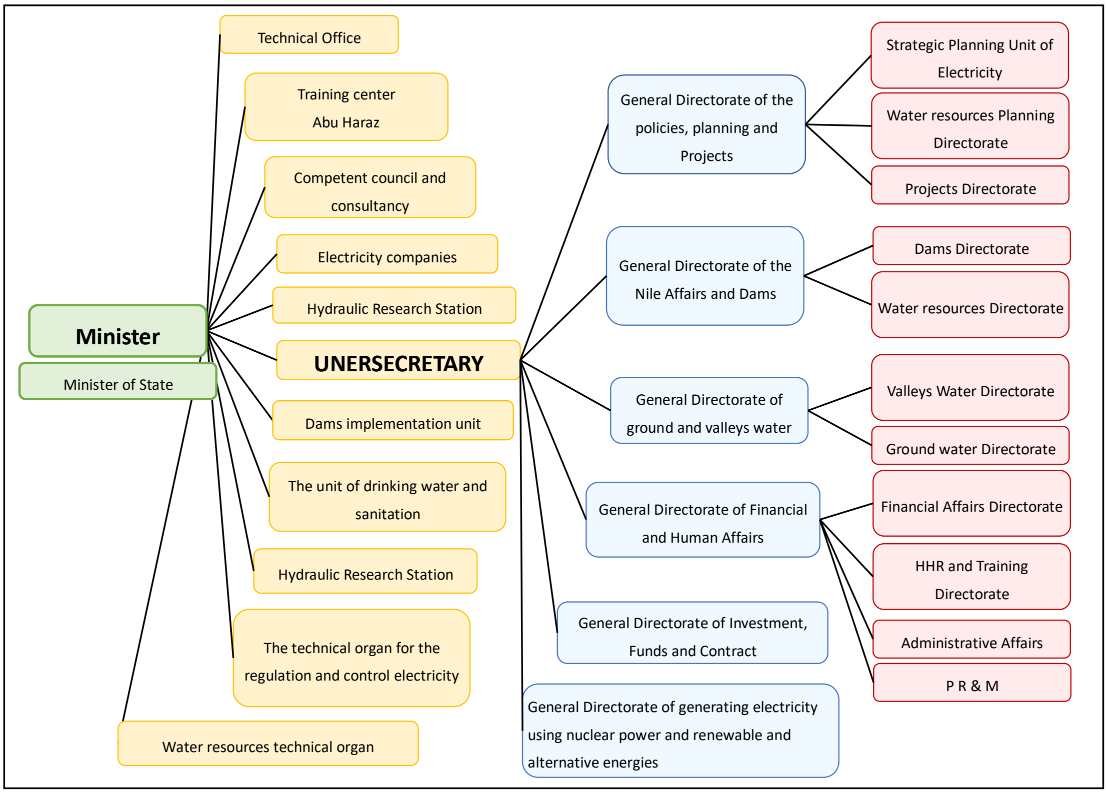


Figure 2.2-1 Organization Structure of the MWIE

Source: Inland Water Resources Management Program

Functions of each directorate are as follows.

1) Directorates under the Under Secretary

The directorates perform their activities at the federal level and put plans in place for better utilizing the available resources. Their main objectives are to develop national resources, supervise the implementation of infrastructure, operate and maintain existing structures, such as dams, and monitor the different usages by the various sectors. The directorates coordinate the usage of water resources among the various states, especially regarding the national cross-states SW and GW.

① General Directorate (GD) for Policies, Planning and Projects

The role of the General Directorate for Policies, Planning and Projects is to lead and coordinate the Ministry, to put together policies, plans and projects before submitting them to the Minister, and to evaluate budget plans from each directorate and negotiate with the Ministry of Finance.

② General Directorate for the Rive Nile Water & Dum

The function of the General Directorate for Rive Nile Water & Dum is to monitor the inflow volume and water level, control floods and droughts, develop a hydrological database, monitor water quality, and undertake policy planning regarding the utilization and rehabilitation of dams.

Its objectives relate to the main affluents of the Nile (White Nile, Blue Nile and Atbara) and the dams, which are constructed on the river.

③ General Directorate for Ground Water and Wadi (GWWD)

The function of the General Directorate for Ground Water and Wadi is to monitor the GW, conduct hydrogeological surveys, evaluate aquifers, and manage the GW database. The directorate has branch offices at the state level, which are responsible for monitoring GW, conducting small-scale surveys and selecting boring points for wells.

④ General Directorate for Financial and Human Affairs

The General Directorate for Financial and Human Affairs is responsible for financial affairs, human resources and administrative affairs

⑤ General Directorate for Investment, Funds and Contracts

The function of the General Directorate for Investment, Funds and Contracts is to find investors and financial resources for projects, as well as manage the project contracts. The directorate engages in investments made at the state level.

2) Offices with specific specialism under the Minister

Some offices and general directorates cover specific specialisms; these are the WRTO, the DWSU, the DIU and the HRC.

① Water Resources Technical Organ (WRTO)

The WRTO was established in 1992. It was then considered to be an executive body for the National Water Resources Council (NWRC) when it was formulated in 1995. The WRTO has close contacts with all riparian countries and is responsible for all matters related to bilateral and regional agreements, as well as cooperation issues dealing with shared water resources. It also represents Sudan in negotiations with riparian countries for the realization of joint projects for the development and management of shared waters in pursuit of mutual benefits. In general, the WRTO is responsible for the integration and coordination of all aspects and duties pertinent to water resource assessment, demand, management and development, especially in respect of shared waters.

② Drinking Water and Sanitation Unit (DWSU)

The DWSU is a federal unit coordinating activities involving the water supply and sanitation among the SWCs. It is responsible for implementing the water supply infrastructure financed by the federal government or financed from loans and grants received from international donors. The work of the DWSU complements the efforts of the SWCs when dealing with new water installations or rehabilitating them. The DWSU organizes regular workshops and training courses for all technicians working on the water supply and sanitation at the SWCs. It also develops appropriate specifications for proper utilization and monitors their implementation.

③ Dum Implementation Unit (DIU)

The functions of the unit are to implement water resource development, construct large-scale dams on the Nile and develop water resources other than the Nile. The unit is also in charge of projects' feasibility studies, tenders, contracts and implementation in accordance with requests from state governments. Around 200 staff members work in the unit as of 2017.

④ Hydric Research Center (HRC)

The HRC was founded in 1976, supported by the UNDP. Its function is to support the decision-making processes related to water resource development through research and capacity building initiatives. The center is located in the Wad Medani and employs more than 100 staff members. It has responsibility for studying the accretion of sand along the water route, the management of water reservoirs, satellite use for water resources management, and hydrogeology.

After the new transitional government started its work in September 2019, the ministries were restructured in September. The electricity sector was taken from the Ministry of Water Resources, Irrigation and Electricity and the new ministry's name became the Ministry of Irrigation and Water Resources (MIWR). The electricity sector was added to the Ministry of Energy and Mines. The electricity sector has historically used a large percentage of the budget, therefore, the budget for the water sector has been limited in the past. Now, the MIWR can use its entire budget for water. The new minister, who was the former director of the Hydraulics Research Centre, was appointed in September 2019.

The MIWR formulated a report, the "Organizational Structure and Job Description" in February 2020 to avoid duplication of works and enable the ministry to function in an efficient way. A working group was established accordingly, and this group reviewed the current and expected tasks of the ministry and each general directorate with appropriate officials. The changes that may affect the project were as follows:

- The DIU will be dissolved after the DIU finishes the current contracted works. Much of the work allocated to the DIU and the GWWD was duplicated, but the most of budget went to the DIU and salaries of DIU officials were much higher than those of the other directorates. It is expected that this change will activate the GWWD.
- GD of the Nile Water and Dam will be divided into the GD of the Nile Water Affairs and the GD of the Dam.
- The GD of Policies and Planning will be changed to the DG of Planning and Projects.
- The DWSU will become the National Corporation for Drinking Water and Sanitation.
- The WRTO's relationship with the NWRC was made clearer. It states that the WRTO sets general policies for water resources and their exploitation, and submits them to the NWRC for approval.

The new organizational chart of the ministry and responsibilities of each directorate are shown in the following figure and table. However, some of the proposed changes have not been materialized.

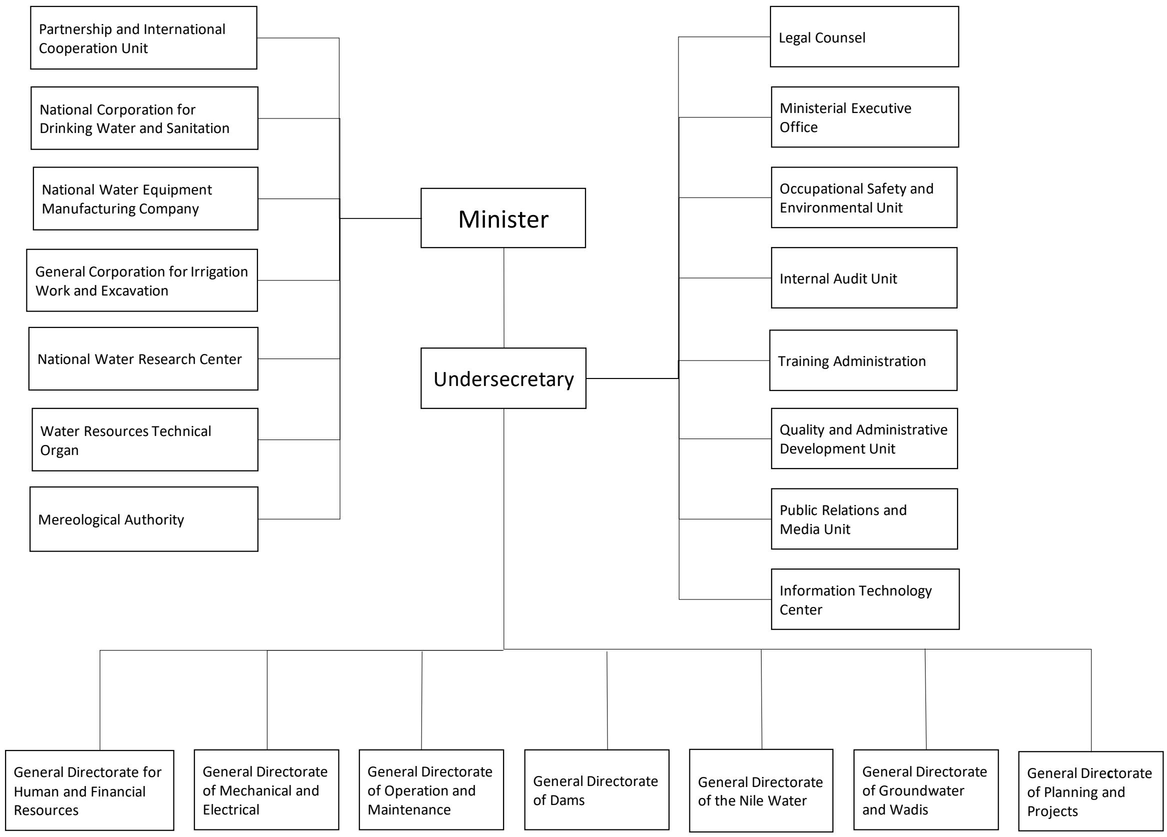


Figure 2.2-2 The New Organizational Chart of the MIWR

Source: Organizational Structure and Job Description, MIWR

Table 2.2-1 Responsibilities of the Main General Directorates

Name	Major Responsibilities
GD of Planning and Projects	• Develops, implements, monitors and evaluates strategies, policies and plans for irrigation water resources. • Evaluates and approves the designs of irrigation projects • Manages the Gash River and provides irrigation water for Gash agriculture projects • Participates in the planning of bilateral, regional and international projects
GD of Nile Water Affairs	• Monitors and conducts the study of the Nile and its tributaries • Forecasts and manages floods • Recommends water withdrawal from the Nile and provides notice of approval
GD of Dams	• Manages dams
GWWD	• Evaluates GW and forecasts the safe yield from both the demand and supply sides • Develops GW and wadis • Conducts studies on the quantity and quality of GW • Monitors wadis • Evaluates the effect of climate change on GW and wadis • Recommends and approves licences for GW withdrawal
WRTO	• Protects the interests of Sudan in water resources such as the Nile and transboundary water resources. • Develops policies for water resources development and submits them to NWRC • Supervises international water resources project and agreements • Recommends the review and revision of laws regarding water resources
National Corporation for Drinking Water and	• Plans, designs and supervises projects for drinking water

Sanitation	• Attracts foreign assistance for drinking water programmes in coordination with states • Develops strategies, policies and programmes for drinking water

Source: Organizational Structure and Job Description, MIWR

(2) Ministries for Water Resources at the State Level

The names and structures of ministries responsible for water resources management are different depending on the state. Drinking water is provided by the SWC at each state under supervision of the state ministry for water resources while SWCs have close connection with DWSU.

(3) Laws and Legislations for Water Resources

The major laws and regulations for water resources in Sudan are shown in the table below.

Table 2.2-2 Laws and Regulations for Water Resources in Sudan

Name	Year	
Water Resources Act	1995	This is the core law for water resources in Sudan and was amended in 2021.
Environmental Protection Act	2001	It stipulates how to protect the environment including water resources.
Regulation for SW	2016	This regulation is supplement to the Water Resources Act 1995. It stipulates the licensing system for SW.
Regulation for GW	2016	This regulation is supplement to the Water Resources Act 1995. It stipulates the licensing system for ground water.
Regulation for Irrigation and Drainage	2016	This regulation is supplement to the Water Resources Act 1995. It stipulates the licensing system for irrigation water.

Source: MIWR

The Water Resources Act of 1995 is considered the main act for managing water resources. Chapter 2 focuses on the NWRC stipulating its creation and its functions and powers such as developing polices for water resources, reviewing laws and regulations and conducting research. Chapter 5 stipulates how to regulate water use which is the basis for three regulations enacted in 2016. Chapter 5 also explains the responsibilities and powers of the Ministry of Water Resources.

Water Resources Act 1995 was amended in 2021. Major changes are as follows.

- The amendments added and clarified the role of the WRTO and defined the relation between the NWRC and the WRTO in practical terms.
- The members of NWRC were added.
- The responsibilities of the MIWR were added.

The figure below shows the different functions of the NWRC, the WRTO and the MIWR as well as the relations connecting these three.

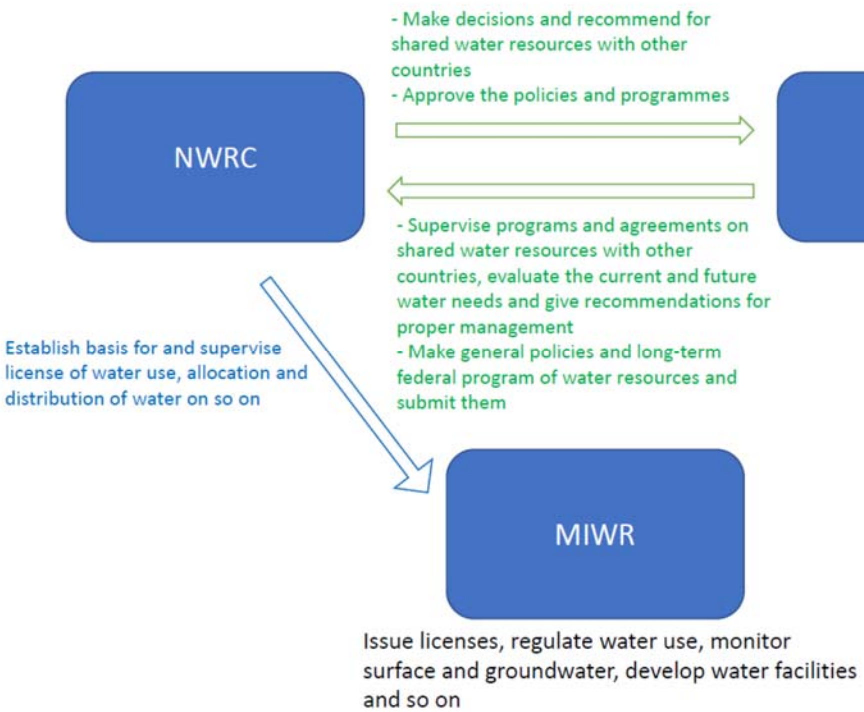


Figure 2.2-3 Functions of the NWRC, WRTO and MIWR

Source: Water Resources Act amended in 2021

According to the amended Water Resources Act, the functions of NWRC are defined as follows: (i) approval of general policies related to water resources, (ii) approval of a long-term federal programme for the optimum and balanced use of water resources with certain priorities, (iii) decision-making on shared water resources with other countries and the building of a foundation of cooperation with international organizations, (iv) periodical review of legislation related to water resources and making recommendations as necessary, (v) encouragement of scientific research in the field of water resources and (vi) forming specialized committees to enhance the performance of the NWRC's duties.

The NWRC is concerned with the following issues: (i) general supervision of the withdrawal of water from the Nile, the non-Nilotic rivers and other streams, GW, distribution and use of water and protection of water from pollution, (ii) laying the foundation for issuing licences for the water extraction, optimal water allocation, regulating the use of water for various purposes, maintaining the records of water used in irrigation projects and determining water use.

The Amendment specifies that the members of the NWRC are the Minister of Irrigation and Water Resources as chair, the Ministry of Defence, the Ministry of Foreign Affairs, the Ministry of Justice, the Federal Court of Judgement, the Ministry of Agriculture and Forestry, the Ministry of Energy and Oil and the General Intelligence Service and Environment. This organization does not include state representatives. And NWRC meetings are to be held twice a year.

The functions of the WRTO include: (i) formulating general policies on water resources and submitting them to the NWRC for approval, (ii) inspecting water facilities and recommending maintenance to the relevant authorities, (iii) developing a long-term federal programme for water resources and submitting it to the

NWRC for approval, (iv) preparing studies and research on water resources and development plans, (v) supervising the programmes and agreements on water resources shared with other countries, (vi) assessing current and future water needs and recommending appropriate management, (vii) presiding over the Sudanese side in the Joint Permanent Technical Commission for the Nile Waters, (viii) recommending the revision and updating of water legislation, (ix) representing Sudan in the field of cooperation and negotiation with regional and international organizations related to water resources and (x) any other competencies and authorities necessary for performing its duties.

The WRTO's headquarters was established in Khartoum and it have branches or offices within the states or regions.

(4) Policies for Water Resources

There are two kinds of strategies for the water sector, namely the Country Strategy on IWRM (2007) and Sudan Water Sector Strategy for 2021-2031.

a) Sudan's Strategy related to IWRM (hereafter IWRM Strategy)

IWRM Strategy was formulated in 2007 at a national level and was developed on the basis of the Transitional Constitution of Sudan, the water policies of 1978, 1992 and 2000, and other macroeconomic and social policies and development strategies.

It is a comprehensive policy document on IWRM, presenting the general situation of water resources in Sudan and a set of recommendations on the promotion of IWRM in Sudan. Sixteen fundamental principles of water resource management policy were established, including multisectoral concepts, such as the basic human need to access sufficient water, the promotion of participation of all stakeholders, demand driven management, comprehensive management, the importance of monitoring, and environmentally friendly outcomes.

IWRM Strategy consists of six chapters: 1) Introduction and Situation Analysis, 2) Water Resources Management, 3) Water Utilization, 4) Legal and Institutional Framework, 5) Capacity Building and 6) Community and Implementation. The structure of the IWRM Strategy is as follows.

Table 2.2-3 Structure of the IWRM Strategy

Ch.	Title	Contents
1	Introduction and Situation Analysis	Water resources availability, present and future usage of water, institutional and legal framework
2	Water Resources Management	Water resources management (water resources assessment, SW, GW, unconventional and marine water, environmental protection and conservation, water quality and pollution control, disaster management, applied research, regional waters and international issues)
3	Water Utilization	Water supply and sanitation, irrigation, drainage and agriculture, hydropower, industry, navigation, aquatic resources and fisheries, tourism and recreation
4	Legal and Institutional Framework	Legislation, regulation and enforcement, institutional framework

5	Capacity Building	Human resource, institutional capacity, gender issues, stakeholder involvement, private sector participation, NGO issues
6	Community and Implementation	Communication and implementation

Source: Country Strategy on IWRM

The next table summarizes its recommendations, focusing on the water resources management section.

Table 2.2-4 Measures for Water Resources Management Recommended by the IWRM Strategy

Subject	Policy track	Recommended measures
1. Water resources assessment	Set up mechanisms for the continuous assessment of resources through all the stages of data collection, storage, analysis, dissemination and monitoring of water resources data and information, using modern and efficient technology.	• Create an inventory of existing data assessment and monitoring. • Determine upgrading requirements. • Expand and rehabilitate monitoring systems. • Upgrade technology for data collection and processing. • Establish/maintain an up-to-date database. • Continue disseminating the daily Nile water gauge and discharge. • Put in place a coordination mechanism to ensure access and linkage to database. • Establish inter-linked databases with institutions with relevant data in IWRM. • Establish an onsite data collection system. • Establish human capacity.
2. SW	• Foster the conjunctive use of SW and GW as an efficient and sustainable water resources development and management option to augment the high cost of pumping GW from deep levels. • Ensure SW is developed and utilized in an integrated manner in unison with irrigation and drainage, hydraulic structures, watershed management and related activities. • SW planning/development must be integrated with land use management at all levels. • Management of SW shall ensure social equity, economic efficiency, system reliability and sustainability norms. • A reliable database and information system is a pre-requisite for sound assessment, planning, management and development of SW resources. • The operation and maintenance of SW systems should be based on cost recovery – 'the user pays' principle. • The storage capacity in rivers, wadis and rainwater harvesting vessels has to be increased to meet the increasing demand for water. • The optimum, reasonable and equitable use of SW should be promoted through cooperation between and within the states in national and local waters. • The government has a regulatory function to ensure that the appropriate standards of service quality, sustainability and environmental friendliness are met by the water suppliers and users.	

3. GW	• GW resources are an indivisible part of the hydrological system, the national water balance and the natural resources base. • GW resources constitute national property, the equitable use of which is common to all, subject to national authority and control. • The correct planning assessment, development and management of water resources cannot be achieved without strengthening the information base at national and state level. • Present and future water users have a right of access to clean and unpolluted GW resources and a non degraded environment. • GW is to be recognized as having a social and economic value. • GW abstraction, particularly from alluvial and shallow aquifers, shall be based on recharge and the safe yield concept. • The sustainability of GW development, investment and supply services shall be planned for and considered as part of the development and management policy of the water resources systems.	
4. Unconventional and marine water resources	• Research planning and development of unconventional and marine water resources will be undertaken. • Regulations to cover marine water use, protection, tourism, recreation fishing, etc. are needed to control marine water resources and coastal areas.	
5. Environmental protection and conservation	The overall policy is intended to ensure environmentally sustainable development.	• Prepare environmental management, protection and implementation plans. • Carry out surveys and map critical water bodies for environmental conservation. • Determine abstraction limits and quality standards. • Enforce the Environmental Act of 2001. • Identify and restore degraded strategic environments,
6. Water quality and pollution control	• The formulation of standards and guidelines for the disposal of undesirable elements should be supported by effective enforcement. • HNCENR and states' councils have to be strengthened to achieve effective monitoring. • Water abstraction and disposal licences should be constantly reviewed and effluent discharge levies introduced as instruments for pollution control. "Polluters-pay-	• Carry out studies on the extent and effect of pollution. • Prepare standards and guidelines for effluent discharge. • Develop, implement and monitor water quality and pollution control management plans. • Develop guidelines and enforce EIA on proposed projects and land use changes. • Strengthen the National Water Testing Laboratory of the MIWR and its state branches. • Establish laboratory linkages and accreditation mechanisms for analytical laboratories.

	principle". • Recognize relationship between water quality and water use. • Use of water for petroleum extraction is posing a serious risk for the local people, requiring control and management.	• Involve the participation of stakeholders and the private sector in pollution control. • Cross-check the implementation of related activities if classifying water bodies according to quality and awareness. • Establish a capacity for the management of water extracted with oil to ensure a clean environment.
7. Disaster management	• A national Disaster Management Policy will be developed to ensure that the country is less vulnerable to disasters. • A policy of investment in water resources management infrastructure should be pursued.	• Cross-check implementation of related activities elsewhere in the strategy in the areas of watershed management, conservation and environment. • Community sensitization, mobilization and resettlement. • Identify and map the flood, drought, desertification and erosion prone areas. • Rehabilitate disaster prevention structures including dykes and dams. • Maintain, establish and operate early warning systems. • Determine training needs and train personnel in water disaster management. • Establish emergency centres. • Provide essential basic needs. • Encourage resettlement away from disaster areas. • Undertake restoration of original waterways.
8. Applied research	Research will be promoted as the basis for sustainable management of water resources, by initiating collaboration with the relevant research institutions and other stakeholders. The intention is to establish a National Water Research Institute complemented by other research institutes.	• Determine research needs. • Develop comprehensive national applied and basic research programmes. • Carry out a study on the capacities of the MIWR and the Hydraulic Research Station (HRS) and recommend requirements for rationalization and upgrading. • Upgrade, rationalize and establish a fully functional National Water Training and Research Institute. • Modernize and update data gathering, processing, analysis, archiving and dissemination of techniques. • Set up a database capable of networking with other research

		institutes. • Set up pilots and trials on selected technologies including modern irrigation. • Continue research in the Nile and tributary flows and other subjects.
9. Regional waters and international issues	• Recognize the rights of all the co-riparians who use the Nile and other waters. • Maintain the share of Sudan according to the 1959 agreement with Egypt and the 1991 protocol with Ethiopia. • Cooperate on the basis of amicable understanding and good faith, sovereign equality, territorial integrity and mutual benefit. • Promote cooperation with the countries sharing SW and GW with Sudan, particularly within the context of the Nile Basin Initiative (NBI), Lake Shad, Nubian sandstone aquifer, Baraka and Gash. • Develop, conserve and use shared water resources in an integrated, sustainable and environmentally sound manner though basin-wide cooperation. • Support the endeavour using different experts from the Nile Basin countries to agree on a cooperative framework acceptable to all. • Sudan calls upon all co-basin countries to exert joint efforts for a unified view of the best ways of following up and implementing the resolution of the recent international water forums and earth summit (Johannesburg, Kyoto, the Hague, UNCED Brazil, Mar del Plata of Argentina, Dublin, New Delhi, etc. • Sudan encourages and promotes cooperation with international and regional organizations.	

Source: IWRM Strategy

Note: The table structure is not consistent among the subjects as shown above, due to the presentation of the original document

The recommendations of high relevance to the JICA IWRM Project are extracted and summarized below from the thematic perspectives of "data management", "water resources management planning", "coordination and participation", "legal and regulatory framework" and "demand management".

Data Management

The need to create an appropriate data management system is proposed for most of the subjects, because data forms the basis of everything, including assessment, planning and activities. The following are the perspectives and actions proposed by the IWRM Strategy.

- The IWRM Strategy defines one of IWRM's fundamental principles as "monitoring of water resources is essential for the proper development, management and protection of water resources".
- It proposes a set of actions, including monitoring and a database, to bolster the data management system as a means of strengthening a continuous assessment system.
- The need for strengthening the information base is significant with regard to SW, GW, water quality, disaster management, applied research and regional and international cooperation.

- Networking and sharing of a database among related institutions is recommended.

Water Resources Management Planning

Water resources management planning is proposed by stressing the need for planning as well as suggesting ways in which plans should be prepared. The need for water resources management planning is explained in such ways as the "provision and equitable distribution of water for different states and users in the country based on comprehensive and integrated plans and allocation principles", the need to "prepare strategies and plans based on the concept of Integrated Water Resources Management", "prepare a plan of actions to ensure water security for at least basic needs" and "formulate water resources management plans that will meet the present and future water demand for the agriculture sector in a sustainable manner".

With regard to the ways in which plans should be prepared, the IWRM Strategy proposes methods, such as the integrated approach, encompassing different factors such as irrigation/drainage, hydraulic structures, watershed management, land uses and environment, application of the "safe yield" concept in GW, water supply planning taking into account present and future demands for industrial and domestic needs, and consideration given to the inter-basin transfer of water, especially in water-scarce, remote areas.

The IWRM Strategy also proposes the development of various kinds of infrastructures such as dams, hafirs, wells and irrigation systems. It goes without saying that appropriate planning should precede the construction of these infrastructures.

Coordination and Participation

The need for participation is repeatedly emphasized in almost all the major areas of the IWRM Strategy. "Participation", the term used in the IWRM Strategy, can be interpreted as "coordination" among states and between the federal government and the state governments. The following summarizes the IWRM Strategy's recommendations on participation.

- One of the IWRM Strategy's objectives is to "promote the participation and engagement of the private sector and other stakeholders in service delivery to improve efficiency and effectiveness and enhance sustainability of the services including water resources management". This concept is applied to all stages of development, including planning, implementation and operation and maintenance.
- The decentralized operation and maintenance of water supply systems is recommended, including cost sharing and self-support.
- Participation of women is recommended.
- With the participation of stakeholders, awareness should be raised in relation to various subjects, such as pollution control and the selection of residence locations avoiding disaster-prone areas, as well as water harvesting.
- Forums should be created for discussions and consultations amongst various stakeholders.
- The participation of the Water Users Association (WUA) should be promoted for large, medium and small irrigation schemes.

- The participation of stakeholders should be legalized.
- Cooperation within and among states (transboundary waters) should be ensured for the optimum, reasonable and equitable use of SW. An appropriate institutional framework should be established from state level down to the lowest administrative structure, so as to promote decentralized management.
- The appropriate linkage mechanisms should be created for the coordination of water resources management activities between the federal and state levels.
- The private sector should be involved to a greater extent to promote their participation in water resources management, for example by creating a consultative committee.
- A venue should be provided for external support agencies and NGOs to provide information, guidelines and direction, as well as coordination.

Legal and Regulatory Framework

The IWRM Strategy dedicates a chapter to the legal and regulatory framework, namely, "Chapter 4 Legal and Institutional Framework". Three directions are proposed as a policy direction as follows.

i. Establishment of a comprehensive and enabling legal environment for the proper utilization, development and protection of the country's scarce water resources, that allow all citizens to have access for water based on the rules and regulation of the government.

ii. Enact and implement the Water Resources Act of 1995 and the Irrigation and Drainage Act of 1990, (following part omitted).

iii. A legal framework for rainwater harvesting concept has to be formulated due to the importance and future prospects of rainwater harvesting to cover the expected escalation in irrigation, human and animal water demand.

The need for an enabling legal environment mentioned as the first proposal is explained in other parts of the IWRM Strategy in more specific formats, such as abstraction licences for SW and GW, water quality control with penalties for pollution, definition of the obligations of EIA and the development of irrigation fields and storm drainage.

The enacting and implementation of the Water Resources Act of 1995, mentioned as the second directive needs review following the official announcement of its amendment in April 2021. Three regulations related to GW, SW and irrigation water, enacted in 2016, may have been the result of the proposal of the IWRM Strategy and the subsequent discussions between the MIWR and other related ministries.

Demand Management

The IWRM Strategy stresses the importance of demand management by defining one of its policy objectives as the need to "promote demand management, conservation and protection of water resources and the overall aquatic environment on a sustainable basis in conjunction with essential infrastructure development". The IWRM Strategy proposes the development of technical guidelines and a framework to enhance irrigation water efficiency in this context.

The cost recovery, based on "user-pay-principle" has been proposed by the IWRM Strategy mainly for financial purposes: to recover operation and maintenance costs by collecting service fees determined at cost recovery level and improving the service quality. An appropriate pricing mechanism, however, would contribute not only to enhancing the financial viability of water supply services, but also to a more efficient use of water, as water users would try to minimize the amount of water they use under a consumption-based tariff system. An appropriate water pricing mechanism, therefore, should be pursued as a tool for demand management as well as financial management. This principle applies to the water supply in urban areas, rural areas and for irrigation water.

b) Sudan Water Sector Strategy 2021-2031 (2021)

The transitional government prepared a strategy document called the "Sudan Water Sector Strategy 2021-2031 – the promise of the MIWR to Transform the Livelihoods of the People of Sudan ("the Water Sector Strategy" hereafter)" in 2021. The MIWR led the preliminary stages through extensive consultations with stakeholders between May and December 2020. It was launched on 4 October, 2021.

The aspiration of the Water Sector Strategy is to deliver improved access to water resources as a basic requirement for domestic use, in a productive sense for agriculture and livestock, in a social sense in terms of equity and coordination among all competing users and in an environmental sense of not harming the environment. The Water Sector Strategy is expected to contribute to the four key priorities of the Sudanese government: (i) to eradicate hunger and ensure food security, (ii) to create dignified and rewarding employment opportunities, (iii) to provide all Sudanese with safe, adequate and accessible water supply services and (iv) to contribute to peaceful co-existence among all competing water users.

The Water Sector Strategy will be operationalized by means of the following three transformative strategic plans.

(i) The National Irrigation Transformation Plan (NITP)

(ii) The National Water Supply Transformation Plan (NWS-TP)

(iii) The National Water Resources Management Transformation Plan (NWRM-TP)

The MIWR has established a new structure called the "Partnership and Resource Mobilization Unit (PRMU)" and a task force, to lead the policy review and development task for the implementation of the Water Sector Strategy. The planned activities and budget for the three respective transformation plans are summarized in the next table.

Table 2.2-5 Budget and Activities of the Water Sector Strategy by Three Transformation Plans

Anchor Pillars	Transformative Package	Budget (US$ Million)	Activities
I. NITP	I. Upgrading and modernizing of 1.1 million ha of existing irrigation schemes	641	• Upgrading of large-scale irrigation schemes: 400,000 ha for Gezia, Suki, Rahad and other schemes. • Upgrading of medium size irrigation schemes up to 400,000 ha. • Upgrading of small size irrigations schemes up to 100,000 ha. • Upgrading of seasonal flood-based irrigation schemes up to 300,000 ha. • Crop intensity improvement.
	II. Development of 400,000 ha of new irrigation schemes	1,200	New irrigation schemes up to 250,000 ha using Blue Nile water and 150,000 ha using Atbara water.
	III. Improving water productivity with at least 50% more crop per drop	15	• Low-to-no-cost improved water management measures. • 250 young water managers updated with local techniques and opportunities for smart water use.
	IV. Inclusive, gender-aware capacity building, institutional strengthening and solution transfer	18	• MIWR institutional strengthening, training of 2,500 MIWR staff and capacity building for 1,000 farmers/pastoralists. • At least six most promising research outputs translated into reality on the ground and four new research initiatives.
	V. Facilitative policy, transparent and participatory governance	1	• Clear policies. • Revised and upgraded laws, regulations and enforcement mechanisms. • Well defined roles for stakeholders (farmers and service providers).
	Sub-total	*1,875*	-
II. NWS-TP	I. Rural and pastoralists' water supply	2,100	100% service coverage in urban and rural areas with 3,412 water yards, 4,360 mini water yards, 10,825 hand pumps/wells, 274 hafirs/dams with treatment and 310,751 household/compound networks.
	II. Urban water supply	3,600	
	III. Institutional capacity development, programme management and enhancing of the environment	183	• Enabling the environment (sector, reform, policy endorsement, legal aspect). • Training of sector specialists.

			• Preparation of guidelines, manuals, etc. • Establishing a community management structure.
	Sub-total	*5,883*	-
III. Water resources management plan	I. Technical aspects: water data, monitoring and assessment	20.0	• Catchment-based institutions strengthened (five by 2023). • Smart IT for Nile expanded to all major catchments. • Water allocation decisions based on risk analysis. • National map for potential water resource use and recharge zoning. • Major non-Nile seasonal rivers with adequate monitoring stations. • Field offices of the Nile equipped with improved technologies and skilled personnel.
	II. Water management instruments: planning and development	4.5	• Water allocation plans with risk reduction provisions and transboundary water governance issues rolled out. • State level and catchment level water allocation plans are introduced (five by 2023). • Cost-benefit sharing among water users is implemented.
	III. Governance ambition: policies and instruments	3.5	• Revive and strengthen the NWRC. • Draft national water policy. • State-level water coordinating councils established (five by 2023). • Governance mechanism introduced in the water-stressed basins of Darfur and Gash.
	IV. Capacity building, research and development	5.5	• Institution-wide review to identify knowledge gaps and options for closure. • Senior staff to acquire improved leadership and management capacity (75% by 2023). • Technical staff to improve skills and knowhow on water resources management (50% by 2023). • Major studies completed (two by 2023) and their findings translated into decision-informing policy briefs. • Societal awareness campaigns implemented.
	Sub-total	*33.5*	-
Total		**7,791.5**	

The impacts on water resources management are promised by the NWRM-TP, as summarized below:

- Fulfilment of institutional reform ambitions, implementation of catchment plans and empowerment of water councils
- Standardization of oversight, facilitative means and alignment of competencies and policies between federal and state levels
- Coordination and quality assurance of data for monitoring, assessment, allocation, development and planning of the water resources.

It was highlighted that the major issues addressed in the IWRM Strategy in 2007 in terms of data management, planning, coordination and participation, the legal and regulatory framework and demand management are also captured in the Water Sector Strategy. The relevant sections relating to these aspects are excerpted from the Water Sector Strategy, as shown below.

Data Management (lack of database)

- *Necessary data and information are usually fragmented, dispersed and heterogeneous and accessing data is often difficult…As a result, the data products of various actors are underutilized and the capacities of producing the information required for efficient water policy implementation are often very limited, there is often little agreement regarding data exchange. As such, each institution produces data for its own purposes without necessarily considering the need for integrated and comprehensive datasets.*
  - *While data produced by public funds should be freely accessible, data institutions need to raise funds to establish their data infrastructure.*

Data Management (inadequate monitoring)

- *Major gaps in time series or in geographical coverage are caused by the lack of monitoring and the means to ensure regular checking and maintenance of monitoring equipment, and by delays in the replacement of faulty parts or even the payment of salaries and fees to monitoring staff.*
- *The Nile River is reasonably monitored by telemetric weather stations, while most of the local streams (wadis) are not regularly monitored.*
- *As a first step towards optimal use of GW and seasonal water resources, we need to strengthen the monitoring system by installing monitoring devices in observation wells and stream gauges to support hydrological studies.*

Water Resources Management Planning

- *The need for an inclusive National Water Allocation Plan (NWAP), in which water allocation priorities are defined and established in a short to medium term horizon taking climate change implications into account, is recommended. Catchment plans and state-level water plans need to be in line with this NWAP.*

Coordination and Participation

- *Internal conflicts include interethnic clashes over natural resources such as land, water and crops. Such conflicts triggered nearly 10,000 new displacements in East and Central Darfur and White Nile State in May and June 2019…Water conflicts, especially those between nomads and settled farmers, are increasing because of climate change, a lack of inclusive governance and the allocation of limited water and natural resources.*
- *The involvement of beneficiaries during the project life cycle is often missing, with the federal MIWR overseeing construction, handing over operations to states after completion.*
- *Public participation and transparency in decision-making is not featured, nor does it refer to the role of the states in managing water resources.*
- *There is a need to strengthen the National Council for Water Resources (NWRC) and other coordination mechanisms and to build on what is available, such as state level water coordination councils and the potential for transboundary coordination mechanisms, such as the Countries Coordination Framework Agreement.*
- *The fragmentation of water management across institutions has contributed to overlapping responsibilities and has constrained the effective implementation of water management functions.*

Legal and Regulatory Framework

- *Some of the obstacles hindering the effective management of water resources in Sudan are found in an incoherent, non-inclusive, non-accountable and fragmented national water policy with concomitant gaps in water legislation and poor enforcement.*
- *It is pertinent to ensure the integration of water-related legal frameworks that promote cross-sector coordination.*
- *Existing regulatory frameworks for water governance fall far behind to contributing to the development of robust institutional building as they suffer from critical gaps, contradictions and inconsistencies. Law enforcement mechanisms are not in place and concrete and socially recognisable water policy and strategic frameworks are lacking*. (The Sudan Transitional Government urgently needs this document).
- *Other sources of pollution that need to be regulated include increases in agriculture inputs, source pollution from industries and mining and GW contamination through unmanaged/poorly constructed septic tanks/sanitation facilities… From a policy perspective, there is a need to include environmental and resources costs associated with damage or negative impact on the aquatic environment in accordance with the polluter-pay principle.*

Demand Management

- *Poorly performing irrigation sub-sector characterized by inefficient use of water and low cropping intensity*. (NITP).

- *Improving water productivity with at least 50% more crop per drop* (NITP, Transformative Package IV).

2.3 Society and Culture

(1) Population Movement

As Sudan is surrounded by fragile states, Sudan has accepted refugees from its neighbors. At the same time, there are many Sudanese refugees in neighboring states, as well as internally displaced persons (IDPs) who have escaped from their respective hometown to IDP camps or other villages and towns in Sudan due to conflicts in Darfur region, South Kordfan and Blue Nile states, as shown in the figure below.

As of November, 2022, Sudan hosts 1.1 million refugees from the neighboring counties and there are 3.7 million IDPs[1].

This significant population movement makes social service delivery difficult. To meet the urgent needs of refugees and IDPs, an emergency and humanitarian water supply is planned and water facilities are constructed, while sustainability of water resources are sometimes neglected.

Conflict is not the only reason why people migrate in and out the country. People also move from rural areas to urban areas to seek out economic opportunities. Floods and droughts also force people to migrate, which has led to rapid urbanization.

(2) Ethnic Groups and Livelihoods

It is said that the ethnic and linguistic diversity in Sudan is one of the most complex in the world. There are tribes of Arab origin, mainly migrated from the Arab Peninsula, and non-Arab indigenous groups near the border, such as Nubian (Northern State), Zaghawa (Darfur), Massalit (Darfur) and Nuba (South Kordofan).

There are also big groups with West African origins. West African Muslims passed through Sudan on the way to Mecca and decided to live in Sudan, and in particular in Gezira as the Gezira scheme gave them job opportunities. Fur has a history of establishing a Sultan Kingdom in Darfur from the 17th to 20th centuries and ruled the many tribal groups in harmony in the controlled area. Jaaliyinm, Shaigiya and Danagla are Arabic ethnic groups which mainly live in cities in the central part of Sudan and have dominated the politics of Sudan.

Ethnic identity in Sudan is complex and has become changeable and fluid in the course of time, in such a way that a group with West African origins start defining themselves as Arabs. In addition, mixture of the tribes has happened through marriage. Although people have a sense of belonging based on tribe and local language, ordinary Sundanese, generally speaking, are not divided along ethnic lines.

While Sudan is an Islamic state, there are Christians living mainly in the South Kordofan and Blue Nile States.

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[1] Overview of Refugees and IDPs in Sudan as of November 2022, UNHCR

Each tribe has a traditional authority called the Native Administration (idarra ahliya), which was formally institutionalized by the British during the colonial era in order to govern the rural area with less cost than by sending in their own officers. Currently, the Native Administration mainly deals with conflict resolution and natural resource management. They have traditional leaders such as those known as sheiks, omdas and nazirs from lower-level to upper-level positions, as shown in the Figure 2.3-1. These traditional leaders are often concerned with leading religious and spiritual families in their areas and represent their own tribes.

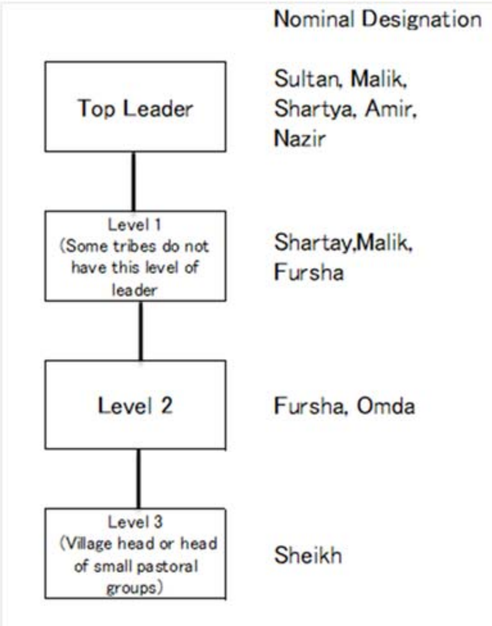

Figure 2.3-1 Traditional Leaders

Source: Traditional Authorities' Peacemaking Role in Darfur

Their power and influence is strong in the Darfur, Kordofan, Red Sea and Kassala areas, but weak in the riverain areas and among nomads, and are almost irrelevant in Gezira and Khartoum. Displaced communities, such as those in IDP camps, also have their traditional leaders as they tend to migrate in tribal or clan groups.

Among the population in Sudan, 9% are nomadic pastoral tribes, such as the Abbala, who are a camel-keeping tribe in the Red Sea, the Abbala, who are both camel keepers and gum arabic farmers in Northern Kordofan and Darfur, and the Baggara (which is the collective name for the Hawazma, Misseriya, Rizeigat, Taisha and Habbaniya) who are cattle keepers in Southern Kordofan and Darfur. The Abbala and Baggara usually migrate with livestock to the north and south; they move southward during the dry season to find pasture and water, and back to the north during the rainy season. They sometimes cross the border into neighbouring countries. Likewise, nomadic tribes come to Sudan from neighbouring countries.

The pastoral overlap with the rain-fed agriculture zones of Sudan. Thus, conflict between pastoralists and farmers over water and pasture usually occur along the migration routes in the southern part of Sudan.

There are different types of livelihoods in Sudan. Livelihood analysis helps us to understand water use and how different livelihood groups relate and compete with each other. Irrigated farming is practiced along the

Blue Nile, White Nile and Nile River. These groups mainly produce cash crops, such as sugar cane and cotton, in an irrigated plantation in the areas where the big irrigation schemes exist. There are several sugar-processing factories in the Sennar and White Nile States along with sugar cane irrigation lands. The camel pastoral area stretches across the middle of Sudan where there is not enough rainfall for agriculture. Cattle pastoralism is practiced in the southern part. Rain-fed semi-mechanized agriculture is practiced in the southeast. Traditional rain-fed agro-pastoralism is a common livelihood in the southwest where sorghum and millet for self-consumption are produced.

The unique element of raising livestock in Sudan is that most of it comes from nomadic or pastoral production. However, nomads and pastoralists have lost pastures and water due to the expansion of farmland involving mechanized and irrigation agriculture, as well as overgrazing. Farmers used to allow livestock brought by nomads or pastoralists to graze crop residues in the farms, while animal faeces were used as fertilizer in the farms. In other words, farming and pastoralism complemented each other. Nowadays, nomads or pastoralists must pay for crop residues as the demand of crop residues has become high and farmers sometimes fence the farmland, which means that farming and pastoralism compete.

(3) Gender

Principle No. 3 of the Dublin Statement on Water and Sustainable Development (1992) reads *"Women play a central part in the provision, management and safeguarding of water." It is explained that "this pivotal role of women as providers and users of water and guardians of the living environment has seldom been reflected in institutional arrangements for the development and management of water resources. Acceptance and implementation of this principle requires positive policies to address women's specific needs and to equip and empower women to participate at all levels in water resources programmes, including decision-making and implementation, in ways defined by them."*

As for Sudan, the IWRM Strategy (2007) reads a need to adopt the policy of the full involvement of women in the planning, implementation, decision-making and training in water resources, as well as the empowerment of women to play a leading role in self-reliance initiatives.

The Water Sector Strategy lists up a luck of gender perspective as one of challenges, and plans to promote participation of users including women.

However, in practice, traditional and religious norms, cultures and customs sometimes prevent women from participating in decision-making and actions, and having equal rights as men. This is particularly true in rural areas in Sudan, although it largely varies between tribes and places. Women-headed households, in particular, have difficulty accessing social and economic infrastructure.

In the conservative areas, women's roles tend to be limited to domestic chores and there is not much room for them to be involved in activities outside home. It is hard to convince husbands and fathers even to send their wives and daughters to a meeting and training in such areas. It is said that women are more conservative and are inactive outside households in northern and eastern parts of Sudan but are less conservative and active in western and southern parts. For instance, the women of Beja, an ethnic group mainly living in Red Sea, are seldom seen outside home and women in Darfur actively engage in agriculture outside their houses.

Women and children usually are responsible for fetching water in rural areas, except the areas where women are confined to the home. Women, as the primary caretaker of their families, are more serious about obtaining sufficient and clean water for their families and for their livelihood activities such as agriculture and raising livestock.

Their concern for the health of family members in preventing water-borne diseases and for the safety of their children and themselves in preventing accidents during water-fetching could contribute to the improvement of water quality, the safe design and location of water facilities and protection of water sources. Their involvement in a water committee at the community level could empower them. They should be involved in the decision-making in water resource management along with men in order to solve problems in Sudan since it has been learned through experiences in other countries that the participation of women enhances the sustainability and effectiveness of water resource management.

(4) Participatory Approach

Principle No.3 of the Dublin Statement on Water and Sustainable Development (1992) reads "*Water development and management should be based on a participatory approach, involving users, planners and policy-makers at all levels. The participatory approach involves raising awareness of the importance of water among policy-makers and the general public. It means that decisions are taken at the lowest appropriate level, with full public consultation and involvement of users in the planning and implementation of water projects.*"

The IWRM Strategy (2007) acknowledges the importance of community participation. The policy states that *"in order to ensure sustainable water resources management there is a need to apply alternative management options and technologies that are participatory rather than those that are wholly recipient."* Supporting community self-initiatives and direct involvement in water resource management is also mentioned.

The Water Sector Strategy says "*Public participation and decisions based on an understanding of the intersectional impacts of decision-making (e.g., based on gender, disability, and tribal and/or ethnic dimensions)*" is one of the important approaches.

Generally speaking, however, the government taken the top-down approach rather than the bottom-up and participatory approach, not only in the water sector. Water resource management needs a variety of stakeholders for consultation and coordination, but there was no institutional framework in Sudan for this purpose. The situation has been gradually changing since the revolution, and the government has been trying to make people participate in water resource management as the Project with the federal and state government has established the framework for participation.

(5) Local Administrations

The local administration system differs from nation to nation and influences how the voices of local communities are heard and reflected. It is important to understand the system when considering how to involve necessary stakeholders and how to materialize the participatory approach. It is also necessary to clarify the division of roles among different administration levels. For Sudan, there are three local administration levels, which are the state, locality and the administrative unit (AU), under the central (federal) government.

<u>State Government</u>

The top of the state government is a governor (*wali*) who has great power and was politically appointed by the president in the past and by the transition government now. There was also a legislative body (State Legislative Council), composed of elected councilors and appointed members. However, the legislative council was dissolved after the revolution. For an executive body, there are sectorial state ministries with ministers.

What ministries are formed for water resources varies from state to state. For instance, the Ministry of Infrastructure and Urban Development in North Kordofan State and the Ministry of Urban Planning and Public Utilities in Gedaref State are responsible for water resources. Such ministries make a water resource development and management plan. Under such a supervising ministry, SWC operates. There are branch offices of the federal MIWR, such as GWWD and DIU at the state level.

As the state had the legislative body, they made laws and regulations. Laws and regulations made at the federal level and laws made at the state level were sometimes contradicting or overlapping.

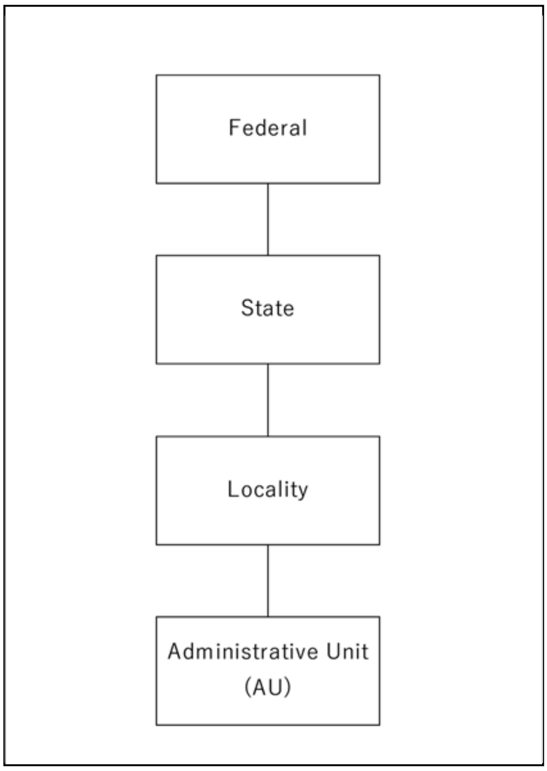

Figure 2.3-2 Administration Level

Source: JICA Project Team

<u>Locality</u>

Each locality is headed by a commissioner (*mutamad*) appointed by a state governor. There are several departments which provide services to residents and the locality makes a development plan and submits it to the state they belong to. For the executive wing, the executive officer is the top position and he/she supervises all the sector departments and matters in the locality. For some primary service delivery, the localities are the core player; however, water supply and the operation and maintenance of water facilities for humans is usually done not by the localities but by the states (SWC). There are some cases in which water facilities are handed over from SWC to the locality and the locality should be responsible for operation and maintenance. In some cases, the water facility is sold or handed over to a rich individual or village, which then collects water fees from users to operate and maintain the facility.

Administrative Unit (AU)

AU is the lowest level of executive body with limited number of officials. For water resource management, the AU does not have a section regarding water.

(6) Organizations Representing Communities

The local government is not the only stakeholder. Understanding what stakeholders exist at the community level as water users, and making them more involved, is necessary. Below are the major stakeholders usually observed.

However, organizations representing communities have been significantly changed since the start of the project due to the revolution in Sudan.

1) Before the Revolution

Popular Committee[2]

The popular committee consists of 20-30 elected representatives of local residents from each block in urban areas and at each village in rural areas. The size of the block ranges from hundreds to over a thousand households. Although the popular committee members are not paid by the government, they collect opinions about public services, such as waste management, water supply, and health services, to convey to the AU, localities and other higher levels. They also supervise public services provided by the government. AUs and localities usually give instructions or messages to local residents through the popular committee. The popular committee often has sub-committees such as the health committee and water committee. Therefore, the popular committee is considered to be a government arm at the lowest level and has a close link with local residents and can mobilize them. In a sense, the popular committee could be considered as a representative body of the community, as they are elected by community members. Although the committee members are supposed to be elected by local residents, they are sometimes assigned by the local government and politics are involved. Therefore, the popular committee sometimes are not welcomed by the community and are not seen as their representative body. The community watershed management project by Nile Basin Initiative (NBI) reported that the popular committees' functions in the project were limited as they were seen as the arm of the government.[3] There are also some popular committees which do not function due to low motivation of members or internal disputes.

Nomads do not have popular committees. The Native Administration composed of traditional leaders is an important structure for them to represent themselves as well as functioning as a communication channel, instead of the popular committee.

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[2] The popular committee is sometimes referred to the people's committee. The village committee is also used at rural area.

[3] Institutional Assessment, Community Watershed Management Component, Bo Lager and Noon Abdelrahaman

A questionnaire and interview survey conducted by the JPT found that water-related institutions at the state level, such as the SWC, GWWD branch and DIU branch, contact the popular committees when a need arises and some popular committees take some responsibilities for water resource management at the local level.

Farmers' Unions

Farmers' unions are organized by farmers at the federal, state, locality, and community level. The main role of the farmers' union is to work collectively for the production of agricultural products. The union is said to be under the control of the government and ruling party.

Pastoralist Unions

Pastoralist Unions are also organized by pastoralists at the federal, state, locality, and community level. The union is also under control of the government and ruling party. Therefore, ordinary members sometimes complain that the union is not independent from the party and is controlled by urban-based elites.[4]

Members of both unions tend to be affected by members who have financial and political power while small scale farmers and pastoralists are underrepresented.

Women's Groups

Community members sometimes establish a women's group on a voluntary basis. While many of them are dormant and do not do practical activities, there are many active women's farming groups in Gedaref State and they open bank accounts for the group to get loans for agricultural activities.

Village Development Committees (VCD)

Many donor-funded projects establish a village development committee, whose members are selected by community members to be responsible for the projects and to take initiative in the development of the village. VCDs can keep a distance from the government as the members are not connected to the government.

Water Committees

SWC is basically responsible for the operation and maintenance of water facilities in rural areas. Therefore, it is not common to establish a water committee at the community level except in donor-funded projects. Some SWCs provide technical training to community members even if they do not have a water committee.

Water Users' Association (WUA)

For an irrigation scheme including flood irrigation, there are cases in which a WUA composed of farmers is established, and they participate in water management. On the other hand, there are cases in which an irrigation scheme is entirely managed by a parastatal organization or scheme management committee without any WUA, although representatives of farmers are included in the management committee. Generally speaking, WUAs in Sudan do not function very well.

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[4] Pastoralist Peoples, Their Institutions And Related Policies, Omer Egemi, 2012

2) After the Revolution

Organizations linked to the former regimes, such as the popular committee, the farmers' union, the pastoralists' union were dissolved. Although organizations have been emerging at the same time, it's been difficult for the government to decide with which ones the government should cooperate.

Forces of Freedom and Change (FFC)

FFC was founded in January 2019 to seek the establishment of a transitional government and includes various organizations such as professional unions, political parties, youth groups, and women's groups. FFC has been playing an important since then.

Women and Youth Groups

In the past, women and youth, who had few opportunities for political and social participation, played a major role in the revolution. The Constitutional Declaration issued in August 2019 states that the rights of women and youth will be established and promoted. Women's and youth groups are active in the urban areas. However, it is not easy to find these active groups in the rural areas.

Chapter 3 Phase-1 Activities and Results

3.1 Phase-1 Activities

The project is divided into Phase-1 and Phase-2. Phase-1 was implemented from August 2016 to January 2018. It consists in is implementing IWRM in the federal government and covers the entire country of Sudan. This phase included a "Water balance analysis" (Outcome 1) and a "Water issues' analysis" (Outcome 2) in aims to analyze the current status of water resources in each basin in Sudan using both quantitative and qualitative information to understand the challenges. Throughout Phase-1 activities in the federal government, a priority region as well as certain issues were selected as targets for Pilot activities to implement water problem-solving practices.

3.2 Water Balance Analysis

3.2.1 Water Balance Analysis Methodology

Water balance analysis is evaluated through balancing three elements: i) the water resources potential of both SW and GW; ii) the capacity of facilities for water resources development and supply; and iii) water demand (refer to Figure 3.2-1). Methodologies for evaluating these three elements in the Nile and the Non-Nile Areas are described in detail in the following section.

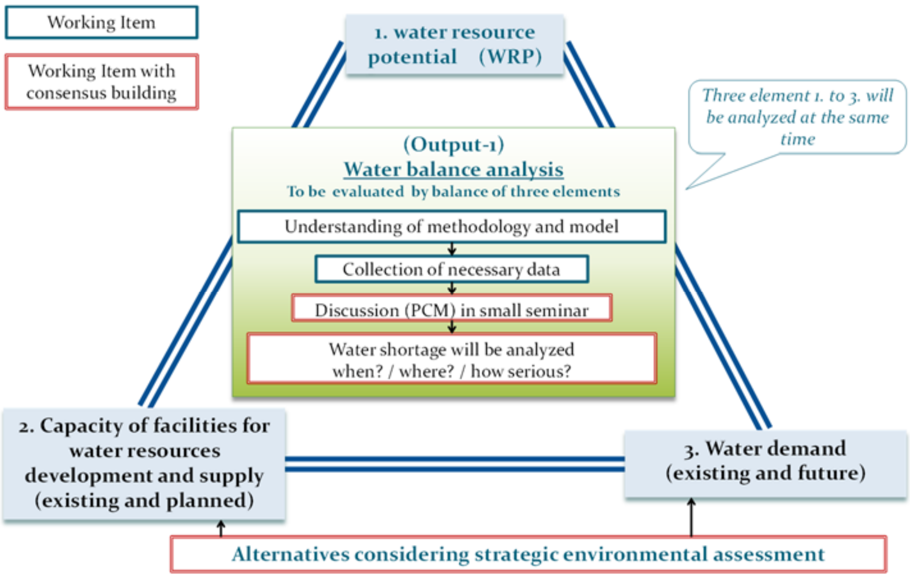


Figure 3.2-1 Workflow of Water Balance Analysis

Source: JICA Project Team

The purpose of the analysis is rough estimation and understanding of water resources. The results of the calculation were used in the selection of the detailed development plan for water resources/supply facilities, pilot areas and the material for consensus building.

(1) SW Resources Potential

Runoff represents the water resources potential for SW. This is calculated using the Rainfall-runoff analysis, which comprises three main elements: Input data, parameters (conditions) and the calculation model (see Figure 3.2-2).

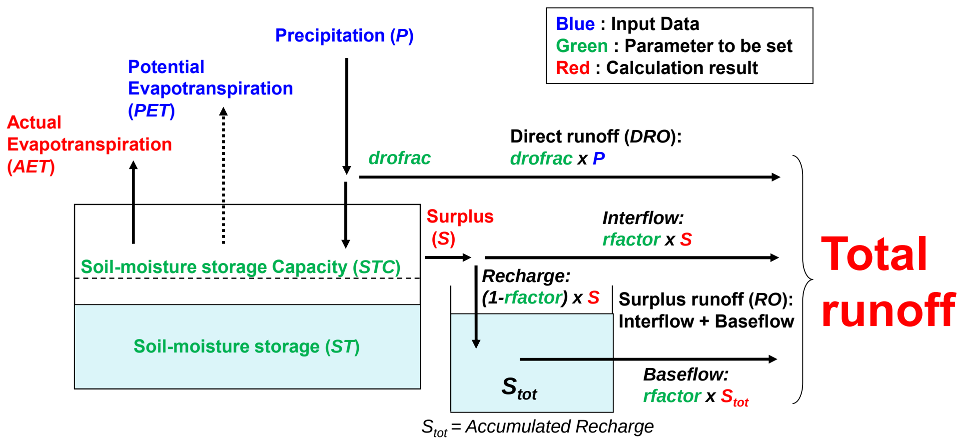


Figure 3.2-2 Basic Concepts of the Analytical Model

Source: JICA Project Team

Delineation of River Basins

River basins are delineated based on the topography data. The flow direction and flow accumulation of stream are calculated using GIS. As a result, 177 sub-basins are set as target sub-basins which are used for water balance analysis of this study. Furthermore, from the view point of future water resources management and development of Sudan, these sub-basins are classified into 12 basins. It is recommended that this 12 basin division is applied for water resource management and development in the future.

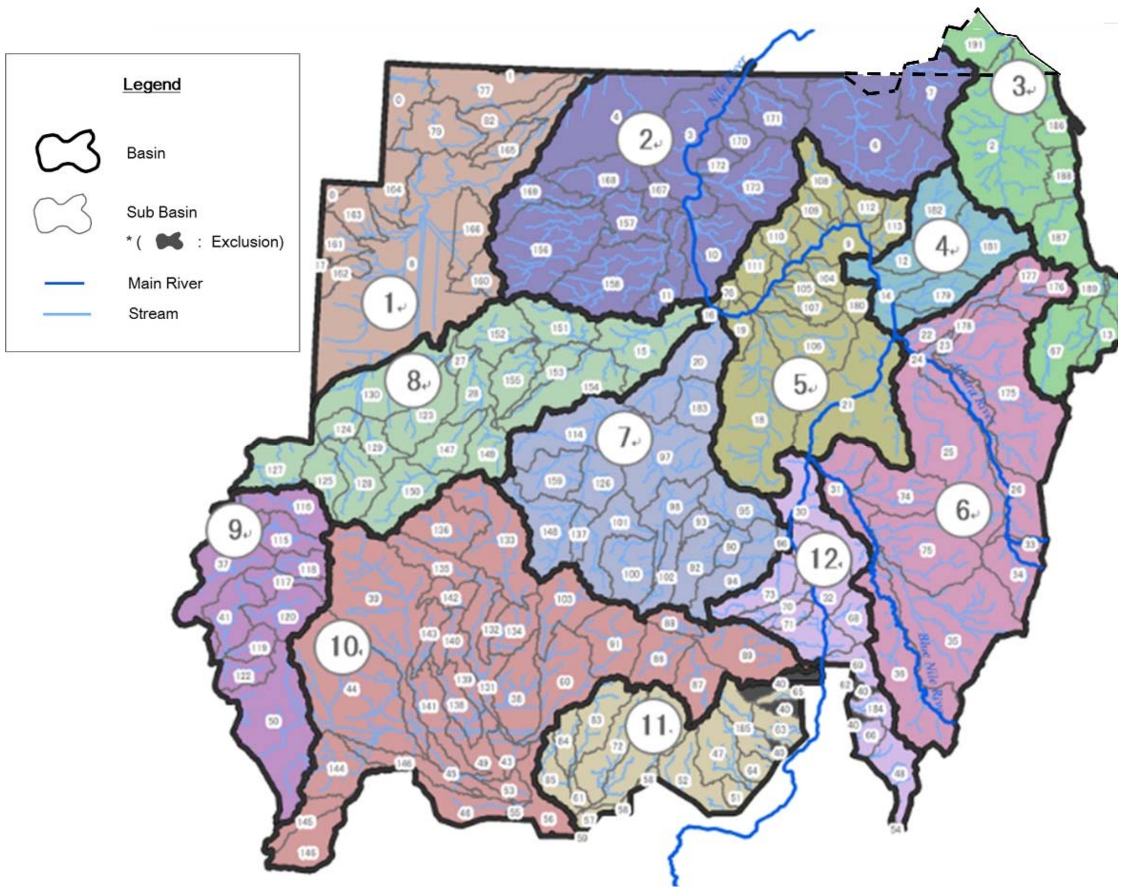


Figure 3.2-3 Proposed Basin Delineation

Rainfall analysis

Observed data from the Sudan Metrological Authority is very limited due to a limited number of observation stations. Such data have been collected from around 30 stations in the course of the Project, which can be utilized for calculation purposes. Meanwhile, several global satellite observation data, such as GSMaP from JAXA are freely available in high resolution from the Internet covering the whole of Sudan. Comparison results show that precipitation values obtained from GSMaP are different from the observed ones. Therefore, the GSMaP data will be calibrated by comparing the observed data. Information on the daily average rainfall over the catchment area is used as the input data for the rainfall-runoff analysis. Considering the above-mentioned conditions, the GSMaP and observed data from the SMA were used in this project. Since satellite data are not available for the period before 2000, the average rainfall is calculated using the Thiessen method. The calibrated satellite data are used in respect of the period after 2000.

Evapotranspiration Analysis

Potential Evapotranspiration (PET) can be calculated following several methods. The Hamon formula, the Penman-Monteith formula and the Thornthwaite formula are the major methods to calculate this parameter. The Hamon formula is used in the context of this project as it is simple and allows estimating PET despite the limited data available. The situation regarding the source of temperature data is similar to that of rainfall data. In fact, several global satellite observation data, such as CRU-TS from BADC, are freely available in high resolution and cover the entirety of Sudan. The monthly average temperature over the catchment area is used as the input data for the rainfall-runoff analysis. Since the satellite data are slightly different from the observed data and the observed data is limited to only 26 observation stations for the whole country, the CRU-TS are used to calculate the average temperature.

Establishment of Rainfall Runoff Model

It exists several models for rainfall-runoff calculations. One of the key criteria when selecting the most suitable model for the present study is the alignment with the project policies. One of the main policies consists in “participatory activity by the C/Ps for sustainable processes”. To achieve this, SHETRAN has been selected. This mode presents various advantages such as simple operation thanks to a user-friendly graphical user interface (GUI) and a library that consists of default parameters for soil and vegetation conditions. Moreover, calculation time is relatively quick. This would enable C/Ps to operate the software easily adopting simple conditions and effectuate calculations within a short period of time. However, the main disadvantage of this model is that the number of available grids is limited. Considering the above-mentioned conditions, it was judged that SHETRAN meets the purpose of rough calculation of the water potential for the rainfall-runoff analysis of Sudan and therefore adopted for this study.

Calibration of Runoff Analysis

Basically, data from wadi stations which are located downstream and have longer continuous discharge records were selected for calibrating the SHETRAN model. However, the selection process was somehow a trial and error. Finally, 10 stations were selected, and trial and error calculations to fix the parameters were carried out by comparing calculated discharge and observed discharge. Since there are limited number of wadi stations in Sudan, calibrated model parameters, such as soil parameters, were applied to the neighboring / similar basins considering the soil classification in each small catchment area.

Evaluation of SW Potential

The total SW potential was evaluated and the main calculation results include runoff ratio and average annual discharge**.** Regarding the first parameter, it is calculated using the following formula, "Runoff ratio = (Discharge / Catchment area) / Rainfall". Results show that runoff ratio is generally less than 5%, and most of the sub basins show less than 1%. Regarding the total annual discharge of SW in Sudan, it was estimated at 4.05 BCM.

As aforementioned, the purpose of the analysis is providing a better understanding of current water resources conditions and a rough estimation of existing resources for water balance analysis. Therefore, it is considered that the calculation results met the above objective.

(2) Evaluation of GW Potential

Aquifer Classification

The hydrogeological map of Sudan is shown in Figure 2-6 of CHAPTER 2. Aquifer is classified into the following:

- Alluvium aquifer
- Continuous aquifer
- Continuous to Sub continuous aquifer
- Dry zone
- Potential very low, red sea deposit
- Basalt
- Basement complex

The Project Team adopted this classification of aquifers to formulate GW development and management plan.

Evaluation of GW Potential of Wadi Basins

GW recharge was analyzed through long term rainfall-runoff analysis. Formula for calculation is show below.

Rainfall (mm/year) = evapo-transpiration (mm/year) + wadi discharge (mm/year) + GW recharge (mm/year)

GW recharge is estimated using soil water balance as shown in Figure 3.2-4. Rainwater (P) infiltrates into the soil and is stored once in the soil (see top tank in Figure 3.2-4). Some of the water then evaporates from the soil (ETR). When the soil moisture content exceeds the field capacity, some of the water becomes SW and some percolates into the aquifer (see lower tank in Figure 3.2-4) and becomes GW (G). Base flow (B) occurs from the aquifer.

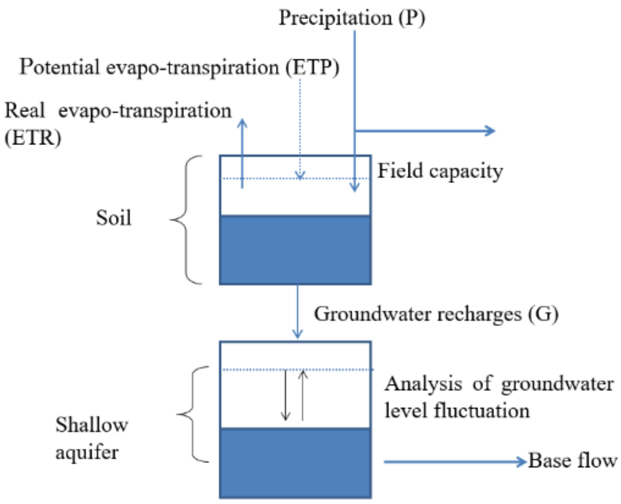


Figure 3.2-4 Concept of Soil Water Balance

Theory of analysis is explained below:

- Soil moisture is analyzed on a daily basis.
- GW recharge happens when soil water deficit is recovered.
- Evapo-transpiration potential is assumed to be 6-7mm/day.
- Maximum evapo-transpiration (ETP) occurs when soil moisture deficit is recovered. In case where soil deficit is not recovered, evapo-transpiration occurs depending on how much water is remaining within the soil.

Soil water balance was analyzed using daily rainfall data of 33 years (1980-2013). As a result of the analysis, the Average GW recharge was assessed for each sub-basin. Resultant GW recharge is different for each sub-basin. It is more realistic that difference in GW recharge of each basin should be adjusted considering the fact that the most important factor of GW recharge is amount of rainfall. According to the result of the statistical analysis, the GW recharge is expressed by the relationship below.

$GR = 0.0005 \times P^{2.43}$ (see Figure 3.2-5)

Where:

GR : GW recharge (mm/year)

P: Rainfall (mm/year)

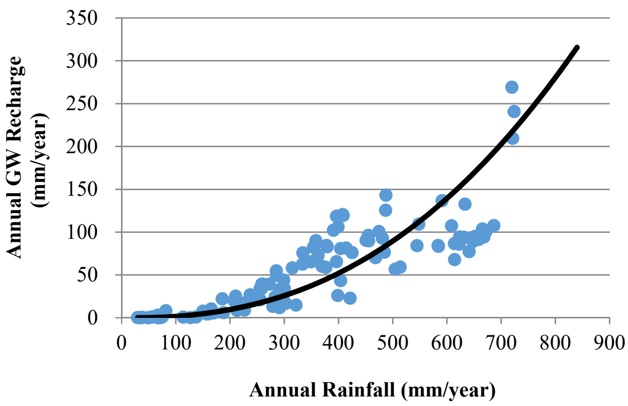


Figure 3.2-5 GW Recharge

The above relation gives more natural result of long-term GW recharge than original ones. Hence, it is employed in this Project. The result of the analysis is shown in Figure 3.2-6. According to the analysis, annual average GW recharge is 25.7mm/year for the entirety of Sudan, which corresponds to 12% of the annual average rainfall. Total amount of the GW recharge is estimated to be 24 BCM/year. It should be noted, in this context, that generally GW will finally flow into river as base flow in case of permanent rivers. However, base flow is not observed in ephemeral rivers such as wadis in Sudan.

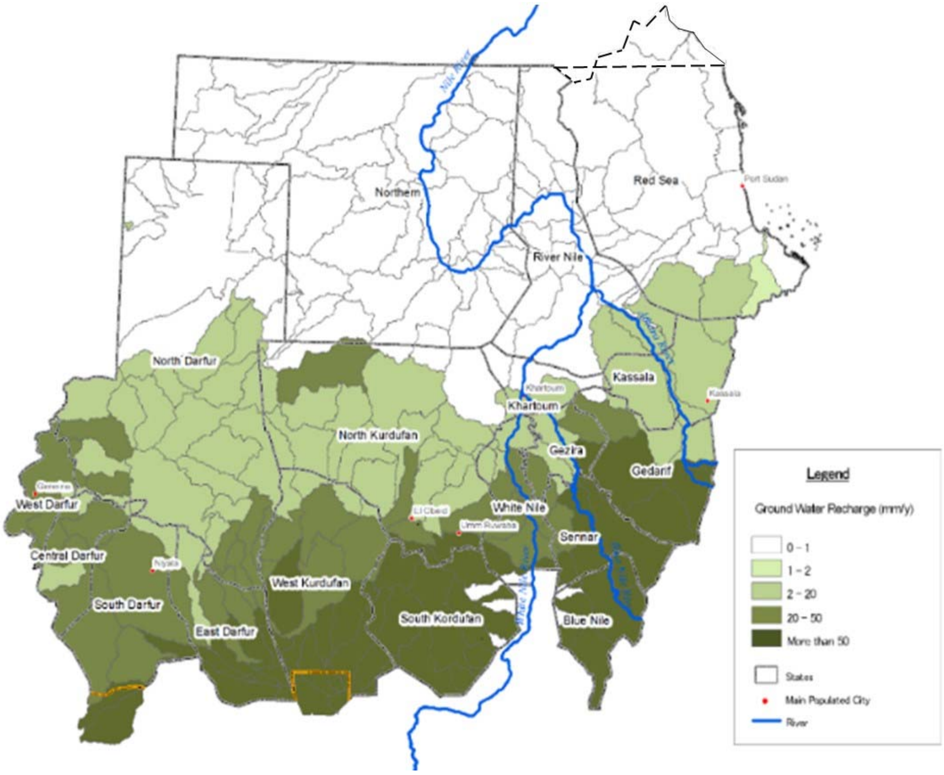


Figure 3.2-6 GW Recharge by Sub-Basin

Source: JICA Project Team

3.2.2 Water Demand

This project started in the year 2016. The year 2035 was set as planning year, which is 20 years from year 2015, one year before the commencement of the project. Therefore, water demand was projected targeting year 2015 and 2035.

(1) Water supply for domestic use

Domestic water use consists of drinking, cooking, bathing, flushing and washing water, and also other water usage in daily life. It typically grows not only by the increase in population served but also because of lifestyle changes and improvements in living standards. Daily average domestic water consumption is calculated by multiplying the population served by the unit of water consumption (LCD).

Methodology Adopted for Water Demand Projection

A flowchart of the water demand projection for the water supply is shown in Figure 3.2-7.

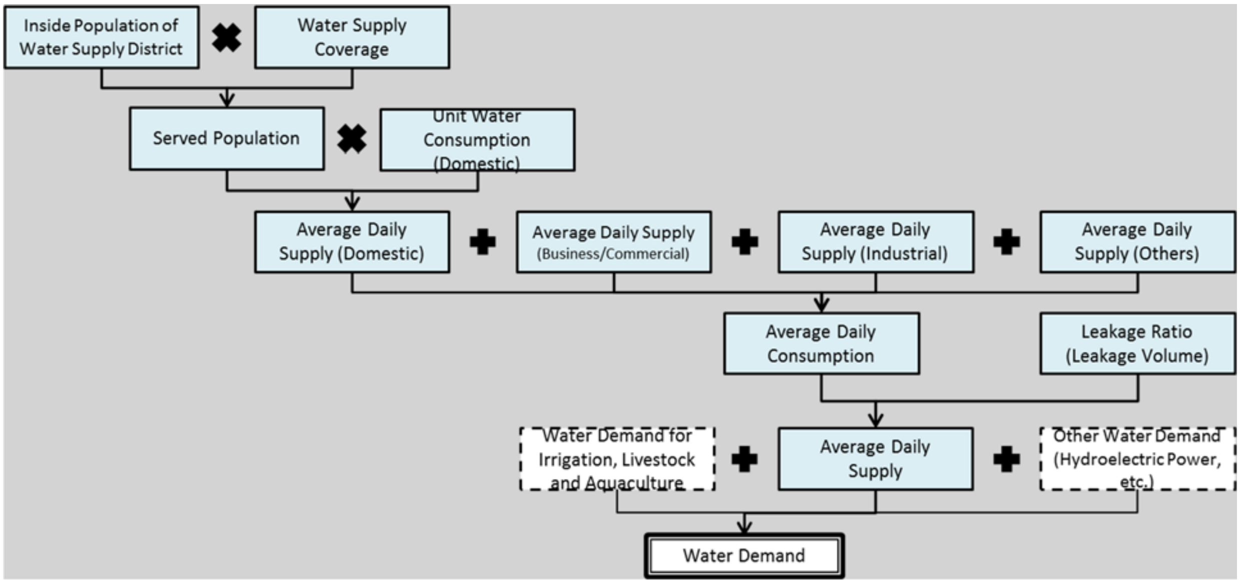


Figure 3.2-7 Flowchart of Water Demand Projections for Water Supply

Source: JICA Project Team

Population

Population for the year 2015 and the target year, 2035, were estimated based on the latest population census of 2008 and the population growth rates, as shown in the following table.

Table 3.2-1 Population Projection for each Locality

No.	State	Population in Total (nos.)		Population in Urban (nos.)		Population in Rural (nos.)		Population in Nomads (nos.)	
		2015	2035	2015	2035	2015	2035	2015	2035
1	Gezira	4,249,806	6,963,516	811,840	1,330,295	3,436,972	5,631,881	994	1,340
2	Northern	813,319	1,253,766	137,966	213,205	659,856	1,019,689	15,497	20,872
3	Kassala	2,125,123	3,480,763	563,161	940,982	1,345,662	2,248,454	216,300	291,327
4	Algadarif	1,612,178	2,687,208	459,135	767,165	1,132,783	1,892,756	20,260	27,287
5	Khartoum	6,486,742	11,715,786	5,254,912	9,490,961	1,231,830	2,224,825	0	0
6	White Nile	2,067,844	3,441,253	695,707	1,162,451	1,329,270	2,221,066	42,867	57,736
7	Sennar	1,528,428	2,510,047	331,564	546,495	1,166,459	1,922,600	30,405	40,952
8	Blue Nile	1,192,844	1,647,913	242,180	404,657	715,529	1,195,573	235,135	47,683
9	Northern Kordofan	2,437,750	4,081,356	569,405	989,201	1,474,816	2,562,126	393,529	530,029
10	Southern Kordofan	1,032,640	1,700,201	262,005	437,782	692,784	1,157,565	77,851	104,854
11	West Kordofan	1,703,319	2,872,831	270,131	460,396	1,302,305	2,236,153	130,883	176,282
12	Northern Darfur	2,495,163	4,026,632	437,754	731,440	1,617,598	2,702,828	439,811	592,364
13	Western Darfur	895,416	1,463,750	227,278	379,757	568,170	949,350	99,968	134,643
14	Southern Darfur	3,263,368	5,215,117	830,194	1,387,165	1,699,873	2,840,299	733,301	987,653
15	East Darfur	1,550,745	2,476,512	225,517	376,816	971,523	1,623,308	353,705	476,388
16	Center Darfur	649,908	1,034,060	43,610	72,868	446,223	745,592	160,075	215,600

Categorization of Settlement on Water Demand Projection

The categorization of settlement by population size, consisting of two categories for water supply planning, has been defined by DWSU. The project, in principle, conforms to this categorization, as shown in the following table. Unit water consumption of domestic water as defined by this categorization is applied in the water demand projections for the project. However, the water demand projections by settlement categories based on population size may only cause inaccuracy because there is a mixture of various water supply schemes, various living or water usage situations, and various income groups in the settlement.

Table 3.2-2 Categorization of Settlements on Water Demand Projection

Settlement Category		Population Size	Typical Water Supply Scheme	Category on Water Demand Projection
1	Urban	More than 20,000	Surface or GW water, piped supply, house or yard connection, metered supply mostly	Urbanized water usage
2	Rural	20,000 or less	Surface or GW, small scale piped supply, communal standpipes, house or yard connection, without metered supply (flat rate) mostly	Ruralized water usage

Source: DWSU

Water Supply Coverage

Water Supply and Sanitation Policy (2011) fixed a national water supply coverage of 59% in 2012 and 100% in 2031 in the urban water supply sector and 62% in 2012 and 100% in 2031 in the rural water supply sector as national goals. These numbers are used as guideposts in the present study.

Table 3.2-3 National Water Supply Coverage by Settlement Category in Target Years

No.	Target Year	National Water Supply Coverage	
		Urban	Rural
1	2012(Current), estimated by the Project	59%	62%
2	2035	100%	100%

Source: JICA Project Team

Population Served

Based on the above coverage, the project estimates population served, as shown in the following table:

Table 3.2-4 National Population Served

No.	Country	National Population Served in 2035 (in thousands)
1	Sudan (Nationwide)	61,405 (100% of water supply coverage)

Source: JICA Project Team

Unit Water Consumption

In view of the present water supply coverage and the high growth of water demand due to the increase in population, progress of the coverage should be prioritized, although revision of the unit water consumption is normally considered due to the possibility of future improvement in living standards. The project thus applies the current standard unit of water consumption, shown in the following table until 2035, the target year of the project.

Table 3.2-5 Unit Water Consumption of Domestic Water Supply in Target Years

No.	Settlement Category	Category on Water Demand Projection	Unit Water Consumption
1	Urban	Urban water usage	150 LCD
2	Rural	Rural water usage	50 LCD

Source: MoWRIE

Table 3.2-6 Water Demand in 2015 and 2035

No.	State	Water demand of 2015 (m^3/day)			Water demand of 2035(m^3/day)		
		Urban	Rural	Nomads	Urban	Rural	Nomads
1	Gezira	56,829	89,361	26	199,544	281,594	67
2	Northern	8,968	32,993	775	31,981	50,984	1,044
3	Kassala	36,042	26,913	4,326	141,147	112,423	14,566
4	Algadarif	22,957	21,523	385	115,075	94,638	1,364
5	Khartoum	1,119,296	232,816	0	1,423,644	111,241	0
6	White Nile	31,307	31,902	1,029	174,368	111,053	2,887
7	Sennar	23,209	36,160	943	81,974	96,130	2,048
8	Blue Nile	9,455	10,229	480	43,087	44,980	1,701
9	Northern Kordofan	28,470	36,870	9,838	148,380	128,106	26,501
10	Southern Kordofan	10,480	16,627	1,868	65,667	57,878	5,243
11	West Kordofan	12,167	32,162	3,166	69,059	111,808	8,814
12	Northern Darfur	19,699	22,646	6,157	109,716	135,141	29,618
13	Western Darfur	5,682	4,545	800	56,964	47,468	6,732
14	Southern Darfur	24,906	28,898	12,466	208,075	142,015	49,383
15	East Darfur	6,766	16,516	6,013	56,522	81,165	23,819
16	Center Darfur	1,090	3,570	1,281	10,930	37,280	10,780

(2) Agriculture (irrigation)

<u>Estimation of the Current Water Demand for Irrigated Agriculture (2015)</u>

The build-up method is utilized for evaluating current and future agricultural water demands. The required water amount is obtained by multiplying the unit water amount and the predicted crop water requirement for major crop groups. Water demand is the sum of the required water amount for each sub-basin area and crop group.

Sub-basins are grouped based on the climatic zoning, major crop production sub-sectors, and water resources for irrigation water. Almost all of the irrigated cultivation is implemented at the watershed area of the Nile River and connecting streams, as well as considerable areas along the Blue and White Niles and the Atbara River.

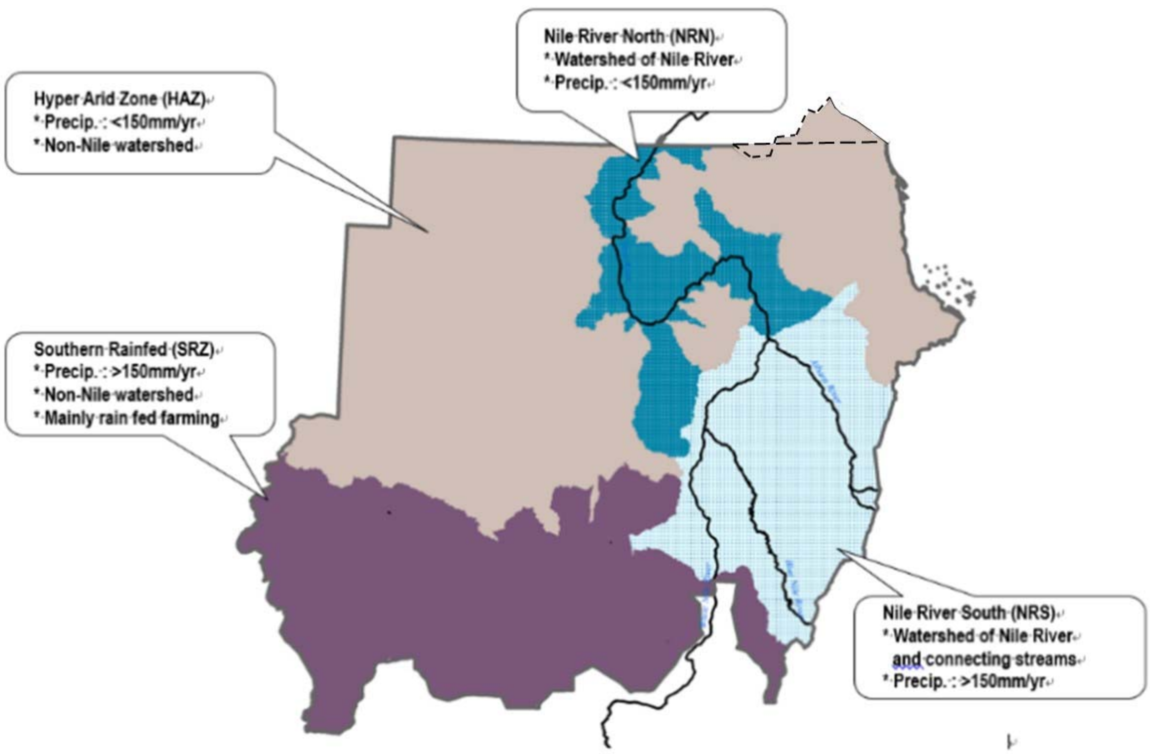


Figure 3.2-8 Major Climatic and Geographical Characteristics

Major characteristics of each Agricultural Climatic Zone (ACZ) are listed below;

Table 3.2-7 Major Characteristics of ACZs

Agricultural Climatic Zone (ACZ)	Major characteristics of the zone
Nile River North (NRN)	Watershed of Nile River. Mean annual precipitation < 150 mm
Nile River South (NRS)	Watershed of Nile River. Other than NRN
Hyper Arid Zone (HAZ)	Mean annual precipitation < 150 mm
Southern Rain-fed Zone (SRZ)	Mean annual precipitation > 150 mm. Other than NRS

Almost all of the irrigation cultivation is carried out only in the Nile River North (NRN) and Nile River South (NRS) sub-basin areas. The source of the water utilized for irrigation cultivation in these sub-basin areas is recognized as SW.

Traditional irrigation is still practiced in the flood plains of the main Nile downstream of Khartoum, as well as over considerable areas along the White and Blue Niles and the Atbara River. In spate irrigation, water from rivers and streams is captured and redirected by diverting canals to flood-wide areas of farming land. The flood period, or wet season, lasts from July to October, with the peak between August and September. The actual irrigated area entirely depends on the volume of water conveyed from the rivers each year. The crops grow due to residual moisture in the soil, meaning that no irrigation is needed. Sometimes, two early-growing crops are cultivated consecutively in one season. The water utilized for crop production is not controllable, and it is quite difficult to estimate the supply and demand for crop production in the flood irrigation system. This is why in this estimation of water requirements for irrigated cultivation, the required water amount for flood (or spate) irrigation is not counted as an irrigation water demand.

<Cop water requirement>

The method to estimate crop water requirement is shown in Figure 3.2-9.

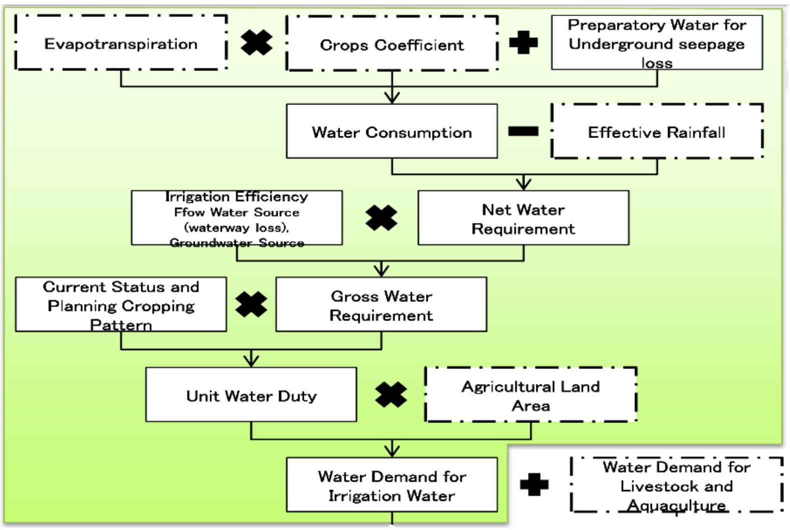


Figure 3.2-9 Work Flow of Crop Water Requirement Calculations

Source: JICA Project Team

To calculate the crop water requirements in sub-basin areas of crop groups, regional topographic and meteorological data including the soil type, temperature (min. and max.), precipitation, relative humidity, evaporation, wind speed and sunshine periods over a decade are collected. Cropping patterns and crop acreages and soil types in sub-basin areas are also needed as supplemental information. The average precipitation of ACZs for 34 years (from 1981 through 2014) is described below:

Table 3.2-8 Average Precipitation in ACZs

mm / mo.

ACZ / Mo.		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
NRN	21SB	0.05	3.18	3.19	0.51	2.32	4.05	4.03	6.05	2.22	0.18	0.03	0.58
NRS	19SB	0.22	5.89	6.09	2.91	14.81	35.09	97.73	110.01	50.64	14.66	0.65	0.04
HAZ	82SB	0.42	3.54	3.54	0.45	2.75	6.72	16.00	19.88	6.21	1.76	0.51	0.80
SRZ	69SB	0.12	8.15	9.05	6.13	29.72	60.11	119.96	132.65	80.20	30.96	1.65	0.11

* SB: Sub basin

Source: JICA Project Team

Reference Evapotranspiration (ETP) is calculated by utilizing the Hamon formula, as in the previous calculation.

Table 3.2-9 Reference Evapotranspiration (ETP / PET)

mm / mo.

ACZ / Mo.		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
NRN	21SB	68.24	72.61	106.63	144.13	188.59	203.67	201.68	188.14	164.66	135.34	90.57	71.98
NRS	19SB	86.85	92.94	127.77	155.86	179.10	171.63	154.69	139.05	130.96	130.85	104.59	90.34
HAZ	82SB	84.96	88.77	134.38	181.53	245.40	261.32	260.64	237.34	200.58	167.95	109.08	87.07
SRZ	69SB	133.54	141.25	203.35	233.31	262.15	230.63	215.70	199.35	186.55	193.97	157.61	138.78

* SB: Sub basin

Source: JICA Project Team

Effective rainfall for each month in each ACZ is shown below:

Table 3.2-10 Effective Rainfall

mm / mo.

ACZ / Mo.		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
NRN	21SB	0	0	0	0	0	0	0	0	0	0	0	0
NRS	19SB	0	0	0	0	0	11	53	63	21	0	0	0
HAZ	82SB	0	0	0	0	0	0	0	0	0	0	0	0
SRZ	69SB	0	0	0	0	8	26	71	81	39	9	0	0

* SB: Sub basin

Source: JICA Project Team

Crop coefficients, production periods and the numbers of days in growth stages of major crops produced in ACZs is determined from references issued by the Gedzira Research Station and FAO.

Table 3.2-11 Crop Coefficient (Kc)

Crop / ACZ	Crop Season	Production period	Crop Coeficient (Kc)			
			Initial stage (1st)	Initial stage (2nd)	Middle stage	Late stage
Wheat	No. days	120	20	30	40	30
NRS	Winter		0.40	0.78	1.15	0.30
Sorghum	No. days	110	20	30	30	30
NRN	Winter		0.30	0.70	1.10	0.55
Cotton	No. days	180	30	40	60	50
NRS	Summer		0.35	0.78	1.20	0.60
Vegetables (Onion)		150	15	25	70	40
NRN	Winter		0.60	0.85	1.10	0.90
Citrus	No. days	365	60	90	120	95
NRN	Perennial		0.75	0.75	0.75	0.75
Alfalfa	No. days	365	cont	cont	cont	cont
NRS	Perennial		0.95	0.95	0.95	0.95

* Gedzira Research Station and FAO

Source: JICA Project Team

Cropping calendars for the typical crop items and planting patterns practiced in each ACZ are assumed. Monthly evapotranspiration (ETP) for selected crop items are determined. Based on monthly ETP for selected crop items, the net water requirement for selected crop items are estimated.

The use of water is estimated using the reference evapotranspiration (ETP), crop coefficient (Kc), and water for land preparation and pre-irrigation. Real crop evapotranspiration (ETc) is computed by multiplying the reference ETP by the crop coefficient (Kc). The loss of water due to land preparation is assumed to be 60 mm in upland fields (FAO). The use of water was calculated by the sum of ETc and water for land preparation and pre-irrigation. The unit water requirement under current conditions in 2015 is estimated below;

Table 3.2-12 Unit Water Requirement (Current: 2015)

Current Unite Water Requirement for Irrigated Farmlands/ Fields
**** Ec (75%) and Ea (60%) = E (45%)***

ACZ	Crop	Net Water Requierment (mm / m^2)	Gross Water Requirement (m^3 / ha)	Crop Intensity (%)	Unit Water Requiremnet (m^3 / ha)	ACZ Unit Water Requiremnet (m^3 / ha)
NRN	Crop 1	267	5,933	50	2,967	11,616
	Crop 2	211	4,689	10	469	
	Crop 3	1,227	27,267	30	8,180	
NRS	Crop 1	325	7,222	30	2,167	11,621
	Crop 2	527	11,711	30	3,513	
	Crop 3	1,338	29,733	20	5,947	
HAZ	Crop 1	0	0	0	0	0
	Crop 2	0	0	0	0	
	Crop 3	0	0	0	0	
SRZ	Crop 1	0	0	0	0	0
	Crop 2	0	0	0	0	
	Crop 3	0	0	0	0	

Note: Water delivery efficiency (E) is culculated by the Conveyance Efficiency (Ec) multiply Field Application Efficiency (Ea)

NRZ: Crop 1: Sorghum, Crop 2: Onion, Crop 3: Citrus
NRS: Crop 1: Wheat, Crop 2: Cotton, Crop 3: Alfalfa

Source: JICA Project Team

The water demand estimation under current condition in 2015 is summarized in the table below. The overall water demand is 16,117.30 MCM year-round.

Table 3.2-13 Summary of the Current (2015) Water Demand for Irrigated Agriculture

ACZ	Sub Basin Area (km^2)	Irrigated Area (ha)	Unit Water Requirement (m^3/ha)	Water Requirement (m^3)	Water Requirement (MCM)
Estimated Crop Water Requirement for Irrigation Agriculture (Current: 2015)					
Sub total (NWN)	147,261	281,457	11,616	3,269,404,512	3,269.40
Sub total (NWS)	335,709	1,105,576	11,621	12,847,898,696	12,847.90
Sub total (HAZ)	952,280	0	0	0	0.00
Sub total (SRZ)	530,197	0	0	0	0.00
Total	1,965,447	1,387,033	---	16,117,303,208	16,117.30

Source: JICA Project Team

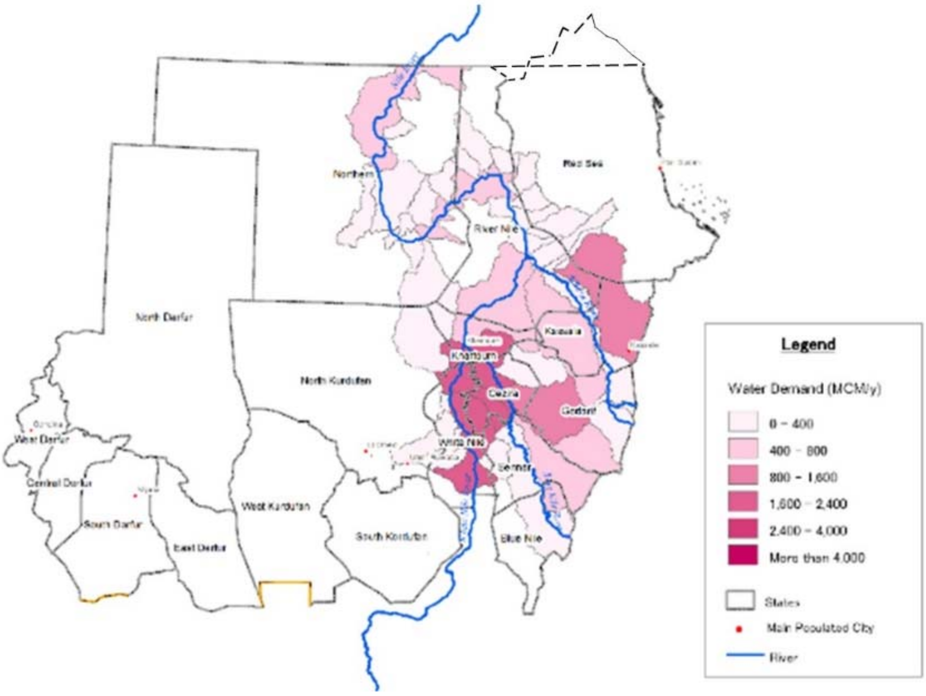


Figure 3.2-10 Current (2015) Water Demand for Irrigated Agriculture

Source: JICA Project Team

Estimation of the Proposed (Future) Water Demand for Irrigated Agriculture (2035)

To estimate the water demand for future irrigated agriculture in 2035, various reports regarding national irrigation development and rehabilitation plans and strategies are consulted. According to the National Investment Profile: Water for Agriculture and Energy (2015: FAO, AgWA , CMESA and Gov. of SUDAN), over 20 projects would develop new irrigation schemes utilizing ground water in the Northern and River Nile States for 807,348 ha, and four national projects would rehabilitate existing large-scale irrigation facilities and revive the dormant land of 597,800 ha in the scheme areas. The crop intensity led by the rehabilitations of irrigation facilities and equipment under the proposed conditions in 2035 is tentatively set below:

Table 3.2-14 Cropping Pattern (Intensity)

ACZ	Current Pattern			Proposed Pattern		
	Crop Intensity (%)			Crop Intensity (%)		
	Cerial	Other	Perennial	Cerial	Other	Perennial
NRN	50	10	30	50	20	40
NRS	30	30	20	40	30	40
HAZ	0	0	0	0	0	0
SRZ	0	0	0	0	0	0

*Note: the cropping plan above mentioned would be further considered from now on.

Source: JICA Project Team

There are several IWRM agricultural practices focusing on water conservation. In this projection it is assumed that several water saving techniques would be introduced and practiced at crop fields in irrigation schemes by the project target year 2035.

Table 3.2-15 Unit Water Requirement (IWRM: 2035)

Unit Water Requirement for Irrigated Farmlands (**CONDITIONED**: IWRM)

**** Ec (85%) and Ea (85%) = E (72%)***

ACZ	Crop	Net Water Requierment (mm / m^2)	Gross Water Requirement (m^3 / ha)	Crop Intensity (%)	Unit Water Requiremnet (m^3 / ha)	ACZ Unit Water Requiremnet (m^3 / ha)
NRN	Crop 1	267	3,708	50	1,854	9,257
	Crop 2	211	2,931	20	586	
	Crop 3	1,227	17,042	40	6,817	
NRS	Crop 1	325	4,514	40	1,806	11,435
	Crop 2	527	7,319	30	2,196	
	Crop 3	1,338	18,583	40	7,433	
HAZ	Crop 1	0	0	0	0	0
	Crop 2	0	0	0	0	
	Crop 3	0	0	0	0	
SRZ	Crop 1	0	0	0	0	0
	Crop 2	0	0	0	0	
	Crop 3	0	0	0	0	

Note: Water delivery efficiency (E) is culculated by the Conveyance Efficiency (Ec) multiply Field Application Efficiency (Ea)

NRZ: Crop 1: Sorghum, Crop 2: Onion, Crop 3: Citrus
NRS: Crop 1: Wheat, Crop 2: Cotton, Crop 3: Alfalfa

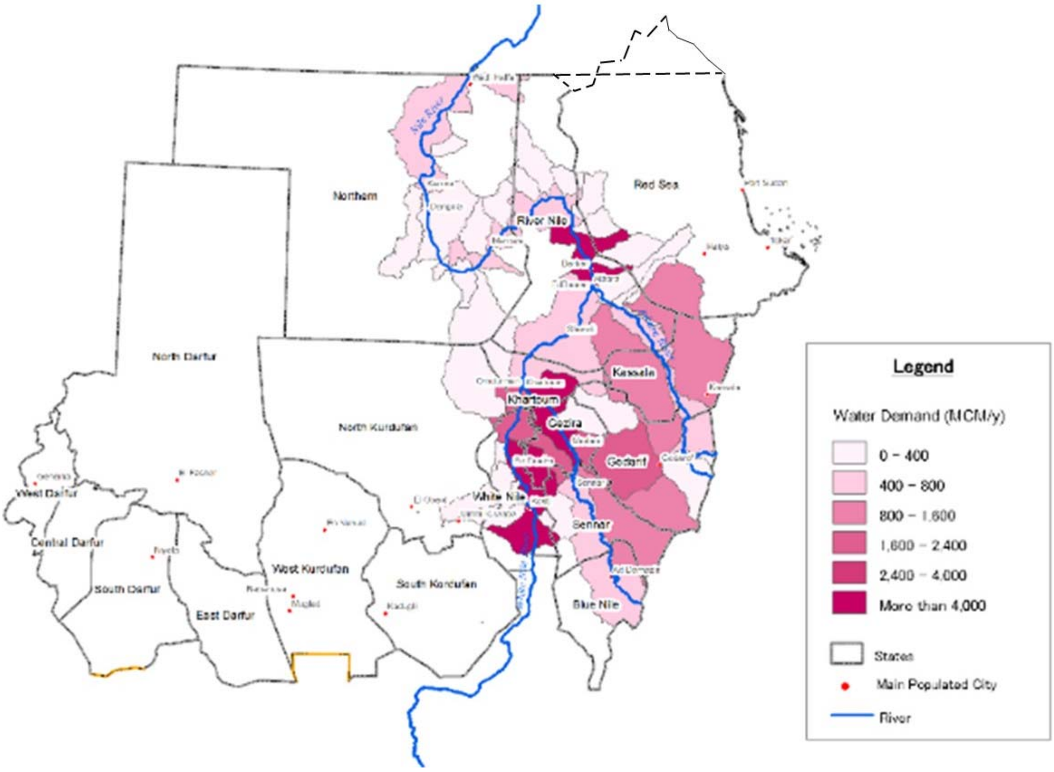


Figure 3.2-11 Water Demand for Irrigated Agriculture under IWRM (2035)

(3) Livestock

The current (2015) and future (2035) water demand for livestock production was estimated. Livestock water requirements are mainly provided by direct water intake and partly by the moisture content of the forage. To estimate water requirements for livestock animals, the present/future number of heads should be identified then simply multiplied by the standard water requirement per head of livestock in the tropical zone, as formulated by FAO. The number of major livestock animals for the past decade is summarized below.

Table 3.2-16 Major Livestock Animal Headcount 2006 - 2015

Item	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Cattle	28,810,584	28,911,788	30,008,993	29,210,477	29,357,983	29,618,009	29,840,000	30,010,001	30,191,001	30,376,002
Sheep	37,868,085	38,064,228	38,376,854	38,743,585	39,137,370	39,296,000	39,485,184	39,566,569	39,844,560	40,208,546
Goat	29,971,955	30,099,540	30,215,905	30,332,270	30,452,142	30,649,000	31,288,260	30,984,949	29,517,950	31,227,957
Camel	4,077,998	4,237,998	4,405,998	4,520,999	4,623,000	4,715,004	4,751,000	4,773,001	4,791,999	4,808,970

The annual growth rate of livestock (2006 – 2015) is shown in Table 3.2-17.

Table 3.2-17 The Annual Growth Rate of Livestock (2006 – 2015)

Item,	The annual growth rate for 10 years
Cattle	0.74
Sheep	0.79
Goat	0.60
Camel	1.28

Annual water demand for livestock was calculated following the FAO livestock guidelines for African regions. The annual consumption rates per head are given below.

Table 3.2-18 Standard Water Requirements per Head of Livestock in Tropical Zones

Source	CATTLE	SHEEP	GOAT	CAMEL	Unit
FAO	21.6	2.0	2.3	24.6	L/ day
FAO	7.88	0.73	0.84	8.98	m^3 / yr

Source: Based on FAO

Table 3.2-19 Livestock Headcount and Water Requirements for 2015 and 2035

CATTLE	2015	2035
Head	30,376,002	33,374,840
Water Req.	239.36	262.99
SHEEP	**2015**	**2035**
Head	40,208,546	45,274,447
Water Req.	29.35	33.05
GOAT	**2015**	**2035**
Head	31,227,957	32,574,005
Water Req.	26.23	27.36
CAMEL	**2015**	**2035**
Head	4,808,970	6,511,854
Water Req.	43.18	58.48
TOTAL	**2015**	**2035**
Water Req.	338.13	381.88

Unit: MCM

Source: JICA Project Team

3.2.3 Water Balance Analysis

(1) **Water Balance Analysis of 2015**

The purpose of water balance analysis for 2015 is to know the current water supply capacity. There are several records of water supply facilities including hafirs, small dams and wells. However, the accuracy of such records is not high because of the limited number of facilities listed in those records. Therefore, the current water supply capacity should be estimated from the current water consumption rate. The water balance of 2015 was analyzed following the procedure explained below.

a) Water balance analysis was implemented for 177 sub-basins, which were delineated for the long-term rainfall-runoff analysis.
b) Monthly wadi flow (m^3/month) and GW recharge (m^3/year), which were analyzed by long-term rainfall-runoff analysis, were assigned to each sub-basin.
c) Water demand for urban/rural/nomad areas and livestock /irrigation for 2015 was assigned to sub-basins.
d) Water demand was given to SW and GW in proportion to the current consumption ratio of SW and GW of the sub-basins.
e) The current water supply capacity including hafirs, small dams and wells in 2015, which was recorded in the inventory, was assigned to each sub-basin.
f) Current water balance was calculated to know whether or not the current water supply capacity can satisfy the current water demand with enough water supply security.
g) If the current water supply capacity cannot satisfy the current water demand of 2015, additional water supply facilities (hafirs/small dams/wells) were added to each sub-basin until the water demand was satisfied. Those additional water supply capacities are considered as currently existant but are not included in the inventory.

Results of water balance analysis are shown in Figure 3.2-12 to Figure 3.2-16.

Total Water Resources Potential

Water resources potential including both SW and GW is shown in Figure 3.2-12. Total potential is expressed by MCM/year by sub-basin. It is clear from the map that the northern half of Sudan has smaller water potential than the southern half.

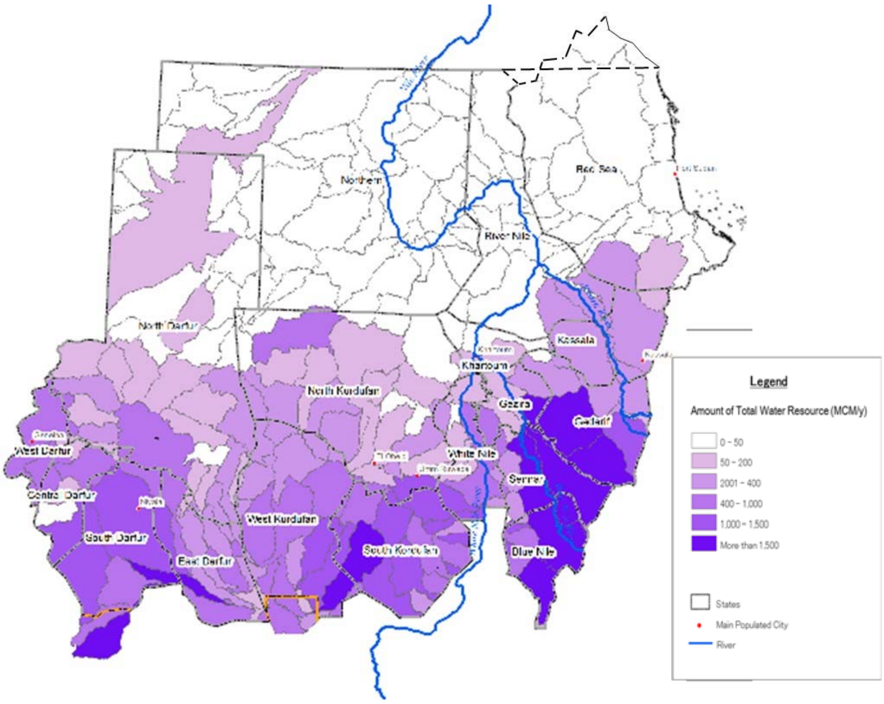


Figure 3.2-12 Total Water Resources Potential

Source: JICA Project Team

Total Water Demand in 2015

Total water demand including urban/rural/nomad water supply and livestock and irrigation water supply is shown by sub-basin in Figure 3.2-13. Although water demand for the Nile area is not considered in this map, it is noticeable that the water demand of the Blue Nile region is high. This can be explained by the fact that rainfall harvesting water is the main source of water in many rural areas in this region.

It is clear that the water demand is very high, ranging between 10 and 20 MCM/y, in the following regions i) Port Sudan, ii) Kassala, iii) Blue Nile and iv) South Darfur. From the same map, the distribution of water demand can be described as uneven throughout Sudan.

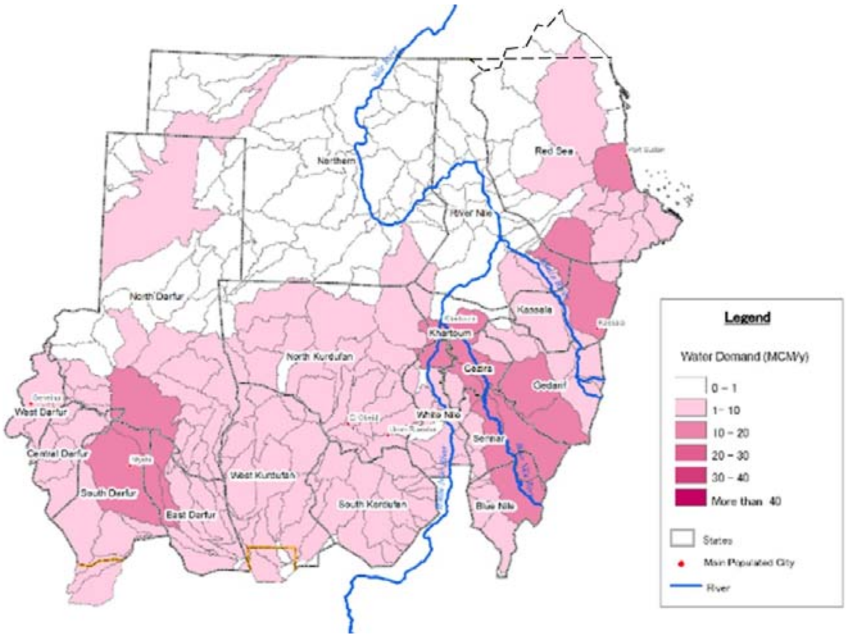


Figure 3.2-13 Total Water Demand in 2015

Source: JICA Project Team

Ratio of Water Demand/Water Resources (2015)

Ratio of Water Demand/water Resources of the years 2015 is shown by sub-basin in Figure 3.2-14. Generally speaking, high ratios of water demand/water resources indicate high risk of water shortage. As shown in Figure 3.2-14 regions with high ratio (10-99.9%) have high water demand. According to the figure, it can be said that water demand is more unevenly distributed than water resources. It is noticeable that the ratio is highest in the sub-basin where Port Sudan is located due to high demand with low water resources in that area.

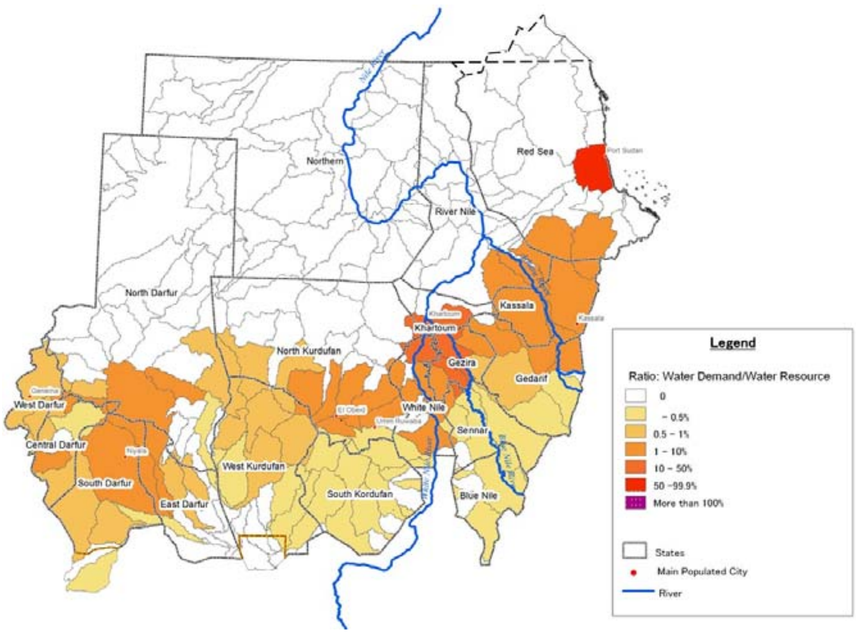


Figure 3.2-14 Ratio of Water Demand/Water Resources (2015)

Source: JICA Project Team

Required Capacity of Facilities for SW (2015)

Water demand was allocated to SW and GW with respect to the current (2015) consumption ratio of SW and GW of sub-basins. SW supply capacity assured by hafirs and small dams to meet water demand of 2015 is shown by sub-basin in Figure 3.2-15. SW supply capacities in this map includes both i) the recorded capacities that were included in the existing inventories and ii) assumed capacities to complement lack of information of the existing inventories. This information represents the baseline to estimate the number of new SW supply facilities necessary to meet the water demand of 2035.

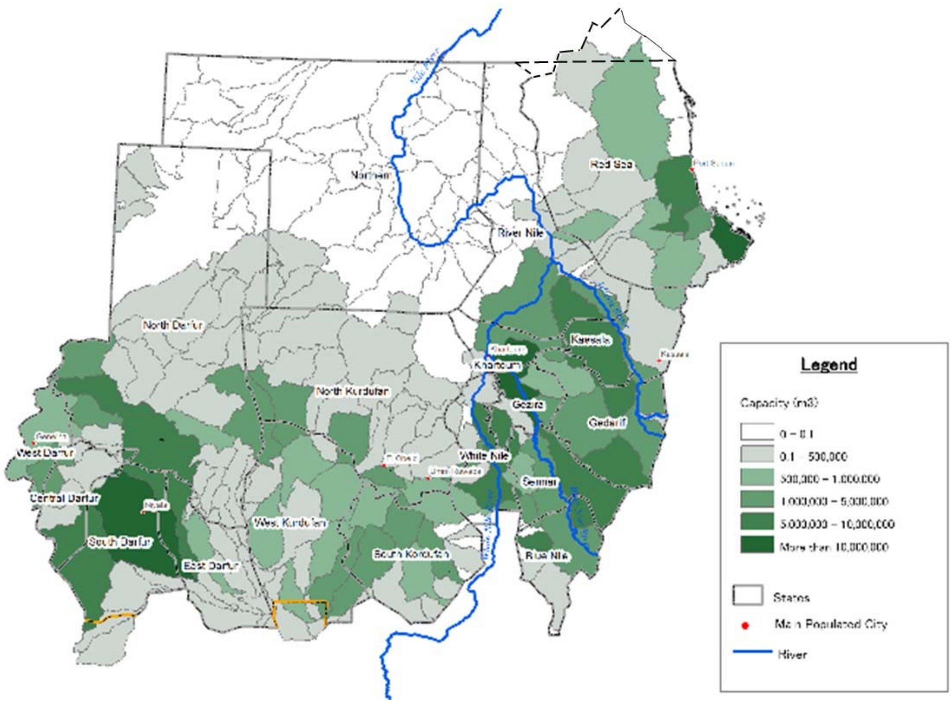


Figure 3.2-15 Required Capacity of SW Facilities (2015)

Source: JICA Project Team

Required Number of Wells (2015)

GW supply capacities, i.e. the number of wells to meet water demand of 2015 are shown in Figure 3.2-16 by sub-basin. The number of wells shown in the map include both i) the recorded wells that were included in the exiting inventories and ii) assumed wells to complement lack of information of the existing inventories. This information represents the base-line to estimate how many new wells are necessary to meet GW demand of 2035.

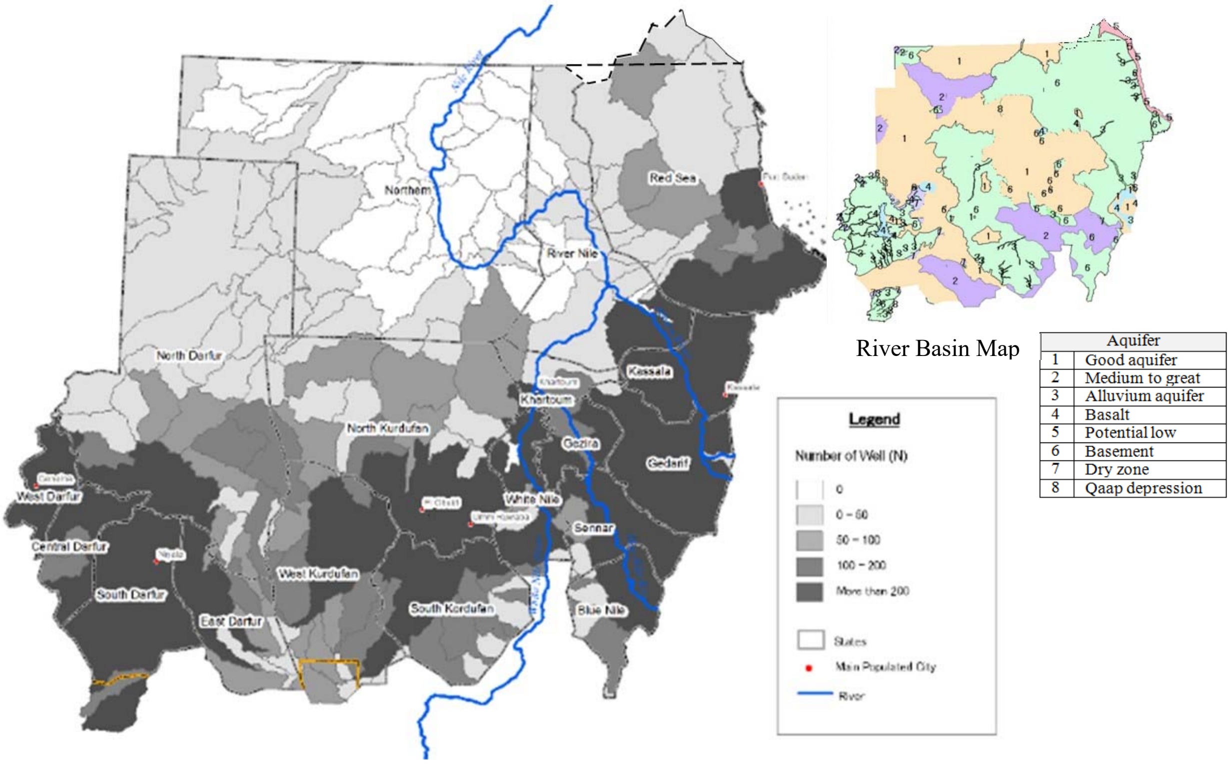


Figure 3.2-16 Required Number of Wells (2015)

Source: JICA Project Team

(2) Water Balance Analysis for 2035

Water balance analysis for 2035 was carried out following the steps explained below.

a) Water demand for the urban/rural/nomad/livestock /irrigation in 2035 was assigned to each sub-basin.

b) Water demand for SW and GW was assigned to each sub-basin with respect to the current consumption ratio.

c) Water balance for 2035 was calculated in order to know whether the existing water supply capacity can satisfy the water demand of 2035 with enough water supply security.

d) If the existing water supply capacity cannot satisfy the demand of 2035, new water supply facilities are planned for each sub-basin to meet water demand of 2035. In planning for facilities in 2035, two factors were analyzed, namely, i) the water supply capacity of the existing facilities (small dams, hafirs and wells) in 2016 and ii) the water demand of the domestic water, irrigation and livestock in 2035. The water resource potential is fluctuating between the wet and dry seasons. Therefore, there will be a period when water supply capacity is less than water demand (see Figure 3.2-17). Important point to plan water supply facility is to minimize this period.

e) The difference between the water supply capacity of 2015 and 2035 is considered as water supply capacity that should be assured by new facilities to be constructed to satisfy future water demand by 2035.

The results of water balance analysis are shown in Figure 3.2-18 to Figure 3.2-22.

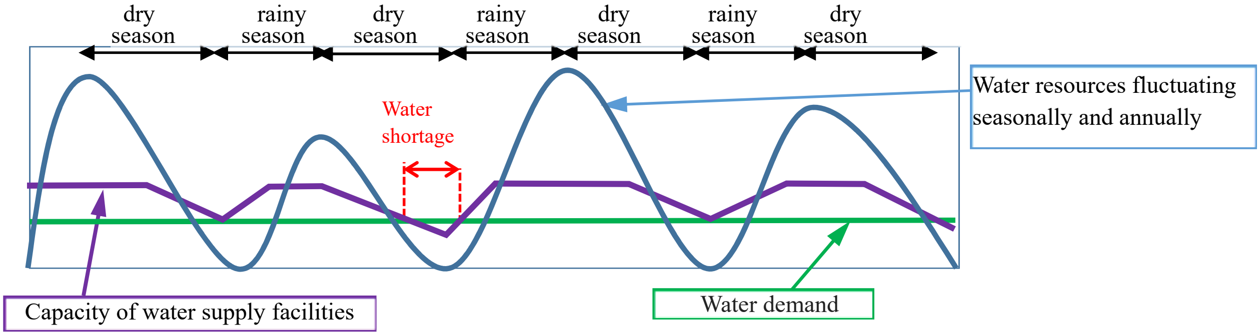


Figure 3.2-17 Key Points for Planning of Facilities

Total Water Demand in 2035

Total water demand in 2035 including urban/rural/nomad/livestock /irrigation water supply is indicated by sub-basin in Figure 3.2-18. Similarly to the 2015 water demand, four (4) regions have high water demand of more than 40 MCM/y, namely i) Port Sudan, ii) Kassala, iii) Blue Nile and iv) South Darfur, which correspond to river basins of No.3, 6, 7 and 10 respectively. It can be said that general trend of water demand distribution of 2035 is almost the same as that of 2015, but difference in quantity of water demand among sub-basins will become lager than that of 2015. It is concluded that water demand will be distributed more unevenly in the future, although water resources is distributed almost the same as the present one.

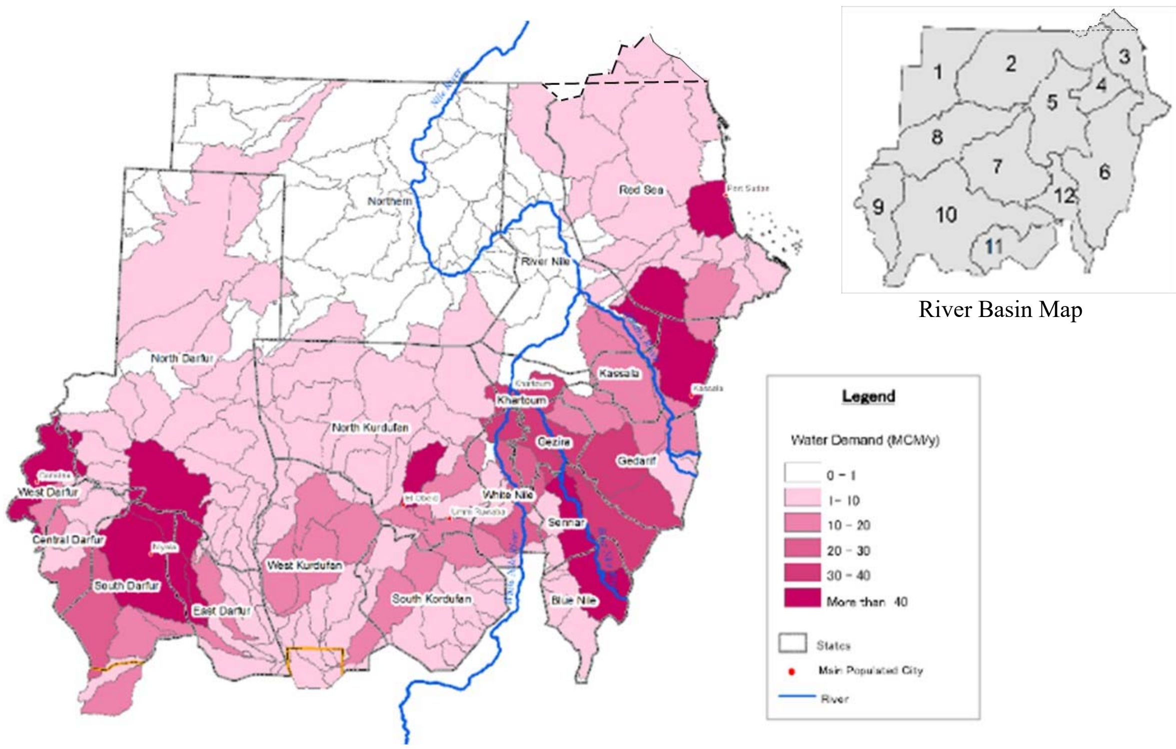


Figure 3.2-18 Total Water Demand in 2035

Source: JICA Project Team

Ratio of Water Demand/Water Resources (2035)

Ratio of water demand/water resources of 2035 is shown by sub-basin in Figure 3.2-19. The entire region shows much higher ratio than that of 2015 (compared with Figure 3.2-18). One fourth (1/4) of the sub-basins indicate a ratio ranging between 10% and 40%. It is important to note here that rainfall occurs only in rainy season during 1/3 of the year, and no rainfall is registered during the other 2/3. This means that a ratio of 30 % indicates that all the rainfall in rainy season must be stored in facilities such as hafirs and small dams to use it in dry season. But it is impossible to store entire wadi discharge in storage facilities. Therefore, it seems that sub-basins with ratios of more than 30% face a serious situation with water supply in 2035. These regions correspond to the highly populated areas of i) Port Sudan, ii) Kassala, iii) North Kordofan, iv) Blue Nile, v) South Darfur and vi) West Darfur. It is noticeable that the ratio is extremely high in the sub-basin where Port Sudan is located due to high water demand /water resources of more than 100%.

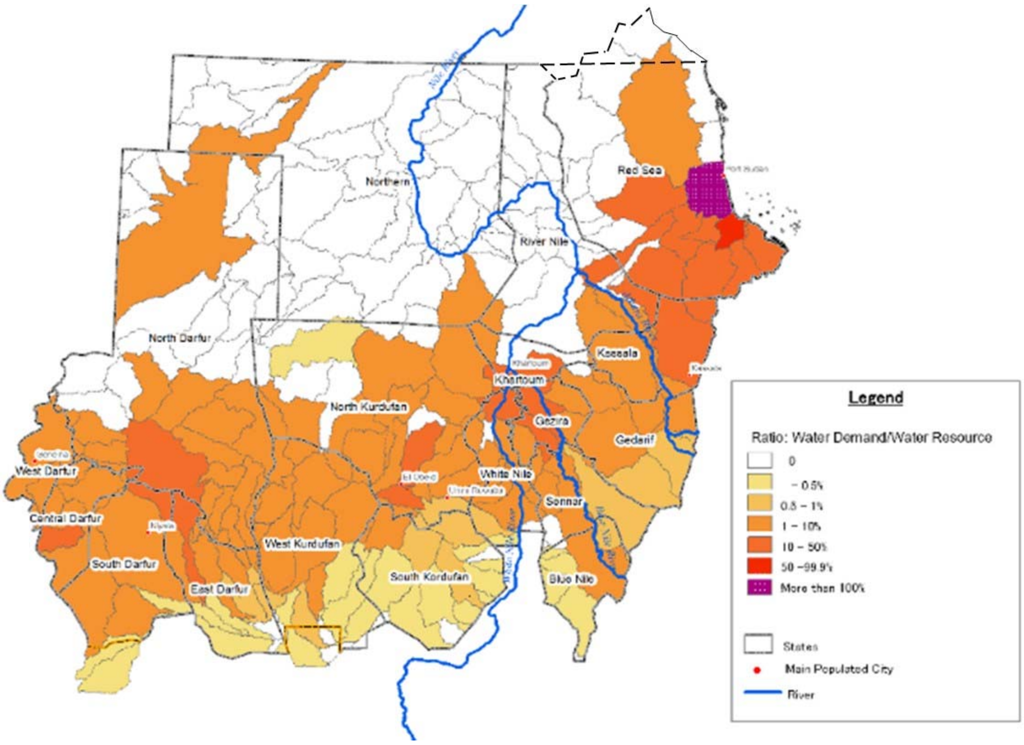


Figure 3.2-19 Ratio of Water Demand/Water Resources (2035)

Source: JICA Project Team

Required Capacity of Facilities for SW (2035)

Water demand in terms of SW and GW with respect to the current (year 2015) consumption ratio were assigned to each sub-basin. However, in cases where that ratio could not be applied, SW or GW was used to make up the shortfall.

Required capacity of SW storage facilities (2035) is shown in Figure 3.2-20. This parameter indicates the total storage capacity (m3) of hafirs and small dams including the existing ones to meet water demand of 2035.

River basin No.9, 10, 11 have large wadi discharge which justifies that many facilities were planned within those basins in the context of this analysis. Similarly, basins No.6 and 12 require establishing many facilities. On the other hand, river basins No.1, 2, 7, 8 have small wadi discharge. Therefore, only few facilities were planned.

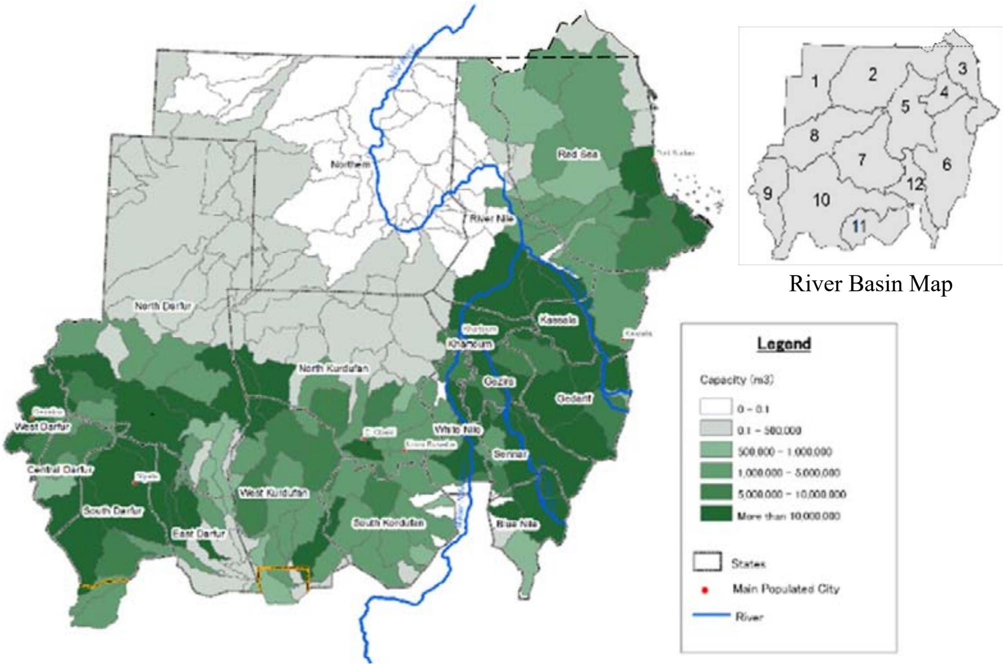


Figure 3.2-20 Required Capacity of SW Facilities (2035)

Source: JICA Project Team

__Required Capacity of New Facilities for SW from 2015 to 2035__

Required capacity of new facilities for SW from 2015 to 2035 (see Figure 3.2-21) reflects the total storage capacity (m3) of hafirs and small dams that should be constructed between 2015 and 2035 to meet water demand of 2035. The size of the circle (○) in Figure 3.2-21 indicates the storage capacity volume. The number of required facilities (m3) between 2015 and 2035 are almost proportional to the required capacity (m3) of facilities of the year 2035. River basins No.3, 6, 9, 10 require the construction of an important number of facilities for storage of SW.

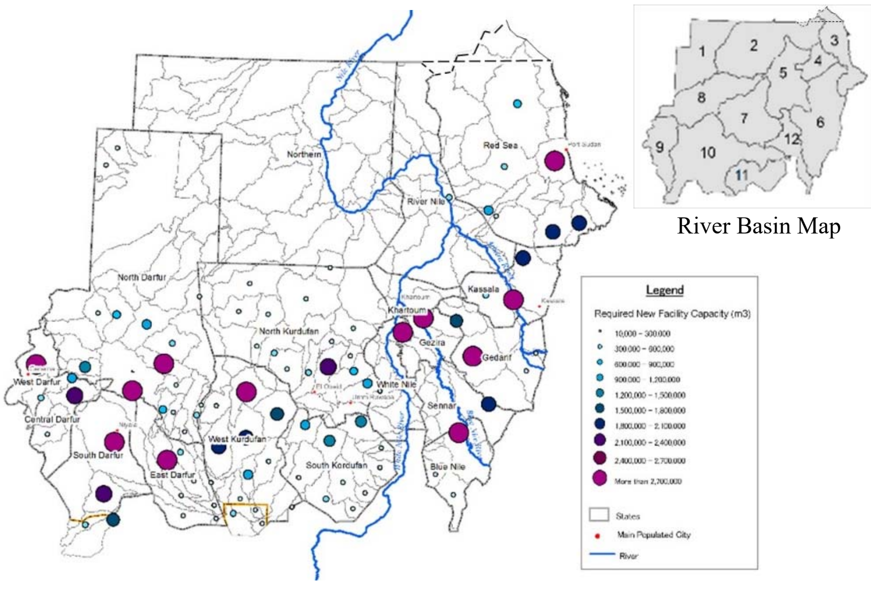


Figure 3.2-21 Required Capacity of New SW Facilities from 2015 to 2035

Source: JICA Project Team

Required Number of Wells (2035)

The required number of wells (2035) is shown in Figure 3.2-22. This figure shows the total number of wells that meets the GW demand of the project target year. Wells are planned mainly in southern part of Sudan covering many aquifers. The number of wells depends on water demand, GW recharge and aquifer capacity. Generally speaking, this number is smaller in sedimentary rock areas with high water yield of individual wells and larger in basement rock areas with low water yield of wells. However, according to Figure 3.2-22, the main factor that dominates the required number of wells seems to be the water demand rather than the type of aquifer.

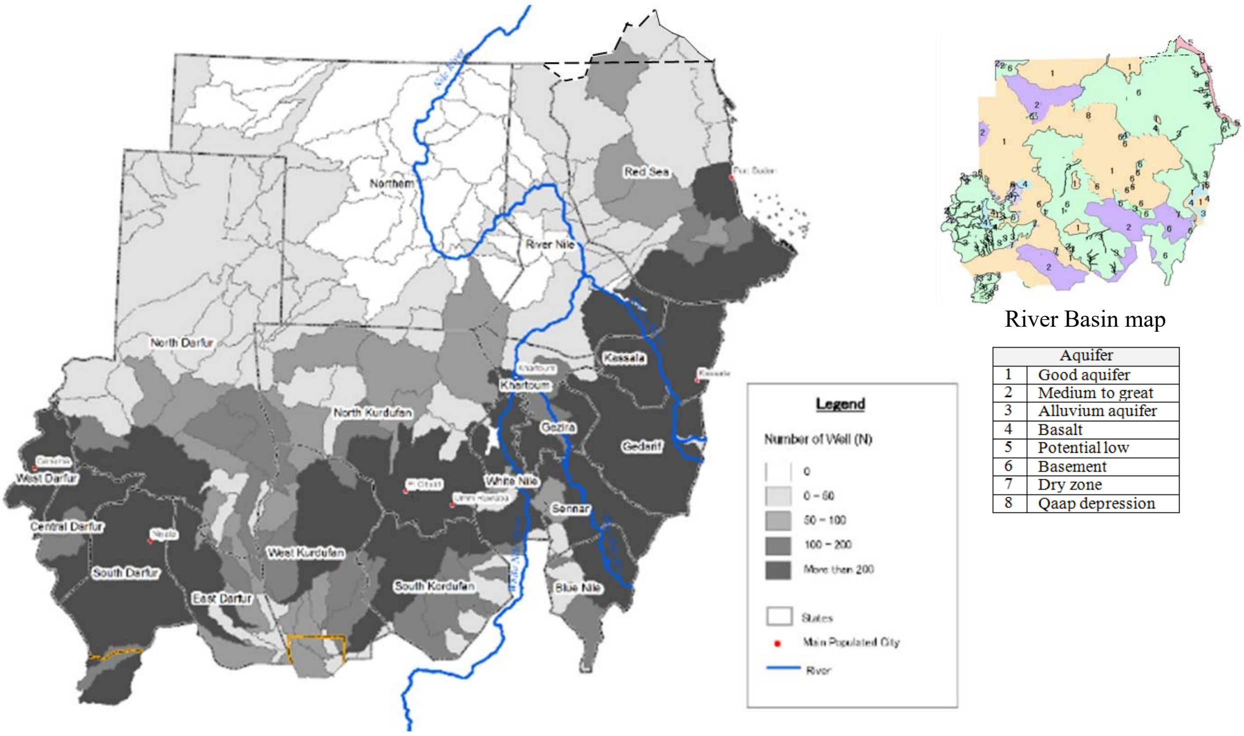
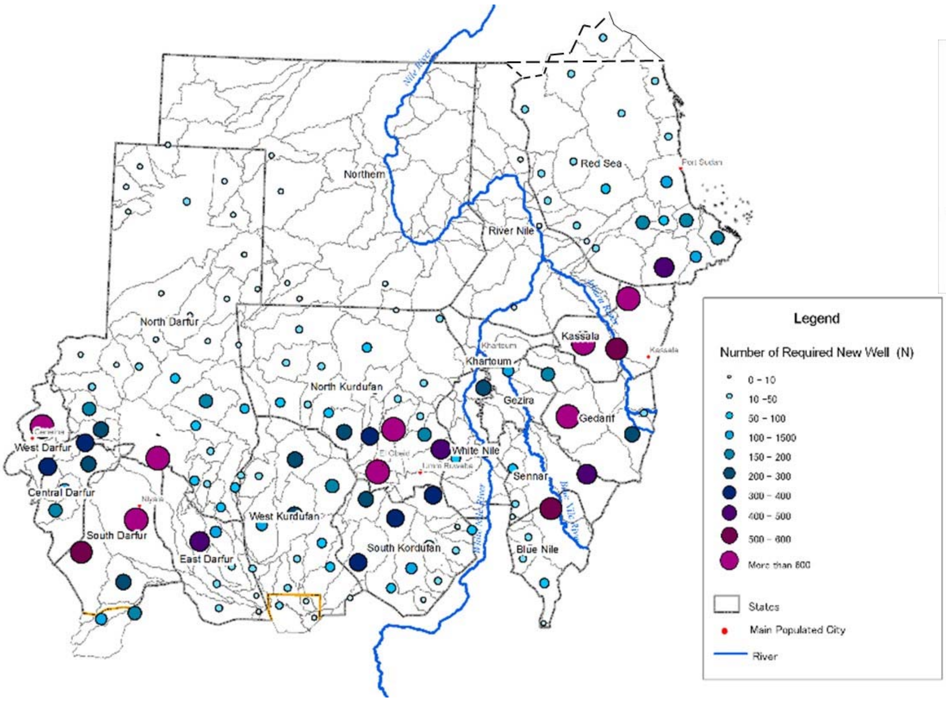


Figure 3.2-22 Required Number of Wells (2035)

Source: JICA Project Team

Required Number of Wells from 2015 to 2035

The required number of wells by 2035 is shown in Figure 3.2-23. This factor indicates the total number of wells that should be drilled between 2015 and 2035 to meet water demand of 2035. In principle, the number of wells required between 2015 and 2035 is proportional to the number of wells that is required by 2035. As a result of GW balance analysis, 25,500 new wells should be drilled by 2035 mainly in basins No.6, 7, 9 and 10.



River Basin Map

Figure 3.2-23 Required Number of Wells from 2015 to 2035

Source: JICA Project Team

(3) Cost of Construction

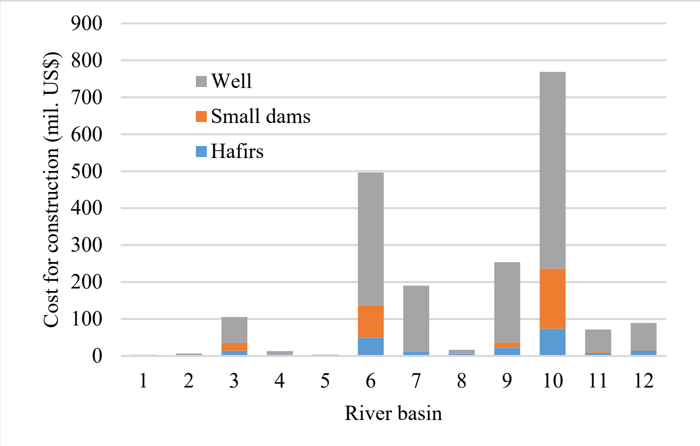
Cost of construction of water facilities to meet water demand in 2035 was estimated by river basin as shown in Table 3.2-20 and Figure 3.2-24. As shown in these illustrations, cost of construction is proportional to the number of facilities to be constructed. Based on Table 3.2-20, there is big difference in the cost of construction of these facilities among river basins. In fact, this cost is particularly high for river basin No.3, 6, 7, 9, and 10.

Table 3.2-20 Cost for Construction of Water Resources Development Facilities to Meet the Water Demand of 2035 (Mil.US$)

Type of facilities / Basin No.	Hafirs	Small dams	Well	total
1	0	0	4	4
2	2	0	6	7
3	20	45	79	144
4	5	0	10	15
5	0	0	4	5
6	69	109	429	608
7	16	1	207	224
8	7	0	14	21
9	28	22	257	307
10	90	202	639	931
11	10	4	75	89
12	30	1	87	118
Total	276	384	1811	2,471

Note) 1. Unit cost for calculation of each facility is based on DIU Report, 2011.
2. Cost includes construction of water yards for water sources

Source: JICA Project Team



River Basin Map

Figure 3.2-24 Cost for Construction of Water Resources Development Facilities to Meet the Water Demand of 2035 (mil.US$)

According to the water balance analysis, construction cost can be reduced by 130 mil.US$ if water demand is controlled by introducing a metering system into urban and rural water supply systems to avoid wasteful water consumption. This reduction cost was estimated assuming that 10% of urban water demand and 5% of rural water demand will be reduced by introducing the metering system, which is one typical IWRM feature.

3.2.4 Findings and Lessons Learnt from Water Balance Analysis

(1) Main Findings

Through the implementation of the water balance analysis, important findings were established, as shown below:

<u>Characteristics of Wadi Flow</u>

The annual and seasonal fluctuations of the wadi flow are so great that it is impossible to make discussions using average values as clearly shown in Figure 3.2-25 and Figure 3.2-26. As a result, the parameter of minimum flow per year/month is used to discuss wadi flow for a sustainable water supply.

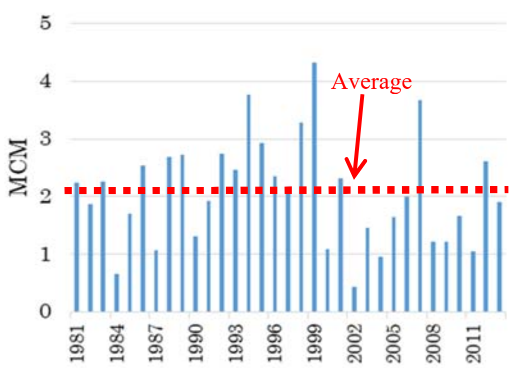


Figure 3.2-25 Annual Rainfall of No.90 Sub-Basin

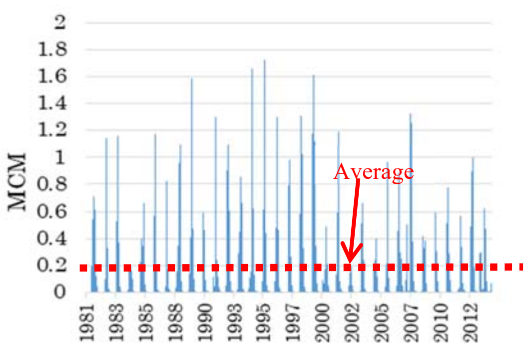


Figure 3.2-26 Monthly Wadi Discharge of No.90 Sub-Basin

The total water demand in Sudan is only 2% of the total water resources. The rainy season and the dry season is clearly divided, and there is no rainfall for eight months during the dry season. As a result, water resources available throughout the year are quite limited. Therefore, the use of water storage facilities are necessary for the sustainable use of water. People must store water in storage facilities and use the water in the dry season. Therefore, the amount of sustainable water available throughout the year is decided by the capacity of storage facilities, such as water harvesting dams, hafirs and wells.

In the case of Japan, river water flows throughout the year and local people are able use this water by constructing water intake facilities along the rivers and canals feeding from the rivers. Before the rapid economic development after World War II, storage facilities were not necessary in Japan. In the case of Sudan, however, storage facilities, such as hafirs, have been necessary for sustainable water use in the non-Nile area dating back to ancient times.

If the amount of water necessary for the dry season could be stored in dams and hafirs, people would not suffer from water shortages in these dry times. Storage facilities with such big capacity are too expensive to construct and too unrealistic. Moreover, stored water will be lost from the surface of the water bodies of dams and hafirs by evaporation in the dry season, leading to inefficient water storage. Therefore, limiting the use of surface water (SW) and alternatively use GW (GW) in the non-Nile area is essential for a sustainable water supply.

Historically, SW development preceded GW development in Sudan. In recent years, however, GW has been developing increasingly thanks to the development of powerful drilling machines. Ideally, SW should be used in the rainy season and GW should be used in the dry season. Such a conjunctive use of SW and GW is the best combination. Depending on rainfall and aquifer characteristics, each area within the non-Nile region has its own suitable SW and GW use combination.

<u>Water Balance and Water Resources Development Plan</u>

The purpose of the water balance analysis is to formulate the water resources development plan. Through this analysis, desirable demarcation between GW and SW development was analysed. During the initial stages of the water resources development plan, the JPT delineated the entire Sudan into 177 sub-basins. Then, the water resources development plan was examined and proposed for each sub-basin, based on the water resources potential and the water demand of each of these sub-basins. The water demand of 2035 was allocated to the SW and GW, depending on the characteristics of the sub-basins. As a result, the construction of water supply facilities to meet the water demand of 2035 was planned. As shown in Figure 3.2-27, the ratio of GW development is larger than that of SW development in the non-Nile area, as the GW can be used even in the dry season and in drought years.

The cost of water resources development is summarized in Table **3.2-21**.

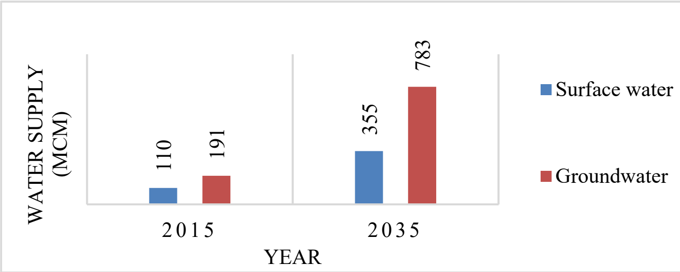


Figure 3.2-27 Allocation of Water Resources to Meet the Water Demand of 2035

Table 3.2-21 Cost of Construction of Water Facilities to Meet the Water Demand of 2035

SW development (Mil. US$)			GW development (Mil. US$)
Hafir	Water harvesting Dam	Total	Well
276	384	660	1811

As shown in Table 3.2-22, the unit cost for SW development is 13% less than that of GW. Moreover, in general, wells need power pumping for their water supply, more so than dams and hafirs. Therefore, the operation costs for SW facilities are less than those of GW. As a result, it is more efficient that SW development should precede GW development in the non-Nile area. GW should compensate the lack of SW through a conjunctive use of both water resources. It must be noted, however, that SW requires more water treatment than GW.

Table 3.2-22 Unit Cost of Construction of Water Facilities to Meet the Water Demand of 2035

Item / Water resources	Amount of development	Total cost	Cost for 1 MCM
	MCM	Mil.US$	Mil.US$/MCM
SW	335（245)	660	2.69
GW	783 (592)	1811	3.06

Rainfall Characteristics

Water resources fluctuate year by year. Therefore, water supply should not be planned based on average rainfall. In the case of planning for the domestic water supply, probable drought annual rainfall with 10 year return periods (PDAR10) was applied. In the case of irrigation water supply, probable drought annual rainfall with five year return periods (PDAR5) was applied in this project.

The relation between annual rainfall (mm) and ratio of drought rainfall/average rainfall (%) is shown in Figure 3.2-28. PDAR5, PDAR10 and PDAR20 are assumed as probable drought rainfall events. This graph was analysed for each sub-basin through a water balance analysis using 32 years of rainfall data covering the entirety of Sudan.

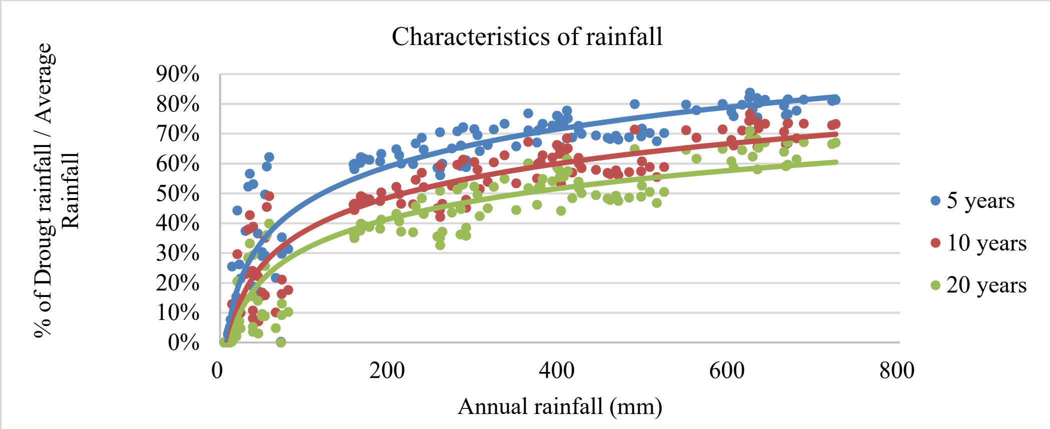


Figure 3.2-28 Relationship Between Average Annual Rainfall and Drought Annual Rainfall

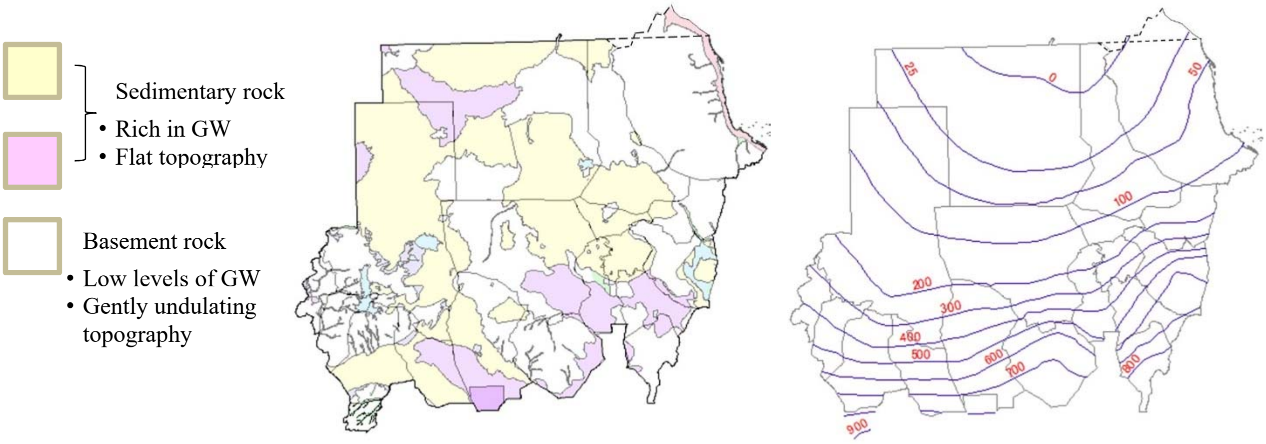
From the above Figure, the following observations are made:

- Areas with less rainfall have greater rainfall variability.
- Areas with less rainfall also have greater variability in drought rainfall. Drought rainfall can be sometimes extremely small (almost zero).
- Thus, the less rainfall an area receives, the more difficult it is to manage water resources efficiently and the greater the risk of water shortages.

It would be ideal if all the rainfall during the rainy season could be stored in dams and hafirs. However, this would require the construction of dams or hafirs with a huge capacity, and the construction cost would be enormous and impractical. Rainfall analysis shows that even if huge dams and hafirs are built and all the rainfall of the rainy season is stored in them, 60% of Sudan's river-basins will not be able to sustainably supply the water demand of 2035. This is because the drought discharge in 60% sub-basins are very small. Therefore, it is not possible to meet 2035 water demand in most of Sudan's sub-basins with SW alone, and conjunctive use of GW and SW must be implemented.

Pattern of Natural Conditions and Water Supply

Through water balance analysis, the relationship between water resources development and natural conditions, such as hydrology, topography and geology was modelled (see Figure 3.2-29). In Sudan, water resources have been developed in harmony with the natural conditions of the region. The number of water resources is mainly decided upon in accordance with the combination of rainfall and topography/geology.



(a)Topography and Geology **(b) Annual Rainfall**

Figure 3.2-29 Characteristics of Natural Conditions

The combination of rainfall and topography/geology are the most basic conditions which dominate the water resources of the region. The two conditions above create four combinations (2×2) to control the types of water resources development (see Figure 3.2-30). Water resources development must be implemented considering the aforementioned relationship.

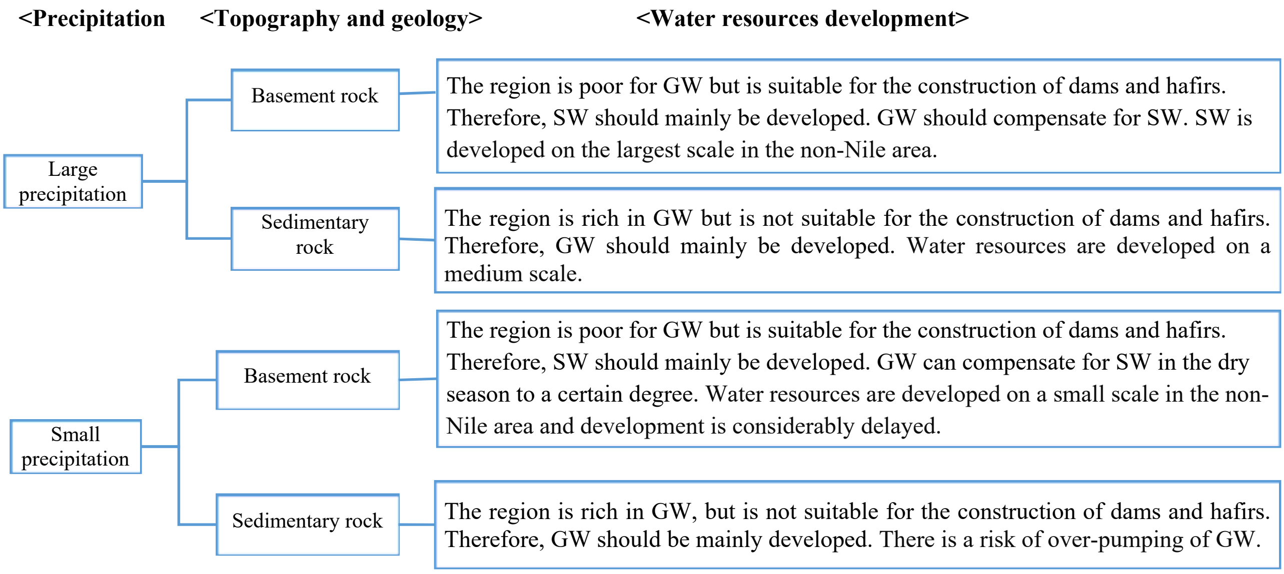


Figure 3.2-30 Typical Pattern of Water Resources Development in Sudan

The water resources potential was analysed for each river sub-basin by water balance analysis, and water resources development was planned for its optimum use. It was confirmed, however, that the economic efficiency of wadi and GW development would be decreased with an increase in water demand. Water resources development is not realistic without economic efficiency, which means there is a limitation in the improvement of the water balance using engineering measures only. Therefore, it is necessary to control water demand and coordinate water allocation within the river basin and inter-river basins.

Policy of Water Intake Within the River Basin

In Sudan, wadi flows resemble floods within a short period of time in the rainy season. As a result, it is difficult to collect water from a wadi flow directly, due to the risks it presents to life. Therefore, wadi water is usually taken from small tributaries, not from the main wadis. The wadi flow will finally inundate the inland delta at the lowermost stream of the wadi, where only flood irrigation is implemented, and there is no other economic activity. Economic activities are usually implemented in the middle and the upper stream of wadi basins. This means that the rainfall over the river basin cannot be taken from the lowermost stream of the wadi. According to IWRM principles, water resources should be allocated in an optimum way and coordinated across the entire river basins. However, water resources allocation must be coordinated in line with the aforementioned special conditions in the case of Sudan.

(2) Lessons Learnt

The lessons learnt from the water balance analysis are described below, based on the aforementioned output and findings.

Background of Water Resources Potential

The project team has analysed the water resources potential of Sudan. However, before conducting such analysis, several authorized documents have already been published regarding this matter. It is to note here that neither the project team nor the C/Ps have been able to confirm the original documents showing the theory and basis of the existing results. Hence, it can be said that only the results of the water resources potential analysis were widely published, without its theoretical background and basis. As a result, the accuracy of these results could not be evaluated, and a comparison between the results of the current study and the existing published results could not be established. The water potential analysis of the project team might be the first attempt to analyse the water resources potential, applying a systematic method covering the entirety of Sudan. Engineers should understand the theory and basis of the analysis from the current report, when they use the present results.

Advantages and Disadvantages of The Current Model Used for the Analysis

Long term rainfall-runoff analysis was conducted to analyse SW potential. SHETRAN software was used for this analysis. It was downloaded from the internet free of charge. This software is user-friendly since it introduces a GUI. Therefore, every C/P was able to join the analysis since this software was easy to operate. In this analysis, 191 sub-basins covering Sudan were delineated. 10 federal C/Ps were included when operating the software. They were given several sub-basins to conduct the analysis themselves. Although the user-friendly version of SHETRAN is easy for the C/Ps to operate, it is not possible to control the boundary conditions of the model flexibly. Moreover, the results of the analysis will provide different results depending upon the engineering judgement of each C/P, which will affect the accuracy of the results. Therefore, the obtained results should be considered as the first step of the analysis. Accuracy of the analysis must be improved from now on by the engineers who will carry on with such analyses in the future.

Water Consumption Rate in Drought Years

Water supply facilities were planned by applying the design standards which ensure that these facilities can meet water demand in the likely event of the worst drought with a 10 year return period. There is a possibility, however, that it is not realistic to apply such a standard to a country like Sudan, where the rainy and dry seasons are clearly distinguished with scarce and highly fluctuant annual rainfall. As a result, the large reservoir capacity of dams and hafirs can be estimated. Sudanese people are accustomed to droughts, using their traditional knowledge and experience to endure scarce water supplies. It might be more realistic and practical to set the unit consumption rate (ℓ/person/day) in a drought year at a lower level than that of an average year (i.e., 90 ℓ/person/day in urban areas, 30 ℓ/person/day in rural areas). The realistic unit consumption rate in a drought year should be discussed further.

Hydrological Characteristics in Sudan

The hydrology of Sudan has special characteristics, influenced by an arid and semi-arid climate, as well as the unique geological setting of Sudan. For example, in general, wadi flow in Sudan will decrease towards the downstream area due to no base flow, which is completely contrary to the river flow of a temperate zone such as Japan. There are still many unknown factors in the mechanism of wadi runoff in Sudan. The accuracy of the existing monitoring data related to wadi discharge is low, which makes the calibration of the model difficult and unreliable. Moreover, the mechanism of evapotranspiration is rather special in arid and semi-arid zones and is completely different from that in the temperate zone. The project team used SHETRAN software, which is commonly used in many countries but might have limited examples in arid and semi-arid regions. Hence, it is strongly proposed that the Sudanese side should strengthen their research to clarify the mechanism of wadi runoff and GW recharge from rainfall, so as to achieve a more reliable water balance analysis.

3.3 Problem Structure of Water Sector in Sudan

3.3.1 Objectives and Methodology

This chapter presents the results of the analyses concerning the problem structure in Sudan’s water sector.

The PCM technique has been applied as an analytical tool, as it is a useful tool for managing the entire process of a project cycle. A problem tree, prepared using problem analysis, shows the core problem, i.e., the most important issue to be addressed, as well as the direct causes behind the core problem and the factors behind the direct causes. The problem tree is therefore developed in a downward direction, based on the cause-effect relations of the factors involved. It can also be developed upwards to show the effects of the core problem. The following is a simple example of a problem tree.

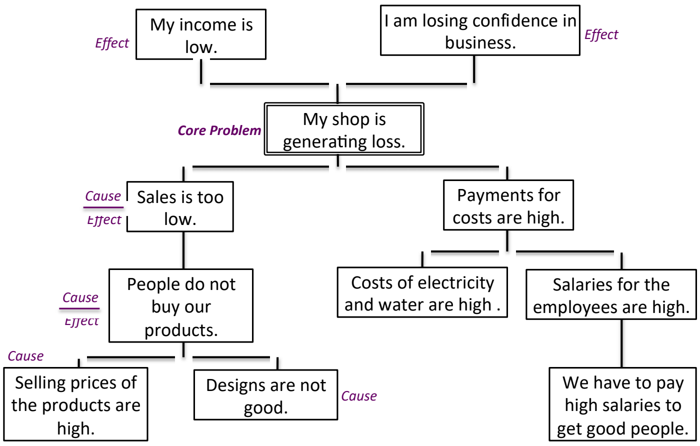


Figure 3.3-1 Simple Example of a Problem Tree

The following part presents the result of the problem analysis conducted in four steps as below.

- 1st step: Problem structure of Sudan's water sector, clarified based on the views of the managers and officers of MWRIE and relevant ministries
- 2nd step: Problem structure of Sudan's water sector clarified based on the views of the JICA Project Team experts
- 3rd step: Summarization of the water problems in Sudan
- 4th step: Problem structure and situations of the water sector at a regional level

3.3.2 Problem Structure of Sudan's Water Sector

(1) Results of PCM Workshops with MWRIE and Other Ministries

The first step was to conduct a series of problem analysis workshops with the relevant general directorates and sections within the MWRIE and relevant ministries. The objective of these workshops was to clarify water-related problems in Sudan from the different perspectives of managers and officers engaged in water issues in different ways. It was intended to capture an overall picture of water-related problems in all over Sudan. Workshops were held in December 2016 and February/March/April 2017 as follows:

- Internal workshop with C/Ps(December 5, 2016)
- Ministry of Livestock, Fisheries and Rangeland (December 7, 2016)
- General Directorate of GW and Wadi, MWRIE (December 8, 2016)
- IT Center, MWRIE (December 12, 2016)
- General Directorate of Nile Water and Dams , MWRIE (December 13, 2016)
- Directorate of Policy, Planning and Projects, MWRIE (December 14, 2016)
- Hydraulic Research Center , MWRIE (December 19, 2016)
- Directorate of Irrigation Operation and Maintenance, MWRIE (December 20, 2016)
- Ministry of Environment (February 13, 2017)
- Dam Implementation Unit, MWRIE (March 15, 2017)

- 13 State Water Corporations and Drinking Water and Sanitation Unit , MWRIE (March16, 2017)
- Ministry of Agriculture and Forestry (April 3, 2017)

At these workshops, 11 problem trees were made with the facilitation of the C/Ps supported by the JPT expert. The problem trees were later improved in close consideration of cause-effect relations among the factors identified, integrating some of the findings outside the workshops. As a result, 11 problem trees were created. The 11 problem trees created from different perspectives were integrated into an overall problem tree, as shown in Figure 3.3-2. This overall problem tree summarizes the important issues facing the water sector in Sudan. The following points are to be noted.

- The issue of *water users suffering from water shortages and poor quality of water* was set as the core problem, given that the ultimate goal of any activity in the water sector is to improve the water-related conditions for end users, in terms of both quantity and quality.
- Six direct causes have been identified: (i) *a decrease in the availability of water under natural conditions*, (ii) *inadequate supply of water for various purposes*, (iii) *inefficient utilization of rainwater,* (iv) *increasing water demand*, (v) *limited access to water*, and (vi) *water quality not meeting the required standards*.

The results of these 11 workshops are summarized below.

<u>Workshop with Counterparts (December 5, 2016)</u>

A problem analysis workshop was held with the C/Ps, which sought to familiarize them with the techniques of carrying out problem analyses and facilitating participants' engagement. The C/Ps were expected to deliver a similar workshop to their own general directorates and departments.

<u>Workshop with the Ministry of Livestock, Fisheries and Rangeland (December 7, 2016)</u>

The issue of *people and animals suffering from water shortages* was selected as the core problem. The technical issues, particularly with regard to the limited water supply capacity, causing this core problem included the poor condition of infrastructure, such as hafirs and wells, and limited access to water points along stock routes. Non-technical factors included an increase in the animal population, sharing of the same sources by animals and humans, and the poor level of security in some areas, for example, due to conflicts between farmers and nomads. As an effect of the core problem, a reduction in the animal population was cited, which leads to problems such as food insecurity, poverty among pastoralists and a decline in the national economy.

<u>Workshop with the General Directorate of GW and Wadi, MWRIE (December 8, 2016)</u>

The issue of the *availability of GW and SW being limited for water users, while water quality is bad* was determined to be the core problem in this workshop. Issues related to both quantity and quality were addressed, due to the closeness of this general directorate to water users in rural areas. In terms of quantity, causes included the poor state of facilities, such as wells, hafirs and dams, sedimentation, the inadequacy of dams and hafirs, and natural conditions, including lower levels of rainfall and evaporation. In terms of quality, pollution was cited as the cause of poor-quality water, due to various polluting sources, such as industry, agriculture, untreated wastewater, animals and human activities.

Workshop with IT Center, MWRIE (December 12, 2016)

The issue concerning the *lack of a unified database and software* was selected as the core problem. Two types of causes were identified: the first is related to the limitations with hardware and software, while the other is related to human resources and organizations. This core problem can be linked to the end problem for water users in terms of quantity and quality, which are not shown in this problem tree, through the effects of the core problem such as the non-sharing of a database among different sections, low work productivity and poor-quality planning.

Workshop with the General Directorate of Nile Water and Dams, MWRIE (December 13, 2016)

The issue concerning *Nile water not being utilized adequately* was selected as the core problem. In terms of physical aspects, inadequate capacities were cited as the direct causes for water source facilities and canals, while non-physical factors of concern included the inadequate enforcement of laws and regulations and the priorities not matching the needs for water by different sectors. It was assumed that the inadequate enforcement of laws and regulations has resulted in an unauthorized extraction of water.

Workshop with the Directorate for Policy, Planning and Projects, MWRIE (December 14, 2016)

The issue of *inadequate and inappropriate planning processes* was determined to be the core problem. Two important points in terms of the inappropriateness of planning were identified: *planning not based on a basin unit* and *an emphasis on development rather than management*. The former refers to the claim that water resources planning in Sudan, if any occurs, does not consider the potential for development on the basis of river/wadi basin and aquifer, meaning that there is a risk of excessive development beyond the threshold limit.

Overall Problem Tree for Sudan

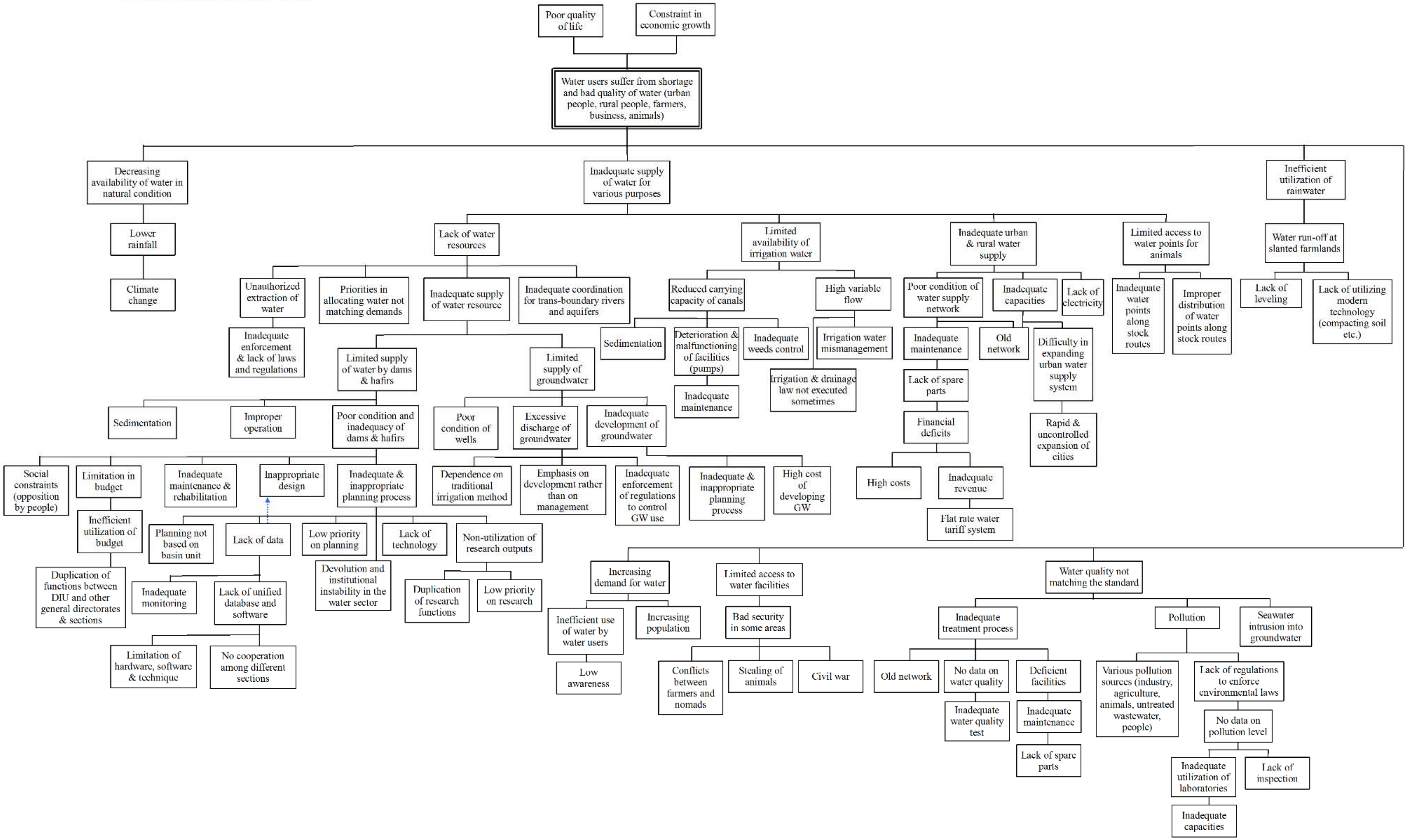


Figure 3.3-2 Overall Problem Tree of Sudan

This leads to the latter point concerning the excessive emphasis on development and management negligence. When 'flipped' into positive expressions, i.e., *planning based on a basin unit* and *managed development*, these aspects represent the basis of IWRM.

Poor quality of planning and *limited utilization of plans* as the effects of the core problem links this core problem to problems closer to water users such as inadequacy and inappropriate distribution of facilities and inappropriate design of facilities.

Workshop with the Hydraulic Research Center, MWRIE (December 19, 2016)

The issue concerning *research outputs not being utilized adequately by other general directorates and organizations* was selected as the core problem. Duplication of the research function with the DIU and the low priority given to research were cited as the direct causes of the core problem. Although not yet happening, ongoing brain drain may result in the degradation of research quality in the future, after the existing capable senior researchers retire in the coming years. This core problem results in decision-making that is not based on technical analysis, which lowers the quality of planning and design.

Workshop with the Irrigation Agency, MWRIE (December 20, 2016)

The issue concerning the *inadequate delivery of water for irrigation and domestic purposes* was determined as the core problem. Technical factors in this context include sedimentation and the poor state of facilities due to inadequate maintenance were cited. There are also management issues, such as the mismanagement of irrigation water which causes high variable flows, the non-execution of irrigation and drainage law resulting in the unauthorized extraction of water (assumption). This core problem may result in weak agricultural production due to water constraints.

Workshop with the Ministry of Environment (February 13, 2017)

The issue of *poor water quality and limited water quantity* was selected as the core problem. The direct causes of this problem are the *lack of law enforcement*, *pollution of the GW as well as the Nile* river water and *water shortages*. Two specific factors can be cited here which are the lack of laboratories and the lack of inspection practices that can explain the reason laws are not enforced to control pollution.

Workshop with the Dam Implementation Unit, MWRIE (March 15, 2017)

The issue of *some people suffering from water and electricity shortages, as well as poor water quality*, was set as the core problem. Two factors explaining the inadequacy of water supply capacity were particularly identified by the DIU: namely, inadequate water projects and limited control over the amount of water from upstream (Ethiopia). The former is likely to be related to the DIU's commitment to the implementation of various projects, while the latter is an important issue in the context of IWRM, which requires international consensus building. There are numerous ways in which the inefficient use of water is manifested, including technical problems relating to water supply facilities and issues concerning water users.

Workshop with 13 State Water Corporations and the Drinking Water and Sanitation Unit, MWRIE (March 16, 2017)

This workshop with participants from 13 SWCs and DWSU was held following the GIS training course taking place prior to March 16. There were no participants at the workshop from the Red Sea, Khartoum, Northern Darfur, Central Darfur and East Darfur states.

Two issues related to water quantity and quality were addressed: *citizens suffering from water shortage and the water quality is poor*. From a quantity perspective, issues related to citizens (wasteful use of water) and the amount of water supply were addressed. Regarding the latter, a great deal of attention was paid to the problem of water supply networks, as a reflection of the task facing SWCs to supply water in cities and towns. Being unable to catch up with the rapid expansion of cities and towns and confronted by an increasing demand for water are the problems that are unique to SWCs. The incapacity of SWCs to conduct water quality tests is also a problem that is specific to SWCs in terms of the quality of water.

(2) Results of the Analysis by JPT

A problem analysis of the water sector of Sudan was conducted by the JPT experts in July 2017 in Japan. Its objective was to clarify the water problem situation of Sudan from the point of view of their experts, integrating the findings from the water demand and supply balance analysis in Sudan (Outcome-1) and taking advantage of their technical expertise developed through international experiences. The problem analysis was conducted classifying the water sector into the following seven subjects.

- SW
- GW
- Urban water supply
- Rural water supply
- Agriculture
- Livestock
- Water quality

(3) Major Water Problems and their Mutual Relations in Sudan

The following part presents a summarized picture of the water problems in Sudan based on all the problem trees created through the workshops in Sudan and Japan as well as referring to the result of the water balance analysis. Useful information collected outside the workshops was also integrated.

1) Core Problem

The availability of water in Sudan is polarized between the Nile area and the non-Nile area. While the amount of water available in the Nile River is 20.5 BCM, according to the international agreement, the amount of water used in the non-Nile area is estimated at 354 MCM in 2015, comprising urban water use at 24%, rural water use at 50% and agriculture water use at 26%. This amount is only 1.7% of 20.5 BCM. While the estimated population in the Nile area is 11.4 million in 2015, that in the Non-Nile area is 22.1 million. Taking into consideration these population sizes, the gap in water availability is as large as 116 times, 1,787m^3 per person per year in the Nile area and 16 m^3 per person per year in the non-Nile area.

The core problems of the problem analyses were established as *water users suffer from the shortage and bad quality of water,* except for the General Directorate of Nile Water and Dams, whose core problem was set as *Nile water is not used adequately*. In most cases, the non-Nile area was assumed in identifying the problems. Bad quality of water affects the amount of water that it reduces the amount of safe water.

The shortage of water indicates an imbalance of water availability and demand in terms of time and spatial distribution. Overall, the water potential in Sudan far exceeds the demand for water as indicated by the average water demand-water potential ratio at 0.26%. In terms of time imbalance, the water shortage happens because all the precipitation takes place in the rainy season and the existing rainwater storage capacity is far too low to meet water demands in the dry season. In some cases, concentration of rainfall happens beyond an annual cycle, as when heavy rainfall occurs only once in five years, especially in dry areas.

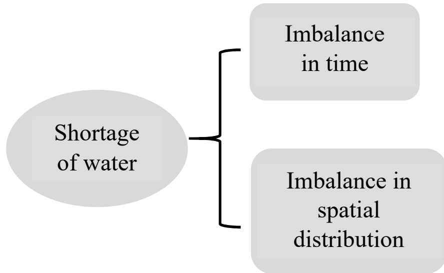


Figure 3.3-3 Factors of Water Shortage

In terms of the spatial imbalance, population is distributed throughout Sudan not necessarily in proportion to the availability of water. The water demand-water potential ratios calculated as part of the water balance analysis indicates a wide range: the highest ratio is at 49% in the coastal area of the Red Sea State, while the ratios are below 5% in most of the basins and Sudan's average ratio is at 0.26%. Population is concentrated in some areas where water is not sufficiently available.

2) Direct Causes Classified into Supply Side, Demand side and Water Quality

In the overall water problem structure in Sudan shown in Figure 3.3-4, the direct causes for the core problem can be classified into the supply side, demand side and water quality. The supply side factors include the amount of rainfall, which is the fundamental factor to determine the availability of water, water supply capacity and the way rainwater is used directly by farmers.

On the demand side, the water shortage is created by wasteful use of water for domestic use and irrigation use as well as an increase in the total demand for water due to the rapid increase of population.

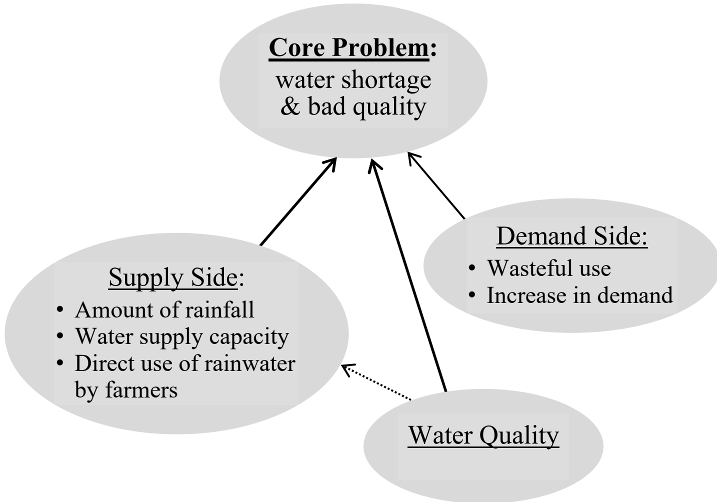


Figure 3.3-4 Structure of Water Problems in Sudan

Besides affecting the core problem through reducing the amount of available safe water, the degraded quality of water is causing other issues such as the degradation of citizens' health.

3) Supply Side Issues

The major problem in the supply side is inadequacy in the water supply capacity. It is caused by the limited level of developing facilities and the deficiency of the existing facilities.

Development of water sources such as dams and hafirs for SW and wells for GW is limited firstly due to natural factors such as the limitation of areas suitable for wadi water collection and a lack of good aquifers. Adding to the natural constraints, there are financial and technical constraints.

Inadequate development of facilities closer to water users, such as the urban water supply system and irrigation canals, is caused by financial and technical limitations. Water points for animals are inadequate and improperly distributed due to inadequate planning, lack of budget and inadequate cooperation between relevant ministries (e.g., MWRIE and the Ministry of Animal Resources).

The other reason for the limited water supply capacity is the deficiency of the existing facilities. The capacity of water resources storage facilities is declining due to sedimentation and leakage at hafirs and dams, GW drawdown and the reduction in the amount of GW extraction. One factor causing these problems is the inappropriate planning, designing and implementation due to technical limitations and lack of data. The limited availability of data is caused by the inadequate monitoring and sharing of existing data. The lack of basin-wise planning often results in the creation of non-functional or malfunctioning facilities.

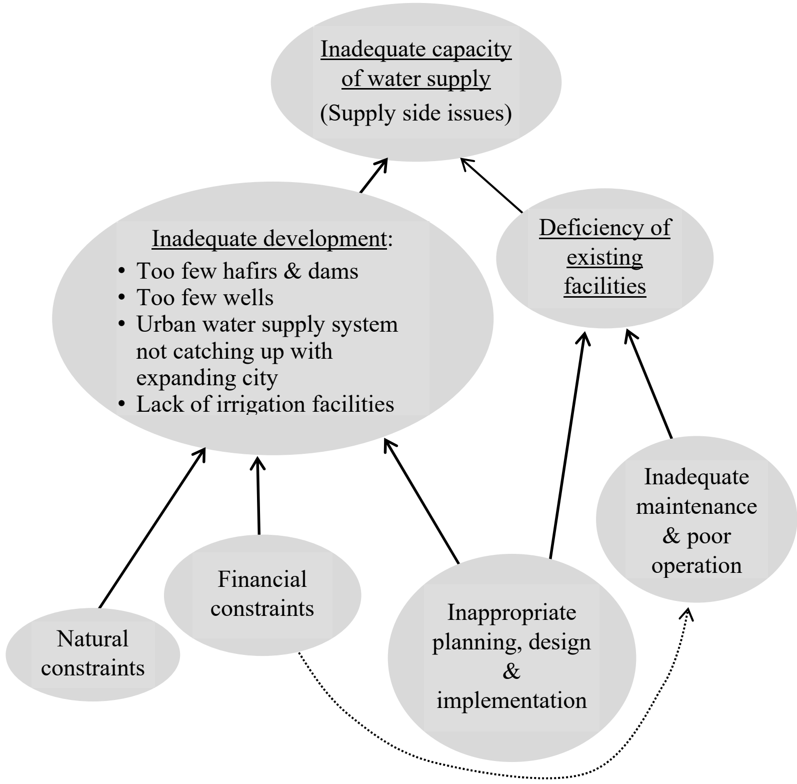


Figure 3.3-5 Water Supply Issues

Other factors causing the deficiency of the existing facilities are inadequate maintenance and poor operation. In the case of hafirs, maintenance is limited due to inadequate revenue as a result of poor water fee collection. For GW, a lack of scientific knowledge on the safe yield is the fundamental issue. An uncontrolled increase in the extraction of GW without scientific basis is causing a decline in GW levels and the amount of GW extraction. Poor maintenance of wells is exacerbating the problem.

For irrigation facilities, inadequate maintenance results in sedimentation at canals and weed proliferation, which combined cause a reduction in the water carrying capacity of canals. In the case of urban and rural water supplies, a lack of spare parts results in poor maintenance and the deterioration of the system.

Financial constraint is affecting not only the level of new development, but also the level of maintenance and operation.

4) Demand Side Issues

It is not only the supply side issues, but also the demand side issues, that are causing the shortage of water.

Water users in urban areas tend to use water with no sense of saving, because water is charged under a flat rate system. Users pay the same monthly fees regardless of the amount of water they use. There is no incentive to save water. The lack of awareness-raising initiatives to promote a sense of water conservation enhances the inefficient use of water.

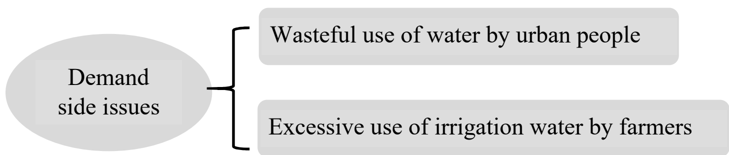


Figure 3.3-6 Water Demand Issues

Irrigation water is used in a wasteful manner in many cases, as well. This is because most farmers do not have correct knowledge on the crop water requirements and water crops too frequently or excessively. Limited dissemination of water-saving irrigation technology is also contributing to this wasteful use of water.

5) Water Quality Issues

The water quality issues include hafir water quality, GW quality and industrial wastewater. The quality of hafir water is often bad due to a number of reasons, such as earth and sand flowing into hafirs, animal waste due to the mixed use of hafir water by humans and animals, contamination by garbage combined with the absence of treatment facilities.

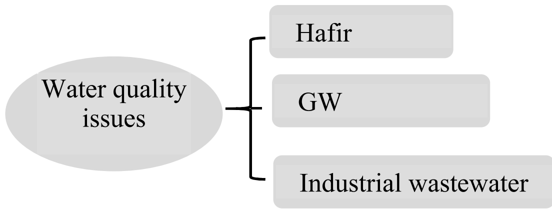


Figure 3.3-7 Factors Affecting Water Quality

Deterioration of the GW quality is caused by the infiltration of domestic and agriculture wastewater into GW, the dissolving of salt content in the soil and strata and seawater intrusion in some coastal areas. Additionally, some sugar factories are discharging wastewater into rivers without treatment, causing pollution in the states of Gezira, Sennar, White Nile and Kassala.

6) Social, Institutional and Organizational Issues

There are a number of social, institutional and organizational factors causing water problems in Sudan, directly and indirectly as follows.

- Conflicts between farmers and nomads/pastoralists (social)
- Conflicts between upstream and downstream (social)
- Lack of participation of water users in water resources management (social)
- Inadequate coordination among relevant government ministries (institutional)
- Investment approval system without a technical foundation (institutional)
- Flat water tariff system for urban water supply (institutional)
- Ineffective well registration system (institutional)
- Ineffective industrial wastewater control system (institutional)
- Limited application of environmental impact assessment (institutional)
- Inadequate coordination and cooperation among different general directorates and sections in MWRIE (organizational)

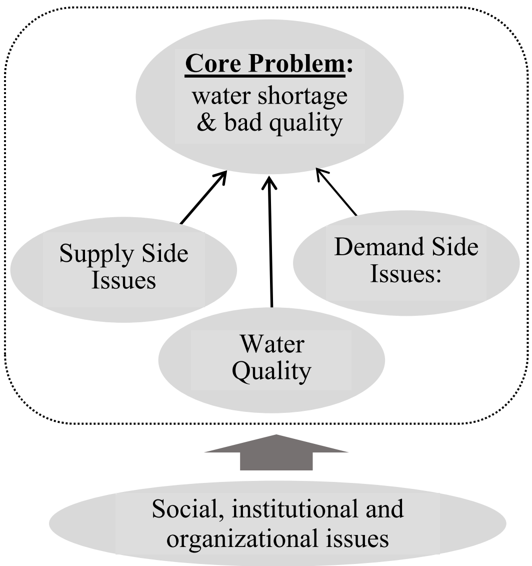


Figure 3.3-8 Non-technical Issues

Social Issues

Farmers-nomads/pastoralists conflict: Conflicts between farmers and nomads/pastoralists result in the core problem of water shortage in the form of limited access to water in some southern states where animal grazing is an important livelihood. Conflicts happen when farmers expand their farm areas, resulting in the blocking of migration routes or the change of migration routes to avoid insecure areas. Decline of traditional conflict resolution mechanisms makes it difficult to resolve conflicts. This conflict issue is, in many cases, a social issue of a broader nature, stemming from ethnic confrontations and the resultant social insecurity.

Upstream-downstream conflict: Conflicts between upstream and downstream happen when water resources are developed upstream without considering the impact on the downstream. Lack of basin-wide planning is the cause.

Lack of participation of water users in water resources management: Inadequate functioning of water users' associations such as VWSC (village water supply committee) and farmers' groups results in inadequate maintenance of facilities, causing deterioration of water supply facilities.

Institutional issues

Inadequate coordination between relevant government ministries and state governments: An integrated approach to water resources management is lacking in Sudan. The National Council for Water Resources tasked to coordinate all the water related activities by different ministries and organizations in Sudan has not been convened, except for a few times after the Water Resources Act was put into effect in 1995. As a result, there has been only limited coordination between the MWRIE, the Ministry of Agriculture and Forestry and the Ministry of Animal Resources and Fisheries and their equivalents at the state level, causing inefficiency in water resources development and management. Mismatch happens between water supply and demand sides, for example between irrigation water and water for power generation, due to a lack of coordination. Lack of coordination between the different states also exists, causing conflicts between upstream-downstream states.

Investment approval system: Recently, there has been an increase in the investments in the agriculture sector by foreign investors utilizing GW as the water source. Investments have been approved with no sufficient coordination between the MWRIE and the Ministry of Investment and their equivalents at the state level with regard to scientific judgment on the safe yield of groundwater, posing a risk of GW depletion in the near future.

Flat water tariff system: The water metering system in the urban areas is applied only to factories for industrial use and in Hawata Project in Gedaref State for domestic use in Sudan. Most of the domestic water used in the urban areas is charged using a flat rate system. As pointed out in demand side issues, the flat rate system discourages people to save water, exacerbating the water shortage problem.

Ineffective well registration system: Registration of new wells is approved by branch offices of wadi and GW at each state almost without any limit, because of the lack of technical capability to judge the safe yield of GW. Many non-registered wells exist which were drilled illegally, causing difficulty in capturing the entire situation of GW use.

Lack of industrial wastewater control system: There is no regulation to control industrial wastewater quality in Sudan. There are a number of cases of untreated wastewater from sugar factories polluting river water, including two cases along the White Nile River (Kanaia and Asalaya in White Nile State), two cases along the Blue Nile (west of Sennar State and El Geneid in Gezira State) and one case in Kassala State.

Limited implementation of environmental impact assessment: Although the Environmental Protection Act of 2001 obligates project implementers to conduct an environmental impact assessment (EIA), its application has been limited due to the lack of understanding of the obligations and the procedure by project implementers and the relevant government authorities at national, state and local levels. Strategic environmental assessment (SEA) has not been institutionalized in Sudan yet. The lack of proper environmental assessment poses a risk of water environment degradation.

Organizational issues

Inadequate coordination and cooperation among the different general directorates and sections in MWRIE: Cooperation and coordination among different general directorates and sections in MWRIE is inadequate in terms of a lack of sharing common databases and inadequate use of research outputs. The lack of a common database leads to an inefficient practice of repeatedly collecting similar data whenever new projects start instead of relying on the data previously collected. Combined with poor monitoring, this problem aggravates the problem of the limited availability of data. Inadequate use of research outputs results in decisions made based on readily available knowledge and solutions, instead of those based on technical judgments. The issue above is a contributing factor to the inadequacy of planning processes in MWRIE.

3.3.3 Sudan's Water Problems by Region

Water problems in Sudan are reviewed at a regional level except in Khartoum. Sudan is divided into the following five regions for this purpose.

- Eastern Region: Red Sea, Kassala, Al Gedaref
- Central: White Nile, Sennar, Gezira, Blue Nile
- Northern Region: River Nile, Northern
- Kordofan: North Kordofan, South Kordofan, West Kordofan
- Darfur: North Darfur, South Darfur, West Darfur, Central Darfur, East Darfur

The presentation hereunder was prepared based on the information collected in the context of the problem analysis workshop arranged for the General Directorate of Wadi and GW state branch office officers, field visits to some states by the JICA project team, statistical data, documents and the interviews with counterparts, directors, managers and officers of MIWR. It should be noted that the level of detail of the information presented hereunder varies from region to region depending on the level of data made available.

(1) Eastern Region

General Condition

The Eastern Region comprises the three states of Red Sea, Kassala and Al Gedaref. The three states have different characteristics in terms natural and socio-economic conditions.

The Red Sea State area comprises two catchment areas divided by the mountainous area running north to south along the coastal line. The highest peak is Mt. Hamoyet with an altitude of 2,780 meters. Its precipitation ranges between 10 and 300 mm per year. Kassala State stretches over a flat area with an altitude of 350 to 500 meters, having a gentle slope from southeast to northwest. Its precipitation ranges between 100 to 400 mm per year. The Atbara River, originating in Eritrea and Ethiopia, runs from a southeast to northwest direction and joins the Nile River at Ed Damer in River Nile State. There is a seasonal river called the Gash River running through Kassala City. The precipitation in Al Gedaref State ranges from 400 to 800 mm per year. Rainfall is higher in the areas bordering Ethiopia with an altitude of 600 to 700 meters.

Agriculture is the main economic activity in Kassala and Al Gedaref. Horticultural crops such as bananas, grapefruits and mangos as well as vegetables such as tomatoes, onions and cabbage are widely grown in Kassala. Farmers in that area are using GW to grow such crops. The other crops with high production in Kassala are groundnut (7.9% of the national total) and cotton (16.8%). Production of cotton in Al Gedaref is 13.6%. Agriculture is almost non-existent in Red Sea State, except in Tokar Locality.

Livestock activities are common in Kassala and Al Gedaref. The total number of four kinds of animals—cattle, sheep, goat and camel—in the two states reached 10 million in 2015, accounting for 11% of the total national headcount. There are many camels in Kassala, especially. Nomads migrate from southeast to northwest in the rainy season, seeking grazing in the north and avoiding insects that cause animal diseases in the south, and from northwest to southeast in the dry season. They travel between Al Gedaref and the White Nile River with cattle, sheep and goats.

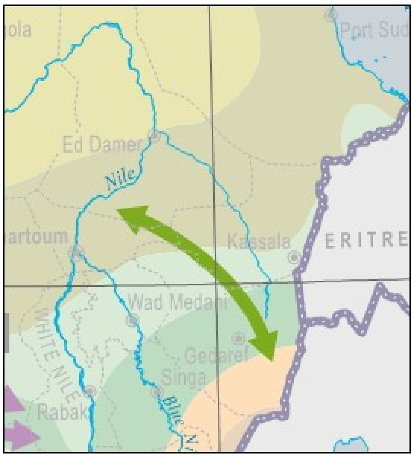


Figure 3.3-9 Migration Route of Nomads in the Eastern Region

Kassala is ethnically diverse. There are the Bejas who are farmers engaged mainly in cultivation and animal raising, the Rashaidas, who are nomads and the Hausas. In 2005, armed uprisings broke out ignited by disparity, famine and poverty. Conflicts on the water took place then. There are Eritrean refugees living in a refugee camp close to Ghirba established by the United Nations High Commissioner for Refugees.

<u>Water problems</u>

The first problem tree made by C/Ps, other officers of GWWD and JPT indicates the problems similar to other regions and those characteristic of the Eastern Region, especially the Red Sea State. The seawater intrusion into GW and inadequate desalination are the problems specific to the coastal strip area of the Red Sea State. The other problems existing in the inland part of the Red Sea, Kassala State and Al Gedaref State are similar to those shown in the overall problem tree.

The water demand-water potential ratios estimated as part of the water balance analysis show that the ratios are high, 24% and 11%, in the two basins stretching north to south along the coastal line in the Red Sea, while the national average is 0.26%. This indicates that both SW and GW are used intensively in this area. The main water source for Port Sudan is the Arbaat Dam, while in other areas people take SW from hafirs and use GW. A problem tree was created for the Red Sea State at the problem analysis workshop held on October 2, 2017 in Port Sudan. The core problems were set as *bad water quality* and *water shortage for people, animals and agriculture*. Bad quality of water is caused by high salinity and water contamination. Unique problems in the Red Sea State are salinity problems caused by seawater intrusion into GW, the contamination of GW by gold mining and extraction of $CaCO_3$ as the raw material for cement. The shortage of water is explained by such factors as the lack of water storage capacity, transportation and distribution problems, technical difficulties and high cost of GW extraction, water scarcity as the natural condition and increasing water demand. The site survey at the Arbaat Dam supported these workshop findings. For example, a deficiency of the water conveyance system was observed. There is a big loss of water, 70% according to some estimate, in such forms as an overflow of water at the canal connecting the dam and the water pipeline and leakage along the water conveyance pipeline to Port Sudan. The water stored at the dam is largely lost before reaching water users.

Desalination is a solution unique to the Red Sea State. The desalinated water is used especially during the summer season to supplement the SW and GW when the water supply-demand balance is tight. The information by SWC Red Sea State indicates that about 10% of the water demand in Port Sudan is satisfied by desalinated seawater. There are five publicly-run desalination plants and 24 small private desalination plants in Port Sudan, while there are four desalination plants outside Port Sudan in Suakin, Agig, Jabiet and Sinkat. The one in Sinkat desalinates GW. There are a number of problems related to desalination such as follows.

- Discharge of highly salinized wastewater and chemicals used in the desalination process from the desalination plants into the sea
- High prices of desalinated water at 4 to 10 SDG per m^3
- High operation cost, especially electricity cost and replacement of osmosis every 4 years
- Non-connection of some desalination plants to the water distribution system
- Limited capabilities of the workers at the desalination plants

The water demand-water potential ratios for Kassala State are estimated to range from 0.5% to 2.9% based on the ratios for the two basins roughly corresponding to the administrative area. The most serious water problem in Kassala is the excessive extraction of GW. It is said that there are about 3,000 wells in Kassala City and its suburbs. The precise number, however, is not known due to the existence of many wells drilled without authorization. GW is used for the cultivation of horticultural crops as well as for domestic use. Due to the uncontrolled drilling of wells and excessive extraction, GW levels are declining and there are some wells that have already dried up. A new ordinance to strengthen the well drilling registration process was put into effect recently. The challenge is to make this ordinance functional by adding the technical capability to make a judgment on the safe yield to be included in the registration process.

The water demand-water potential ratios for Al Gedaref State range from close to 0% to 0.9%. SW is the main source of water in Al Gedaref because of the coverage of the basement complex and the difficulty in extracting GW. Water shortage is severe in the state throughout the year, including the rainy season. Water demand rises sharply in sesame harvesting season because of the many agricultural workers. Water shortage problems in Gedaref City, however, will soon be resolved once the construction of a new dam, treatment plant and pipelines are completed. The problem will remain in the rural areas. Rainwater harvesting is needed, especially in area such as Al Burana, a grazing area, and for Ethiopian refugees. Al Gedaref State is in a relatively advantageous position with higher rainfall than other states. There are areas along the border with Ethiopia where annual rainfall reaches 1,000 mm. There is, therefore, high potential for rainwater harvesting.

SWC suffers from certain problems such as the limited availability of spare parts, poor water quality and troubles with pumps for distribution networks and boreholes. There is a law regulating the usage of water, but this law is not functioning. For example, a Syrian company drilled wells recently without reporting its activities to the government.

The type of solution required in Al Gedaref State is simple: rainwater harvesting in rural areas. A multi-sectoral approach such as IWRM may not be required in this area.

(2) Central Region

General Condition

The Central Region comprises the four states of White Nile, Sennar, Gezira and Blue Nile. The total population of the Central Region was estimated to be 6.9 million in 2016 accounting for 17.5% of the national population. The total area is 142,000 km^2 or 7.6 % of the national territory. The population density, 49 persons per km^2, is as high as 2.4 times the national average.

The annual precipitation is relatively high ranging between 200 and 900 mm per year.

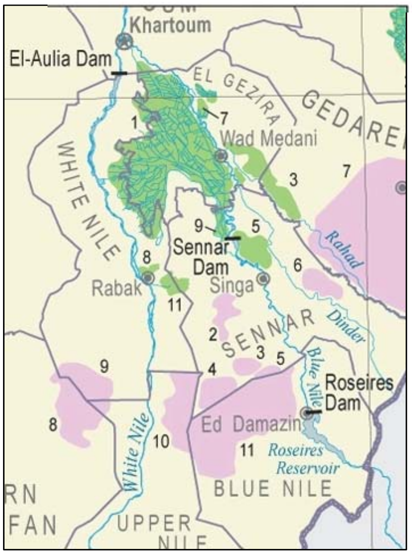
In the Central Region, a number of large-scale irrigation schemes have been implemented. The Gezira irrigation scheme is one of the largest in the world. In an area of 871,000 hectares, crops such as cotton, wheat, groundnut, sorghum, horticulture crops and forage are grown with irrigation water. Mechanized agriculture schemes present another tool for promoting agriculture. In the northern part of Blue Nile State and in the southern part of Sennar State, a large-scale mechanized agriculture scheme is planned.

Figure 3.3-10 Central Region

Table 3.24 Major Irrigation Schemes in the Central Region

No.	Name of the Scheme	State	Irrigation Area (ha)	Crops
1	Gezira and Managil	Sennar, El Gezira	870,750	cotton, wheat, groundnut, sorghum, horticulture, forage
3	Rahad	Gel Gezira, Al Gedaref	121,500	cotton, groundnut, sorghum, wheat
5	Suki	Sennar	35,235	cotton, groundnut, sorghum, wheat, sunflower
7	Guneid Sugar	El Gezira	15,795	sugarcane
8	Assalaya Sugar	White Nile	14,175	sugarcane
9	Sennar Sugar	Sennar	12,960	sugarcane
11	Kenana sugar	White Nile	45,000	sugarcane
-	Total	-	1,115,415	-

Note: The numbers in this table and those in Figure 3.3-11 for green areas correspond to each other.



Note to Figure 3.3-11: Green areas are the existing irrigation schemes. The pink areas are the planned mechanized agriculture

Figure 3.3-11 Major Irrigation Schemes in the Central Region

Cotton produced in the central region amounted to 169,000 in 2015, accounting for 66% of the national production. Al Gezira State is the major cotton producer, whose production accounted for 37% of the national production. Production of sorghum, groundnut and sesame are also high with the proportions at 60%, 43% and 36%, respectively. The numbers of animals are relatively high for cattle, sheep and goats, but low for camels.

<u>Water Problems</u>

The second problem tree presents the problem structure in the central region. Unfortunately, the number of opinions expressed was rather low. Still, participants identified problems such as the improper design of wells, salinity for GW, pollution and bad design of the urban water supply system for SW.

The problem structure for the irrigation sector was prepared by the managers and officers of the Irrigation Center. This problem structure largely reflects the problems in the Gezira Irrigation Scheme and other irrigation schemes in the central region. Since the canal water is used by local residents for domestic purposes as well, it partly illustrates the problems in the rural water supply. It identified problems such as a reduction of water as a result of climate change, the unstable flow of irrigation water due to the mismanagement of irrigation water, a reduction in the capacity of canals caused by sedimentation, deficient facilities and difficulty in weed control and non-adherence to irrigation and drainage laws. The factors causing these problems include a lack of capacity for development, inadequate monitoring, lack of equipment and lack of maintenance practices.

Other problems have been identified as follows.

(Urban water supply)

- High turbidity of water supplied by urban water supply systems due to inadequate application of chemicals such as flocculants and chlorine
- Poor maintenance causing leakage

(Rural water supply)

- A large disparity in water consumption rates in rural areas, with some cases of very low consumption rates of 3, 9 and 10 LCD.
- Water taps shared by humans and animals
- Lack of spare parts due to insufficient budgets, mainly because the revenues from water supply are versed into the state general budget
- Inability to cope with problems during rainy seasons of villages due to their limited access to the rural water supply system because its operation and maintenance is limited to state SWC (Blue Nile State)

(Water resources)

- Uncertainty of the impacts of the Grand Ethiopian Renaissance Dam in Ethiopia (Blue Nile State)

(Drainage)

- Poor urban drainage situation posing a risk of malaria proliferation and other diseases (Ed Damazin, Blue Nile)

(3) North Region

<u>General Condition</u>

The North Region comprises the River Nile State and the Northern State. The population in these two states solely depends on the water from the Nile River and GW recharged by the Nile. Most people live along the Nile River and there are almost no villages in the desert area away from the Nile River. The population of the North Region was estimated at 2.5 million in 2016.

The entire Northern State area is classified as desert, while the River Nile State has a north-south long desert area in the north and a semi-desert area in the south, where there is the Nile-Atbara confluence. The annual precipitation is low (10-50mm per year in the Northern State) and the rainy seasons are shorter (July to October in the River Nile State and July to September in the Northern State).

Agriculture is developed along the Nile River utilizing the abundant Nile water.

Figure 3.3-12 Northern Region

<u>Water Problems</u>

The biggest difference between the Nile-area and the Non-Nile area is the availability of water resources. While the Non-Nile area is struggling to secure water resources by water harvesting, the problems in the Nile-area lie more with the usage of the Nile water either directly or as a GW recharge.

The third problem tree shows the problems in the North Region. The problems identified include a decrease of water resources due to climate change, a decline in the GW level and a rising GW level in some areas caused by over-irrigation utilizing the Nile water and resultant damages to old houses. In Al Bourgaig Locality in the Northern State, 200 to 300 traditional mud made houses have been totally destroyed by the rising level of the GW since 2013 when the capacity of the irrigation canal was enhanced and the amount of irrigation water increased.

Excessive extraction is causing a decline in GW level in Atbara and Ed Damer in the River Nile State as well as in Dongola in the Northern State. In Atbara and Ed Damer, there are 77 sprinkler irrigation areas developed by investors. They do not conduct monitoring nor an evaluation of the GW potential. There is a case in which the GW level declined by 20 meters in a year. Recent active investments in the agriculture sector are causing this problem. In Northern State, a decline in the GW level is observed especially in the Silen area located northeast of Dongola across the Nile River. A number of large-scale investments in the agriculture sector, 3,000 feddan (1,260 hectares) to 135,000 feddan (56,700 hectares), by Sudanese and foreign investors (UAE and Saudi Arabia), for the cultivation of alfalfa and wheat are the cause of this problem.

Water treatment plants along the Nile River have a number of problems, such as aging facilities including the floating water intake facilities, inadequate maintenance, inappropriate installation of pipes and leakages caused by weak pipes. In some towns along the Nile River, bad water quality is the problem because the Nile water is directly distributed to people without treatment. This is observed especially in the northern towns and southern towns in the Northern State.

A workshop was held on October 8, 2017 in Dongola with the participation of 20 state government water-related officers from SWC, DIU, the General Directorate of GW and Wadi state branch and the Ministry of Agriculture, Animal Wealth, Fisheries and Irrigation. It clarified some problems unique to the North Region, in addition to the problems mentioned above. The Merowe dam completed in 2009 is operated mainly for the purpose of power generation and affecting the water flow downstream in a way not matched with the irrigation purpose. While the Merowe Dam is contributing to preventing flood damages, it has been reducing the amount of sedimentation downstream making the dry season cultivation difficult.

(4) Kordofan Region

General Condition

The Kordofan Region comprises the three states of North Kordofan, South Kordofan and West Kordofan. West Kordofan was created in 2013, separated from South Kordofan. The population of the Kordofan region was estimated to be 7.1 million in 2016, accounting for 18% of Sudan's population. The Kordofan Region is characterized by a high proportion of nomads up to 12 and 13%.

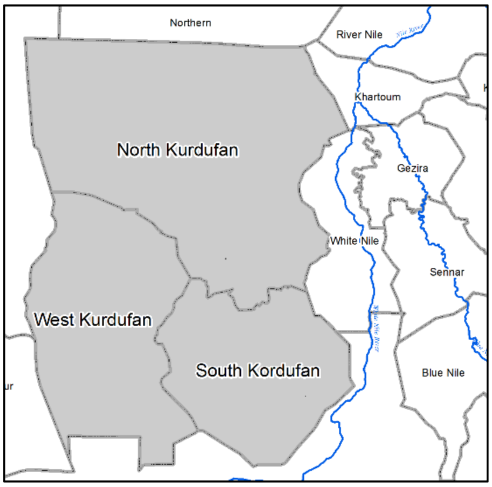


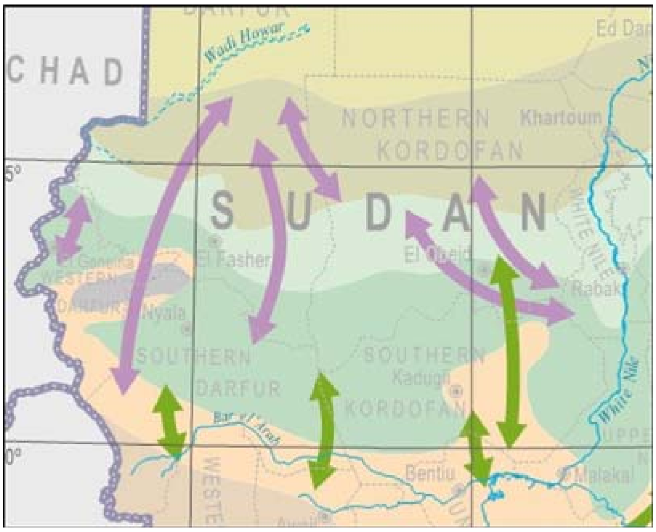
Figure 3.3-13 Kordofan Region

The Kordofan Region stretches over an area of 371,000 km^2, equivalent to 20% of the Sudan's territory. It is about 700 km long north-south and 500-600 km wide east-west. The land is almost flat, with an elevation of 500 to 600 meters, except in the Nuba Mountain area in South Kordofan State has an elevation of about 1,000-1,400 meters. The region is divided into desert/semi-desert areas in the north, an arid area in the middle and a semi-arid area in the south. The population density is 19.2 persons per km^2, similar to the population density of Sudan at 21.2 persons per km^2.

The annual precipitation varies among the three states: 200-600 mm in North Kordofan, 400-700 mm in West Kordofan and 500-900 mm in South Kordofan.

Cultivation of sesame and millet are high, each accounting for 29% and 42% of the national production. North Kordofan and South Kordofan are leading in sesame production, while West Kordofan and North Kordofan are leading in millet production. Sorghum and groundnut are also grown, but their productions are lower at 11% and 14% of Sudan's total production, respectively. Livestock production is high in the Kordofan region for four kinds of animals: cattle (28% of the national production), sheep (26%), goats (23%) and camels (38%). Migration of animals takes place from south to north in the rainy season and from north to south in the dry season. In the Kordofan Region, migrations occur mainly in the eastern part.

There is a social and security issue in the Kordofan Region. Anti-government movements in Abyei, the southern locality bordering South Sudan and the Nuba mountains has been generating a lot of internally displaced people (IDPs), destabilizing the social conditions. IDPs evacuate to the neighboring states and the state governments need to cope with an increased water demand. Refugees from the South has also evacuated to the Kordofan region. OCHA estimates that the number of IDPs temporarily living in the Kordofan region was 49,000 in 2015. The same estimate indicates that there was a total of 230,000 refugees living in South Kordofan and White Nile.



Note: Green arrows shows the movements of cattle, sheep and goats and pur ple arrows for camels and sheep.

Figure 3.3-14 Migration Routes of Nomads in the Kordofan Region and Darfur Region

Water Problem

The fourth problem tree illustrates the major water problems faced in the Kordofan Region. They addressed the issues of bad water quality caused by pollution, inadequate water quality tests and a lack of control, limited supply of GW due to inadequate development and improper management and the limited supply of SW caused by bad irrigation systems and poor condition of hafirs and dams.

The field visits made by the JPT in March and August 2017 clarified some of the water-related problems existing in North Kordofan State, as summarized below.

- Water shortage is especially severe in the northern part of North Kordofan such as in Jabra, Um Dem, Sodari and west Bara. While the state government proposes GW development by drilling deep wells, there is a concern among Sudanese officers over the sustainability of this method. Due to the lack of proper monitoring and the limited capability of GW analysis, it will be difficult to accurately measure the allowable extraction amount of GW.
- In the northern part of North Kordofan, there is a center pivot irrigation scheme for fodder invested by Saudi Arabia. The irrigation area is planned to be expanded to two million feddan (840,000 hectares) in the future. Since there has been no technical survey on hydrogeological conditions, the same concern over the possible depletion of GW resources in the near future exists.
- A problem in the institutional aspect is the lack of coordination among related government offices such as SWCs, the office of GW and Wadi, DIU and the Ministry of Agriculture.
- Conflicts between the government and anti-government movements disrupt water harvesting, irrigation, farming and agriculture investments.
- There is an inadequate utilization of the Abu Habil River water manifested by a gap of 96 million m^3 between the amount of water used (65 million m^3)a nd the amount of water available (156 million m^3).

- There are various constraints in maintaining Turda Lake, located close to El Rahad, in a good condition, such as the lack of funds for rehabilitation and silt removal, technical issues with pumps and network renewal.
- Various problems of rural water supply in Um Rawaba such as malfunctioning pumps, chemicals damaged filters, lack of spare parts, lack of periodic maintenance and the increased strain on pumps due to the increased water demand, caused by rural-urban migration and deficient operation and maintenance systems (lack of vehicles, inadequate tools for maintenance, etc.)

(5) Darfur Region

General Condition

The Darfur Region comprises the five states of North Darfur, South Darfur, East Darfur, West Darfur and Central Darfur. Central Darfur was created in 2013 when it was separated from West Darfur. East Darfur was created after separation from South Darfur. The population in the Darfur Region was estimated to be 1,051,000 in 2016, accounting for 21% of Sudan's population. The proportions of nomads were high, at 19%, 24% and 18% in 2008 in North Darfur, South Darfur and West Darfur, respectively, prior to the division of these states. Migrations of nomads and animals takes place in the north-south direction.

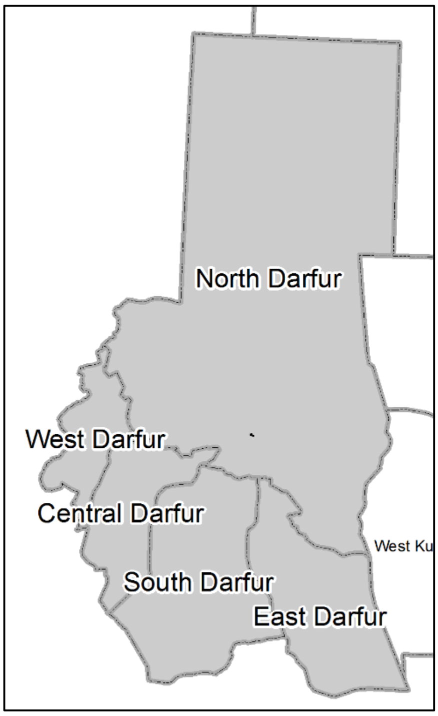


Figure 3.3-15 Darfur Region

Internal confrontations in the Darfur Region have created massive migrations of IDPs and refugees. The United Nations Office for the Coordination of Humanitarian Affairs estimates the IDPs in the Darfur Region at two million, equivalent to 24% of the population, and refugees at 62,000. The Sudanese refugees who evacuated to neighboring countries such as Chad and the Central African Republic are estimated to be 300,000 and 2,000, respectively.

The land area is 506,000 km^2, about 1,250 km long north-south and 600 km wide east-west at the widest points. The northern part of the Darfur Region is a desert area. As it goes southward, the land shifts to semi-desert, arid and semi-arid areas. The southwestern part is a dry monsoon area. Most of the land is flat with altitudes ranging between about 400 and 600 meters, except the Marrah Mountain area where Mount Marrah sits. It is the highest peak in Sudan with an altitude of 3,088 meters.

Production of millet and groundnut is high, each producing 48% and 33% of Sudan's total production. East Darfur and South Darfur are leading the groundnut production.

Water Problems

The water problem in the Darfur Region is deeply related to internal confrontations. Resolving water problems in this region should not be limited to technical solutions, but should include reconciliation and consensus building among opposing parties.

Given this fundamental social issue in the Darfur Region, more water-specific problems were identified. The workshop participants were successful in creating a comprehensive problem tree. The problems identified include the following:

- Bad water quality due to the lack of treatment of SW and pollution of GW and SW
- Lack of integration of water users

- Limited supply of GW due to a declining amount of GW and insufficient drilling of wells
- Limited supply of SW due to the limited construction of dams and hafirs and deficient urban supply networks
- Location of some settlements distant from water resources
- Impact of climate change

The information collected by the questionnaire survey conducted in March-April 2017 with the General Directorate of Wadi and GW state branch offices and the state water corporations provides some indications about the water problems in the Darfur Region as shown below.

- The water problems are ranked as follows: (most serious) lack of qualified cadre and deterioration of drilling system (second) lack of mobility (third) lack of training in electricity, civil engineering, mechanics and chemistry. – SWC West Darfur
- Many cases of farmers-nomads conflicts caused by farmers bound to their lands and nomads with animals pursuing grazing areas and water wherever they are available – GW and Wadi Office North Darfur
- Many cases of non-adherence to laws and regulations such as excessive use of water, random drilling, causing water pollution and uncontrolled discharge - GW and Wadi Office North Darfur, South Darfur, West Darfur
- Refugee camps and IDP camps - GW and Wadi Office North Darfur
- Difficulty in involving women in solving water problems due to traditional values - GW and Wadi Office North Darfur
- Some boreholes and hafirs not working due to mismanagement and lack of capacity in planning and design - GW and Wadi Office West Darfur

3.3.4 Result of National IWRM Survey

Water problems in terms of existing water resources development and management were identified through the pilot activity of the JICA in North Kordofan State and the national IWRM survey conducted in 2019. The representative water issues are listed in Table 3.3-1. Especially, the national IWRM survey identified 5 sites having typical water issues of ten target states. Five sites having serious water problems were identified in each target state (see Table 3.3-1). These water problems are classified into nine (9) categories. (See Table 3.3-1). Three sites having the most serious water problems are marked with ◎, and the other two are marked with ○. As shown in Table 3.3-1, many water problems have common content in each state, and water problems can be classified into nine types. This means that systematic solutions can be applied according to the types of water problems.

In some cases, the same type of water problem is found in more than one site in a state. In such cases, multiple ◎ are indicated in one column, such as in case of Northern state.

Table 3.3-1 Representative Types of Water Issues in Sudan

Typical water issues \ State	N. Kordofan	White Nile	Gezira	Sennar	Gedarif	Khartoum	Kassala	Red sea	River Nile	Northern
Decline of GW level due to over-pumping	◎ EL Bashiri		◎Lotah scheme		◎ Rashid Village		◎ Kassla city		◎ East Dar Mali village	◎ Elgolid city ◎ Algaab zone ◎ Elselaim scheme
Scarcity of GW	◎Thirsty triangle area	○ Salima village	◎ Butana, Umgazair village	◎ Lotah scheme	◎ Gadambalia village	◎ Elsabrab village ◎ Eltomaniat water station	◎ Degain locality	◎ Al Damer city		
Scarcity of SW								○ Atbara city	○Atbara city	
GW contamination (by geology)	◎ Ombalagei village	◎ West Dewm, Habagra village	○Abugota village			◎ Elsalha village, ○ Sharg Elneel locality	○ Wad sherifi village	◎ Elgambrat village	◎Al Damer city	
GW contamination (by human activity)					◎ Elsharif Elagib Village	○ Elselet village	◎ Elka		◎Al Damer city	
SW contamination (by human activity)	○ Elobied and bara cities	◎ Kenana City	◎ Segaida village	◎ Tozi village						
Poor planning and design of small dams and haffirs		◎Tacsboon locality		◎ Aatshan Dam ○ Tir and Trari village	○ Gadambalia village Hafir			◎ East Dar Mali village		
Poor water supply network in local cities	○ Elsedir village	○ Kosti and Dewm cities	○ Wadmedani city	○Sennar city	○Gedarif city		○Kassala city	○ Atabra city, Al Damer city and Abu Hamed city	○Atabra city, Al Damer city and Abu Hamed city	○Dongla city
Ove use of water for irrigation										○Alburgaig locality

Note: ◎ Water issues that were ranked from No.1 to No.3, ○ Water issues that were ranked from No.4 to No.5.

① Decline of GW Level due to Over-pumping

The over-pumping of wells occurs across the entire non-Nile area of Sudan in both the shallow aquifer and the deep aquifer. Water use for irrigation is the cause of the water issues. In the case of the shallow aquifer, irrigation farmers were over-pumping in many shallow wells. However, in the case of deep aquifers, over-pumping was identified in large-scale commercial irrigation schemes. Mechanism and scale of GW recharge dominates the magnitude of GW depletion. GW is recharged from rainfall in the non-Nile area in small-scale. On the other hand, GW is recharged from the sub-surface flow along the Nile River in large-scale.

② and ③ Scarcity of GW and SW

A lack of water supply, due to the scarcity of water resources, is particularly serious in the northern and the central regions of Sudan, where rainfall is scarce and the Basement rock is distributed. Rainfall which occurs during the rainy season over a three-to-four-month period will be stored in dams and hafirs, and the stored water will be used for eight to nine months during the dry season. GW can compensate lack of water during the dry season. However, the Basement rock is poor in GW and cannot compensate for the water stored in dams and hafirs. As a result, water shortages usually occur in the Basement rock area. It has been reported that water shortages occurred with the lowering of the GW level, due to a decrease in GW recharge. The river flow velocity of the Gasi River in Kassala State has increased because of improvements to the river embankment structure. As a result, GW recharge from the bottom of the Gasi River decreased, and the GW level along the Gasi River has declined, leading to a lack of GW.

SW Issue Along the Nile River:

- The river flow course of the Nile River has changed, and the water intake from the Nile River has been suspended. Soil sediment near the intake facilities makes the situation worse.
- The water level of the Blue Nile River is affected in February and March every year due to the construction of a large, new dam in Ethiopia, new Renaissance dam.

④ GW Contamination (due to geological issues)

GW contamination of geologic origin is more likely to occur in deep aquifers than in shallow aquifers. This is because of the longer flowing time of GW within the aquifer and the longer contact time between GW and the minerals that constitutes the aquifer.

- Various salts found in the rock minerals of the aquifer had dissolved into the GW.
- Fluorine (F) found in the rock minerals of the aquifer had dissolved into the GW. A deeper aquifer contains more fluorine.
- The aquifer along the seacoast has been breached by sea water. When the GW level is lowered, sea water penetrates the inland area. Conversely, when the GW level rises, the sea water recedes towards the sea.

⑤ GW Contamination (due to human activity)

GW contamination is caused by pit latrines. Domestic wastewater flows from the pit latrines into the GW, therefore, the GW of the shallow aquifer is contaminated. In general, the shallow aquifer consists of an upper and lower section, separated by an impermeable clay layer; usually, wastewater flows into the upper section of the aquifer. Shallow wells collect GW from both the upper and the lower section of the aquifer. Therefore, GW contamination can be avoided if the GW of the upper section is sealed, so as not to flow into the lower section within the well. This is usually determined by the well construction technique. The contamination is serious in many cities, especially in Khartoum.

⑥ SW Contamination (due to human activity)

Regarding SW contamination, three types of contamination were identified.

- Wastewater drains into the ponds from the sugar factory without any water quality treatment; this contaminates the SW and GW.
- Water from the canal is supplied for domestic use without purification.
- Water is stolen from the pipeline for urban water supply by nomads and pastoralists. Water is contaminated in the areas where the water is stolen from the pipeline; the contaminated water flows towards the downstream area of the pipeline in urban area.

⑦ Poor Planning and Design of Small Dams and Hafirs

With regard to the technical failures in planning and the design of dams and hafirs, three examples are listed below.

- Inadequate selection of the construction location of the hafir resulted in insufficient water storage capacity of the hafir.
- Inadequate hydrological studies prior to dam construction caused the wadi to change its flow path, and the wadi floods destroyed the dam embankment.
- Improper dam operation caused silt to settle in the dam's reservoir, reducing its storage capacity and resulting in water shortages.

⑧ Poor Water Supply System For Local Cities

The current water supply facilities in local cities were constructed many years ago. The population has been increasing rapidly since then, and the capacity of the water supply facilities is much less than the current water demand. Moreover, a lack of maintenance of the facilities has worsened the situation.

⑨ Over Irrigated land

Due to the over-use of irrigation water, the GW level rose and damaged the foundations of houses and buildings. Water is conveyed from the Nile River for irrigation, and GW is also pumped up for irrigation. Too much irrigation water raised the GW table, which reached the foundations of houses and buildings. As a result, the foundations were dissolved/damaged or the bearing capacity of the foundation decreased. This lack of instructions for famers on adequate irrigation water and the lack of monitoring are the causes of the issues. Capacity building to solve the water issues requires engineering techniques.

(1) General Technical Issues Throughout Sudan

(a) Lack of Monitoring

In many non-Nile areas, GW and SW are used for water supply and irrigation purposes. However, there are very few cases in which fluctuations in GW levels and SW flows are continuously monitored. Even with regard to the operation of a large urban water supply by GW from wellfields, GW levels are not monitored in some cases. The amount of GW that can be pumped up sustainably in Sudan is very small, due to the small amount of GW recharge. In the case of aquifers where fossil water is pumped up without GW recharge, such as the Nubian sandstone and the Bara aquifer, the GW level will definitely decrease with continued pumping. Therefore, for sustainable GW use, it is essential to monitor the GW level while pumping.

One of the reasons why monitoring is not conducted is the lack of budget for monitoring. There is no guarantee that the information and data necessary for design will be available at the time of planning and designing stage. This shortcoming is compensated by monitoring. It is important to understand the gap between the initial water resources development plan and the actual conditions after its implementation. To fill the gap, monitoring can make the necessary adjustments according to the progress of the implementation (see Figure 3.3-16). In reality, however, the role of monitoring is often neglected, as it is assumed that the development and management of water resources will proceed according to the original plan and design. As a result, most of the budget is spent on the planning, design and construction of the facilities, with little provision for post-construction monitoring.

Since the characteristics and contents of water resources development and management differ from state to state, monitoring needs also differ from state to state. There are three purposes of monitoring as shown in Table 3.3-2. Each state should select the type of monitoring it needs.

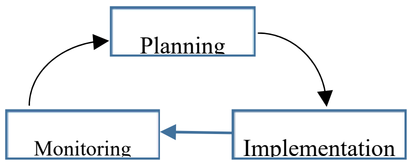


Figure 3.3-16 Importance of Monitoring Results

Table 3.3-2 Objectives and Types of Monitoring Based on Water Resources

Purpose of monitoring		Type of expected monitoring	
Type	**Purpose**	**GW**	**SW**
①	To understand the potential of water resources.	Long-term observation of the GW level to understand the amount of GW recharge.	To understand the development potential of a wadi by observing its flow rate on a long-term basis.
②	To establish the efficient operation of water source facilities.	Understand the fluctuation of the GW level in water source wells and adjust the pumping rate.	To observe the water level in reservoirs and hafirs to adjust the water intake.
③	To confirm compliance with water regulations.	Periodically observe the volume of water pumped from wells and confirm that it is below the limit of pumping volume.	To periodically observe the amount of water withdrawn from the wadi and confirm that it is below the water withdrawal limit.

The three types of monitoring are not properly understood in Sudan. Of the three monitoring types above, only type ① is implemented on small scale in Sudan to determine the potential of water resources so far.

(b) Problem in Information Sharing

The AfDB planned to develop the GW of the Bara aquifer for the local urban water supply of El Mazroub town in North Kordofan State. Preliminary studies of the impact of this development were carried out and assessed by the federal government. Unfortunately, the negative impacts of the AfDB project were not properly assessed because the environmental impact study did not have sufficient information on the current water use in the area where the GW development would take place. In addition, the results of the study were not shared among the stakeholders involved, and the project proceeded without any problems being highlighted. Fortunately, the problem was identified at an early stage of the project, so the project was temporarily suspended in order to resolve the problem by reviewing the environmental impact assessment. The problem came to light when a brief comment was made regarding the concerns of the AfDB project during a discussion at the TC meeting held by the JICA project. This comment did not come from an engineer, but from a financial officer of the state government. As this example shows, information sharing is important and can only be effective if there is a platform for information sharing that includes stakeholders from a wide range of fields. In particular, information sharing with local stakeholders is essential, as water users in the target area of the project hold important information regarding the historical and current water use in the area.

This fact illustrates the difficulty of information sharing. It is highly desirable to learn from this and resolve the lack of information sharing by introducing effective platforms for information sharing and consensus building, such as SWRC and NWRC.

(c) Reason Behind Lack of Technology in Design

Within the domain of planning and design, there is a lack of technical skills among the engineers in charge. One of the reasons behind this lack of skill relates to the lack of motivation of engineers. In order to motivate engineers to fully demonstrate their abilities, it is essential that the organization to which they belong, provides them with a position commensurate with their abilities and achievements, as well as a stable income commensurate with these. In other words, unless there is a system within the organization where the efforts and achievements of the engineers are fairly evaluated, the engineers will not be able to demonstrate their abilities with a sense of purpose.

The GWDD of the MIWR is in charge of the development and management of water resources in the non-Nile areas and although the GWWD has experienced engineers, it is currently facing the following problems:

- There is a lack of young generation of engineers to carry on the skills of experienced engineers.
- The role of the GWDD has been reduced to that of a consultant for the DIU, and there are few opportunities for the GWDD to fully demonstrate its accumulated technology and knowledge. After 2019, however, the above trend is improving as the scope of DIU activity has been shrinking.

(d) Lack of Data Sharing

Water resources development and management should be planned based on technical judgement. Needless to say, the basis for technical judgement is technical data. In the early stage of consensus building, it is very important that collaborative data collection and sharing lead to joint recognition of the causes of problems among the stakeholders concerned. Data sharing is essential in building a common understanding among stakeholders to solve water problems, without which there will be no consensus among the stakeholders with regard to solving issues.

Unfortunately, however, Sudan lacks an accumulation of basic technical data on water resources development and management. This is a hindrance to rational and efficient water resources development and management. The actual situation of the lack of technical data related to water resources development and management in Sudan is manifested as follows:

(1) There is a lack of data in terms of both quantity and quality.
(2) Although there were many data, this data was not correctly registered nor saved when it was no longer being used. As a result, the data could not be used in other projects.
(3) Data are collected and stored but are not shared with others due to data ownership and confidentiality constraints.

The aforementioned problems from ① to ③ are serious. Out of these problems, ③ is of an institutional nature which is related to restrictions on the right to use existing data. In order to solve this problem, it is strongly recommended to lift certain unnecessary restrictions so that data be shared among the stakeholders involved, based on agreements to be signed by the stakeholders. Although confidentiality is important, the practice of adhering to the principle of confidentiality without objectively comparing the advantages and disadvantages of data sharing, should be reconsidered in the future.

(e) Water Quality Considerations

Deterioration of water quality in the Sudan has made water shortage even more serious. In the non-Nile areas, SW has traditionally been stored and used in hafirs. The problem of water quality in hafirs has been widely discussed, and methods for dealing with the problem are widely known. On the other hand, the use of GW for water supply has been rapidly increasing in recent years. This is due to technological advances in well drilling machines and the rapid spread of pumping equipment. SW pollution, manifested by turbidity, is visually obvious and easily recognizable by water users unlike the case of GW pollution since no visual characteristics can be observed. As a result, there is a high risk of using GW without noticing GW contamination. Notably, there are cases of households without sewage treatment facilities discharging domestic wastewater into shallow wells on their properties. This leads directly to contamination of shallow aquifers. In the large city of Khartoum, the discharge of domestic wastewater into household wells has resulted in the contamination of shallow aquifers on a large scale.

(2) Current Condition of Consensus Building in the Surveyed States

The survey revealed that two states, Kassala and River Nile, have established a new organizational mechanism in the form of a council, as means of promoting consensus building on water issues. The other eight states have not created such a mechanism, but recognize the importance of an institutional mechanism in which all the water-related stakeholders, both government and private, are able to meet together, discuss water issues and collaborate to solve water problems. It is noteworthy that the survey had the effect of raising the awareness of high-ranking state officers of the benefits of a state water resources council and they immediately recognized the importance of such an organization, when answering questions posed by the Gezira University team.

The results of the survey for each state are summarized below:

<u>North Kordofan</u>

- They have no organization such as a state water resources council.
- They have not considered establishing such a council but think this is necessary because water is linked with other development sectors. Other ministries and organizations, however, are not interested.
- Water users participate in the planning, financing and operation of water facilities through water committees for water yards in rural areas.
- The purpose of creating a consensus building mechanism is to strengthen community participation.

<u>White Nile</u>

- They have no organization such as a state water resources council.
- They have not considered this, but regard it as very important because collective action is better.
- Water users participate in water management as payers of the water tariff.
- A consensus building mechanism should be created by establishing a higher committee for water.

Gezira

- They have no organization like a state water resources council.
- They think it is very important because it will help to integrate ideas. They do not have enough information about IWRM. According to their experiences, it is necessary to have a system in which water users can participate, because most successful water projects are those which have involved local communities.
- A consensus building mechanism should be created by establishing a higher committee for water.

Sennar

- They have no organization such as a state water resources council.
- They have not considered this, but believe that such a system is necessary, because ideas from all stakeholders would be beneficial when implementing water projects.
- Water users participate to some extent in water management at village level, to ensure the timely maintenance of water facilities.
- A consensus building mechanism should be created initially by formulating laws and regulations, before establishing a water council.

Gedaref

- They have no organization such as a state water resources council.
- They have not considered establishing such an organization, but think that such a system is very important because it will help solve the water problems.
- There is no clear system in which water users can participate, but there are committees associated with water management.
- A consensus building mechanism should be created by raising awareness and carrying out research initially, before establishing an IWRM council.

Khartoum

- They have no organization such as a state water resources council.
- They have not considered this but think that such a system is necessary because it will help solve water-related problems. Some ministries like agriculture, however, are not interested in participating since they believe that working together may hijack their responsibilities.
- Water users participate in water management through public committees, micro finance committees and cooperative committees.
- A consensus building mechanism should be created to formulate laws and regulations and to function as a coordination committee, providing an enabling environment.

Kassala

- An IWRM council was established in 2016. It comprises members from 27 institutions including associated ministries, local administrations and all stakeholders, such as the farmers committee, pastoralists committee, fruit and vegetables producers committee, women representatives, UN representatives and NGO representatives.

- Its main business is to coordinate different water-related institutions in the state.
- The council is supposed to meet every three months, but only two meetings had been held as of August 2019.
- They mentioned that the council is not functioning well because the IWRM council has no working facilities yet. They want the council to continue because it is the only body keeping all stakeholders together.

Red Sea

- They have no system such as a state water resources council.
- They have not considered this but think that such a system is important because so many joint projects are more likely to be successful, if water-related institutions work together.
- Water users participate in water resources management through local committees, particularly in rural areas. It is very difficult for water engineers and workers to settle in remote areas.
- A consensus building mechanism should be created to formulate laws and promote consensus building.

River Nile

- The IWRM council was established in 2018. Its members include Wali, the Ministry of Health, Ministry of Finance, Ministry of Investment, Ministry of Infrastructure and Physical Planning, Ministry of Agriculture, DG of the SWC, Wadi Elneel, University Vice Chancellor, Shandi University Vice Chancellor, Elbadawi Vice Chancellor, Bank of Sudan, Zadna Company and representatives of legal institutions and the metrics authority.
- Its main objectives are the establishment of rules and regulations for water use, formulation of general policies on water resources, protection of water sources from pollution and the securing of financial resources for research into the development of existing and new water resources.
- The council is supposed to meet three times a year, but only two meetings had been held as of August 2019.
- Water users participate in water resources management through the IWRM council.

Northern

- They have no system such as a state water resources council.
- They have not considered this but believe that such a system is necessary to enable discussion of water issues. It will help solve water issues and bring various groups together.
- Water users participate in water resources management through local committees.
- A higher council for natural resources management should be created to promote consensus building. It should be represented by all associated ministries.

Chapter 4 Phase-2 Activities and Results

4.1 Phase-2 Activities

Phase-2 of the Project consists of "pilot activities" and "recommendations for IWRM promotion". Phase-2 was implemented from August 2019 to March 2023. Based on the Phase-1 activities, North Kordofan State was selected as a priority region in which to implement the pilot activities and work on problem-solving practices (Output-3).

The pilot activities were implemented in a participatory manner with the stakeholders, namely, state agencies and water users, including farmers and residents in North Kordofan State.

4.2 Phase-2 Selection of Pilot Activity Area

(1) Process of Selection for Pilot Activity Area

At the beginning of Phase-2, the project team started to discuss how to select the pilot activity area considering on the Phase-1 activities.

In selecting candidate regions for the pilot activities, water problems occurring throughout Sudan were identified and narrowed down, based on the following four selection criteria (see Figure 4.2-1).

① Seriousness of water problem
② Necessity of IWRM
③ Replicability to the other regions
④ Efficient achievement by pilot activity

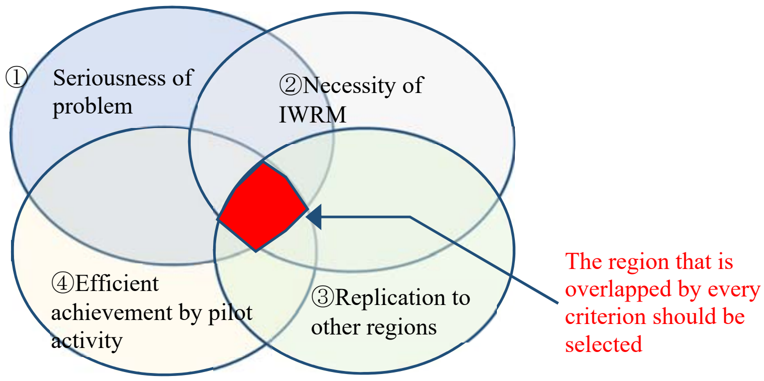


Figure 4.2-1 Image of the Selection of Candidate Regions for Pilot Activities

For the purposes of identification of water problems in Sudan, the JPT and the University of Khartoum worked together to list the water problems in the various regions of Sudan. As a result, water problems were identified in 23 regions (see

Table 4.2-1).

Table 4.2-1 Regions in Sudan Where Water Problems Were Identified

No.	Region	No.	Region
1	Kassala	13	Wadi El Qaab
2	Atbara–Ed Damer Area	14	Wadi El Selaim Dongola
3	Wadi al Ghalla	15	Egoled

4	West Duem Area	16	Wadi Elku Sagen Nnaam
5	Wadi Shelongo	17	Sag En Naam
6	Wadi El Mugaddam	18	Port Sudan
7	Genaina	19	Nuba Mountains
8	Toker	20	Ingessana
9	Nyala	21	Kabkabia
10	Gedaref Rural Area	22	AbuGuta
11	El Obeid	22	AbuGuta
12	Sinja-Sennar Area	23	Butana

A summary of the water problems and sub-basins where water problems were identified are shown in **Figure 4.2-2**.

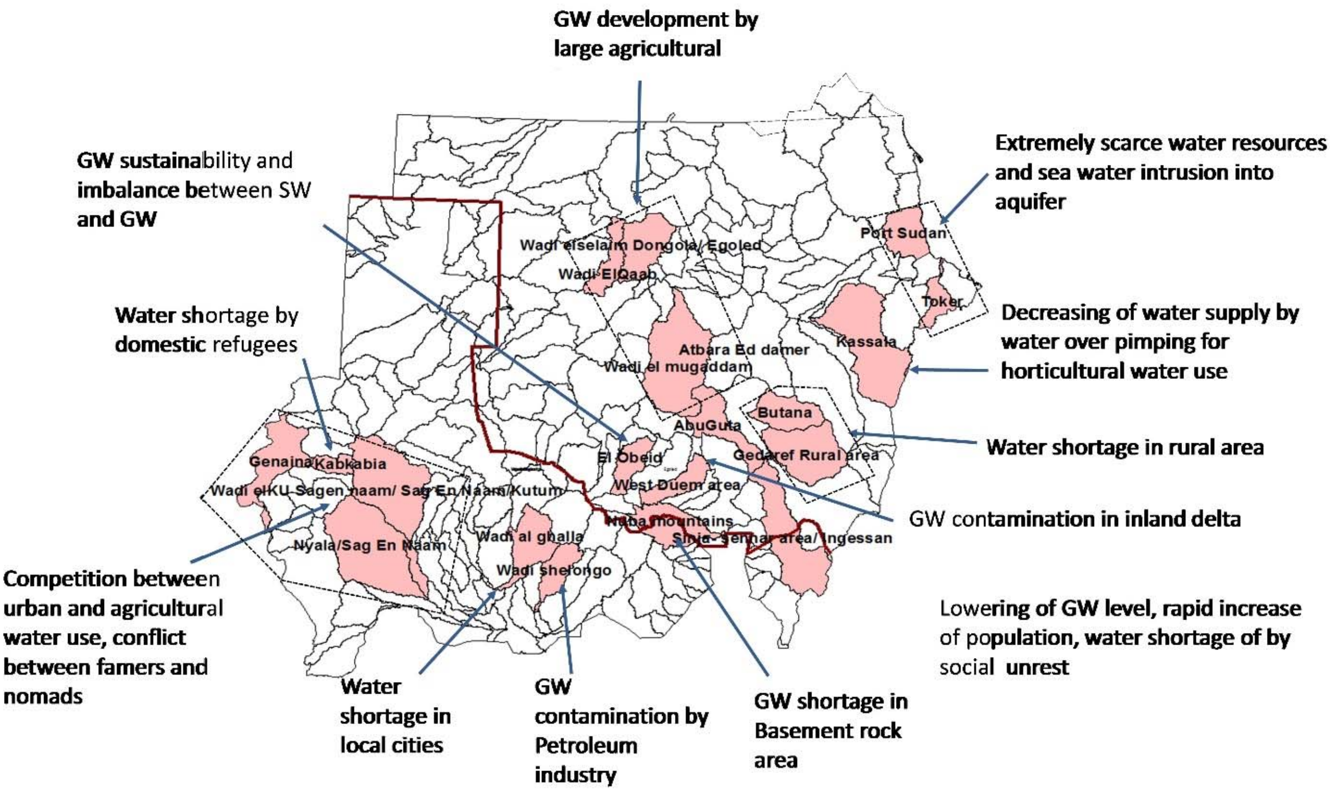


Figure 4.2-2 Water Problems and Sub-Basins Where Water Problems Were Identified

(2) Finalization of Region for Pilot Activity

To determine the region for pilot activity, the JPT screened 23 regions, based on the decision criteria to narrow down the target regions. The 23 candidate regions were given points for each of the four criteria, and the total score was calculated to rank the 23 candidate regions according to the total score. The results showed that El Obeid and Kassala city scored significantly higher than the other candidate regions. As a result, two regions, El Obeid and Kassala city, were selected as the final candidates in the 3rd JCC of Phase-1 of the Project. After commencement of Phase-2 of the Project, El Obeid was finally selected as a region for pilot activity in the 4th JCC of the Project. The reasons for the selection of El Obeid are summarized below. El Obeid and Kassala city have water issues relating to the depletion of groundwater (GW) resources. Both were very serious (problems ① in Figure 4.2-1). Comparing the current situations of El Obeid and

Kassala city, El Obeid has many similar issues as other regions of Sudan in terms of IWRM. Therefore the pilot activity in El Obeid and the surrounding area will provide more knowledge and lessons than Kassala city on IWRM (problem ③ in the criteria of Figure 4.2-1), which is applicable to the other regions in Sudan. El Obeid has fewer studies and surveys related to IWRM than Kassala city to date. The potential of water resources and the water balance between water demand and supply were still unknown in El Obeid, and there were many items that needed to be studied and surveyed to identify water problems for the pilot activity. The target area for the pilot activity in El Obeid covers a wide area of the Bara Sub-Basin. There were many stakeholders, and the need for collaboration and coordination was high. At the same time, there was a considerable need to integrate the technical and social aspects, indicating the relevance to IWRM (problem ② in Figure 4.2-1). Both El Obeid and Kassala city are state capitals and house the offices of state agencies. This made it easy to gather information suitable for project activities, and the output of the activities were therefore likely to be more promising (problem ④ in Figure 4.2-1). On the other hand, there have been many studies and surveys carried out in Kassala city to date. The potential of water resources and the water balance between water demand and supply have already been analysed to some degree, and water problems have been clarified. The target area in Kassala city would cover a relatively small area of Kassala city and the surrounding area along the Gash River. The Sudanese side has already started planning the countermeasures to solve the water issues. Considering the above situation, El Obeid and the surrounding area was finally selected as region for pilot activity.

When considering El Obeid and Kassala city, they are comparable as regards Problem ① and ④ in Figure 4.2-1, but El Obeid outperforms Kassala city in relation to criteria ② and ③. As a result, El Obeid was selected as the final candidate region.

4.3 Status of Water Resources and Issues in the Pilot Activities' Area

4.3.1 General Conditions

(1) North Kordofan State and Bara Locality

North Kordofan State is located in the centre of Sudan. As a result of this central location, the capital of the state, El Obeid, has been the transportation and trade hub connecting Khartoum, the Darfur region and South and West Kordofan.

There are eight localities in North Kordofan, namely, Shiekan, Um Rwaba, Um Dum Haj Ahmed, Bara, West Bara, Gabra El Shieku, El Rahad and Sodary.

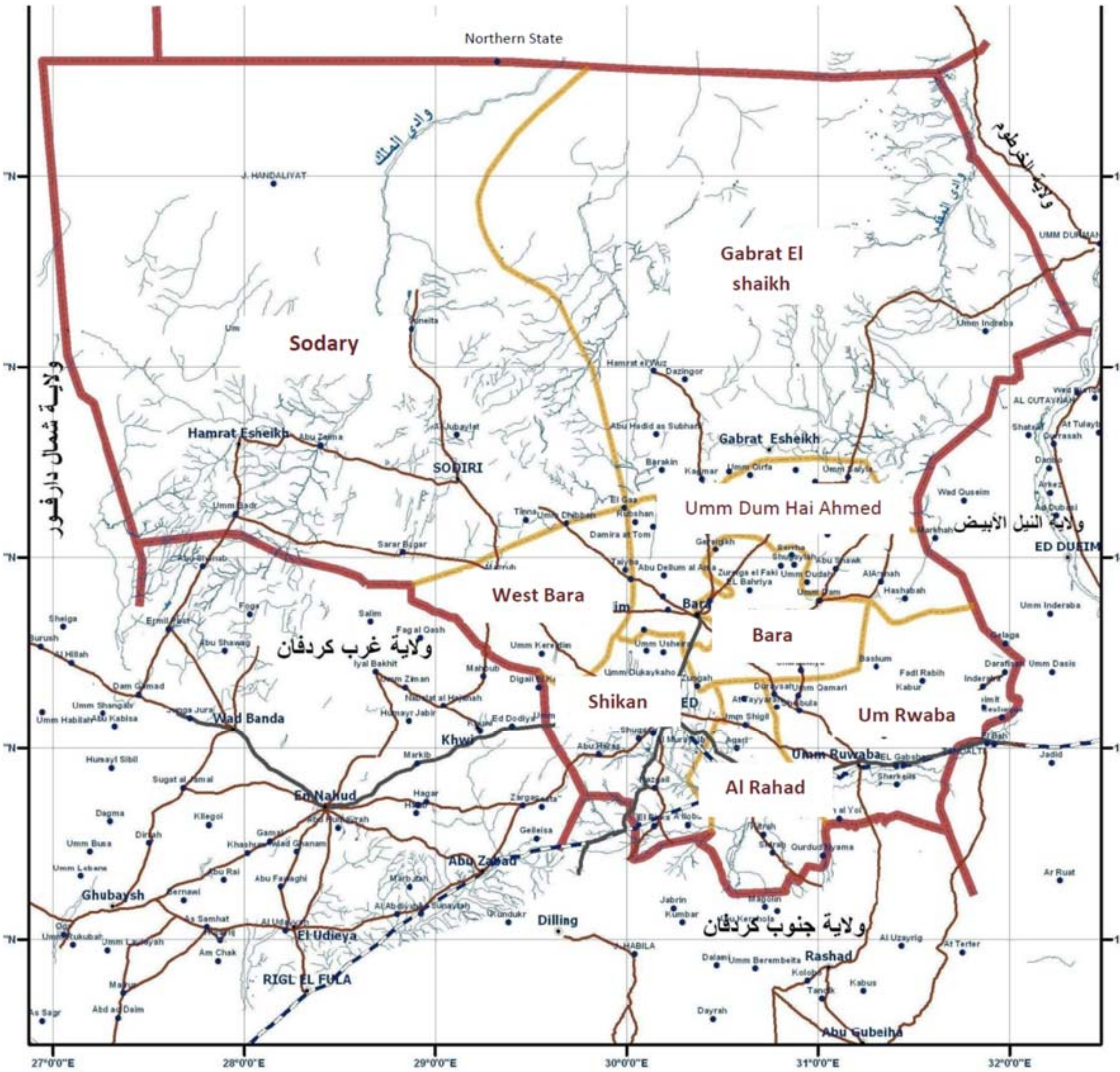


Figure 4.3-1 Map of North Kordofan

The population of the state was 2,039,495 in 2008 (Population Census, 2008). The Central Statistics Office uses the population growth rate of 2.8% for the state for population prediction after 2008[1]. The next table shows the population in 2008 and 2018.

Table 4.3-1 Population of North Kordofan

2008 (Baseline)	2018 (Estimate)
2,039,495	2,688,152

Source: JPT

Table 4.3-2 Population by Locality

	Locality	2018 (Estimate)
1	Shiekan	704,475
2	Um Rwaba	452,846
3	Um Dum Haj Ahmed	175,151

[1] The World Bank estimated the population growth of Sudan to be 2.4% in 2017. World Development Indicator, World Bank.

4	Bara	239,157
5	West Bara	231,277
6	Gabra El Shieku	286,648
7	El Rahad	205,720
8	Sodary.	342,477
	Total	2,637,751

Source: Central Bureau of Statistics, North Kordofan
Note: The total number is different from the estimate with a growth rate of 2.8%

There are four major cities and towns in the state, El Obeid, El Rahad, Um Rawba and Bara. The next table shows the population in the four cities and towns in 2008 and 2018. Around 20% of the population live in these four cities and towns.

Table 4.3-3 Population of Major Cities and Towns in North Kordofan

	2018 (Estimate)
El Obeid, (Shiekan Locality)	449,503
El Rahad	81,843
Um Rwaba	75,945
Bara	19,092
Total	626,383

Source: Central Bureau of Statistics, North Kordofan

There are ten major tribes, Dar Hammed, Kababeesh, Gawama, Hawaweer, Dawaleeb, Dhanabla, Kawahla, Bederea, Shwehat, Maganeen and other minor tribes living together in North Kordofan. Moreover, nomadic tribes such as Baggara and Abbala pass through the state with their livestock.

Traditional leaders of the native administration, Shiek, Omda and Amir, are respected by people and they play important roles in natural resource management and conflict resolution in North Kordofan State especially in rural areas. Firstly, people consult traditional leaders when they are experiencing difficulties. Then, traditional leaders work together with governmental officers, such as policemen and forest inspectors in the case of difficulties relating to natural resources, if necessary. There are nine Amir, 196 Omda and 2,227 Sheik in the state. One Amir sometimes administers more than two tribes[2].

Generally speaking, the traditional and religious norms, cultures and customs sometimes prevent women from participating in decision-making or having equal rights in Sudan, although the situation is changing. Women in the Kordofan region are not particularly conservative compared to the eastern part of Sudan. They work together with the men in the agricultural sector, both for rain-fed and irrigation purposes.

The main industry of the state is agriculture, with 80% of the population engaging in agriculture within the state. The industry sector is small and there is only light industry, such as food processing and soap manufacturing. The following tables show the size and structure of state GDP by sector from 2012-2016. The share of the agricultural sector is around 70%, the industry sector equates to 5-6% and the service sector, 22-23%.

Table 4.3-4 State GDP 2012-2016 (Unit: Billion SDG)

	2012	2013	2014	2015	2016
Agriculture	7368.9	9016.8	13452.9	16748.2	19524.1
Industry	670.3	803.6	925.5	1214.5	1513.9
Service	2284.7	2790.8	3588.6	5073.2	6406.9

[2] Interview with University of Kordofan in 2018

Total	10323.9	12611.2	17967	23035.9	27444.9

Source: Central Bureau of Statistics, North Kordofan

Table 4.3-5 Structure of GDP by Sector 2012-2016（Unit:%）

	2012	2013	2014	2015	2016
Agriculture	71.4	71.5	74.8	72.7	71.1
Industry	6.5	6.4	5.2	5.3	5.5
Service	22.1	22.1	20	22	23.4
Total	100	100	100	100	100

Source: Central Bureau of Statistics, North Kordofan

Within the locality of Bara, there are five Administrative Units (AUs) and 309 villages. The main livelihood is agriculture and livestock raising. Most farmers engage in rain-fed farming and own small numbers of animals. Bara town and its surrounding area, as well as the Al Kheiran region are the two major irrigation areas. The new road linking Omdurman via Bara town to El Obeid was constructed in 2019. The locality expects an increase in trade of agricultural products as a result of this new road.

(2) Baseline Survey

The Project conducted a baseline survey to understand the target areas and water use. The baseline survey was contracted out to the UNESCO Chair in Water Resources (“UNESCO” hereafter). UNESCO began collecting information in September 2018, and the Final Report was submitted in March 2019.

1) Objectives of the Survey

The objectives of the survey are shown below:

a) To collect information on current water use of both surface water (SW) and GW, provided by the existing water users in the target area:
- Irrigation farmers
- Rain-fed farmers
- Settled pastoralists
- Nomads passing through the target area
- Urban residents in Bara town and El Obeid city
- Rural residents in the target area (the Bara Rural AU) utilizing GW from shallow wells

b) To collect information on the current farming practices of irrigation framers and rain-fed farmers in the target area

c) To collect information on the social and cultural backgrounds of water users

d) To collect information on the environment surrounding water users

e) To confirm the readiness of water users to participate in the WUC to be established under the SC of the JICA Project

2) Target Area

The target area of the survey is Bara town and the Bara Rural AU, which roughly correspond to the Bara Sub-Basin (Al Bashiri Sub-Basin), as shown in Figure 4.3-2. This area includes Bara town and its vicinity. The extent of covering El Obeid is limited to its position as a demand centre in terms of the conjunctive use of Bara’s deep aquifer GW and the Shikeran Basin’s SW.

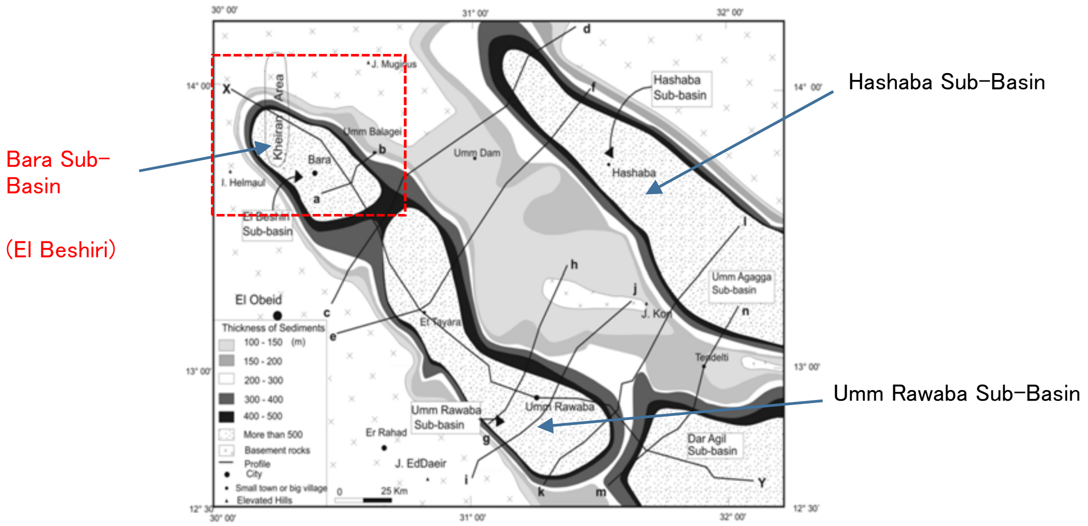


Figure 4.3-2 Target Area of Baseline Survey

3) Method of the Survey

Interview surveys, focus group discussions and key informant interviews were used as the methods of the survey. The sample sizes are shown in the table below.

Table 4.3-6 Number of Samples by Interview Method

Target Group	Individual Interview	Focus Group Discussion	Key Informant Interview	Parent Population	Remarks on Sampling
Irrigation farmers	100	3		475 farms (farms in use only)	-
Rain-fed farmers	80		40	Total estimated population in Bara AU is 41,000 in 2018. 63 villages in Bara AU	Two farmers each from 40 villages out of 63 villages were picked up for individual interview, and village representatives from 40 villages out of 63 villages were interviewed in key informant interviews
Settled pastoralists	20	-	5	63 villages in Bara AU	Villages which obtain more money from livestock than cultivation were picked up.
Nomadic pastoralists	-	-	7	N/A	-
Bara town water users	36	-	-	Around 2,000 households (HH) on the subscriber list	Three HH each were picked up from 12 administrative blocks
El Obeid city water users	49	-	-	Around 73,000 customers on the subscriber list	Seven HH each were picked up from seven water supply sections
Traditional leaders (Omda)	-	-	2	N/A in the target area,	-

				196 in North Kordofan	
Women in Bara town	-	2	-	-	-
Youth in Bara town	-	2	-	-	-
Women in rural areas	-	2	-	-	-
Youth in rural areas	-	2	-	-	-
Total	285 people	8 times	55 interviews	-	-

4) Major Findings

The major findings according to the five objectives of the survey are summarized below.

a) To collect information on current water use of both SW and GW, provided by the existing water users in the target area

- In the case of irrigation farmers, it is expected that the water demand for irrigation will increase in the future, if irrigation farmers use irrigation water in the same way. Around 18% of the irrigation farmers stated that they were not satisfied with the quantity of irrigation water currently and 93% maintained that they would expand the irrigation areas to increase their income.
- There are several water sources in the villages for rain-fed farmers. The major water sources are water yard (58%) and traditional well (40%). The water is used for humans (100%) and livestock (95%) as well as nomads passing through or staying in the village (50%). The problems faced in the villages are an insufficient quantity of water (53%) and difficulty in fetching water (40%). All 40 village representatives stated that they wished to have a new well in the future to cover insufficient water availability and the growing demand resulting from an increase in population and animals; they also hoped to start irrigation farming. Twenty-three villages indicated that they wished to upgrade the traditional wells to water yards to alleviate the difficulty of drawing water.
- The settled pastoralists were generally neither satisfied nor dissatisfied with the water use. They use wells outside their villages to water their livestock.
- Each nomadic group follows a routine pattern of migration annually, seeking areas with abundant grazing land and water. The nomads discuss and decide upon which wells they should use with other tribe leaders while moving around. All of the surveyed groups spoke of the challenges of practicing nomadic pastoralism because of the difficulty of accessing pastures and water. Moreover, they face many problems during migration, such as finding suitable water points, increased water charges and a decrease in rainwater.
- There are two water sources in Bara town which are the piped water (56%) and water yard (61%) or wells with generators. Around half of Bara citizens do not yet have access to piped water, which leads to a relatively high dissatisfaction rate (27%) with regard to the current water supply, although water quantity is not a problem for Bara citizens.
- El Obeid citizens use piped water (100%) and also buy water, as the frequency and volume of the urban water supply are not sufficient. This group is the most dissatisfied with the current water supply. The dissatisfaction rate is as high as 47% in summer (March to May), while 100% are satisfied during the other seasons. This is because the insufficient urban water supply, and users have to spend a considerable amount of money to buy water in summer.

- Reliable data on water consumption were not obtained because water meters are not used by all groups and there were limited answer choices.
- Regarding the payment for water, all groups pay between 50 and 100 SDG/month. However, El Obeid citizens spend on average 300 SDG/month in winter and 700 SDG/month in summer to buy water.
- Water demand in the future is expected to increase. Of the irrigation farmers, 93% stated that they would expand the irrigation farms, 70% rain-fed farmers claimed that they would start irrigation agriculture, 65% settled pastoralists maintained that they would increase the number of their livestock and all 40 villages wished to have a new well.
- Around 43.5% of the irrigation farmers and 8% of villages stated that the GW level had declined in the wells they use. As for awareness of water resources, 91% of Bara citizens and 47% of El Obeid citizens were worried about the sustainability of the water resource. Contrastingly, 98% of the village leaders of 40 villages believed that there is an abundant and limitless amount of water under the ground.

b) To collect information on the current farming practices of irrigation framers and rain-fed farmers in the target area

- Irrigation farming is male dominated.
- Fruits and vegetables are cultivated by irrigation. The criteria for selecting the crops grown are market demand followed by high selling price, then family demand.
- The main constraint of irrigation farming is "low availability of fuel" followed by the "high cost of fuel" then the "high cost of labour".
- The percentage of male, rain-fed farmers interviewed was 75%; 25% were female.
- High family demand, a high demand in the market and a high selling price are the main criteria for selecting crops to grow in rain-fed agriculture.
- The main constraints of rain-fed agriculture are the high labour cost, the low availability of fuel and the high price of seeds.

c) To collect information on the social and cultural backgrounds of water users

- The survey confirmed that traditional leaders and the popular committee play an important role in water resource management. They are also members of water committees which maintain wells at village level. For the nomads, the Sheik is the sole manager of natural resources in nomadic groups.
- According to the village leaders, problems relating to settled and nomadic pastoralists have occurred in the past regarding natural resources, such as conflict over the boundaries of agricultural lands, use of grazing lands and insufficient pasture or loss of pasture, caused by the expansion of agricultural lands. Livestock occasionally eat the crops in agricultural lands, an issue which is solved by asking the Sheik to demand that the owner of the livestock pay compensation to the owner of the agricultural lands. Water was not mentioned as a problem, probably because the target groups can easily use GW from the Bara Aquifer.
- The Omda operates at a higher level than the Sheik; the Omda supervises the Sheiks and several villages or nomadic groups, while the Sheiks solely supervise and control issues within their own village or nomadic group. The role of the Omda includes determining the boundaries of villages to resolve the conflict between different villages, or when a conflict cannot be solved at village level. The Omda also supervises discussions between settled villages and nomadic groups to decide their migration routes and timing.

- According to the focus group discussion with the youth and women in Bara, the participants did not believe that they were fully involved in the decision-making process in the areas where they live. While the youth and women in rural areas have an opportunity to participate in the discussion to some extent, the youth and women in urban areas feel they are not involved.
- From a cultural and religious perspective, the Sudanese are willing to share water with others, as explained by the Omda interviewed. Settled and nomadic pastoralists, in particular, accept the social value of water, which is to connect people. Pastoralists use water sources owned by others, which means they interact with other villages and groups. Pastoralism, as a traditional livelihood, enhances the relationship between different villages and groups through water use.

d) To collect information on the environment surrounding water use

- As a result of the interview survey, several findings on the environmental viewpoint in the Bara GW Basin emerged. Of the 40 interviewees, 32 of the 40 responded to the question, "Have you noticed any change in the natural conditions and biological environment recently?" Thirty of the interviewees responded "yes". Of this group of respondents, all 30 had recognized a change in vegetation, while seven respondents noted changes in flora and fauna. The existence of waterfowl, which shows the soundness of wetlands, was not recognized in this interview. Moreover, it has been found that there are no other endemic species or rare fauna and flora in the respondents' area except for Euphorbia-sp and Adenium-Obesum. Only three interviewees stated that the lack of rainfall is an environmental issue. It seems that lack of rainfall is due to the influence of climate change. The result shows that few farmers have recognized the impact of climate change.
- Twenty-two of the 37 interviewees claimed that there were no natural disasters or environmental pollution in the area. Seven interviewees mentioned that the deforestation of flora had been recognized as a natural disaster. Those who answered "others" (10 interviewees) specified natural disasters as strong winds with rain, dust storms, desertification and drought.

e) To confirm the readiness of water users to participate in the WUC, established under the SC of the JICA Project

- Among the villages, 93% stated that they were willing to send their representative(s) to the WUC.

(3) State Government and State Law for Water Resources

The structure of the ministry responsible for water has been changed during the Project period. When work on the Project started in the state, the name of the ministry was the State Ministry of Water Resources, Energy and Mining (SMWREM). As the name showed, the ministry was responsible for the water, electricity and mining sectors. In 2018, this was changed to the Ministry of Infrastructure and Urban Development (MIUD) and the mining sector was detached. The organizational chart of the MIUD is shown in Figure 4.3-3.

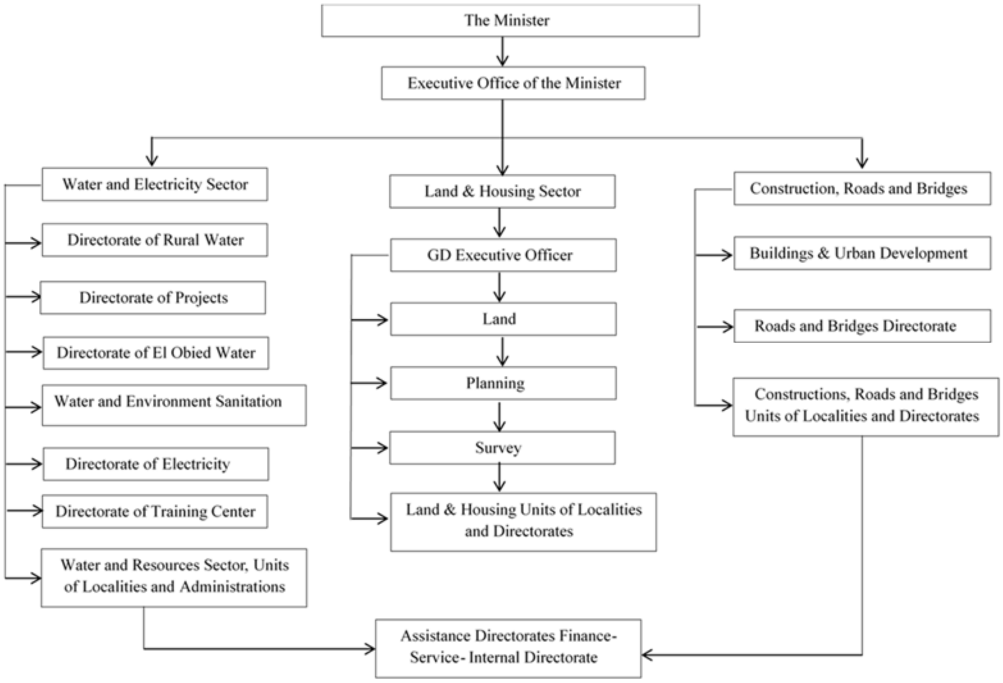


Figure 4.3-3 Organizational Chart of the MIUD

The SMWREM drafted the Water Law for North Kordofan State. The law comprises six chapters: preliminary provisions; tasks, duties and responsibilities of the water sector; council of water management; prohibition; water tariff and general provisions. According to the law, the tasks, duties and responsibilities of the ministry are defined as policymaking, creating the plan and programmes, the preparation of proposals for laws and legislation, as well as research and study. As for the council of water management, it is composed of 13 members with functions such as decision-making and authorization. The powers and competence of the minister, and the appointment of the secretary and director general, are defined in the law. It is notable that the law describes the creation of an investment environment for the water industry, and coordination of activities with the relevant national authorities. In addition, the law includes the critical sentence, “Water is a common right for all without distinction or monopoly or class or individuals”.

However, this law has not been approved by the state legislative council. The state legislative council was dissolved in 2019, and the council has not been formed since then. It is planned that the Water Law, once enacted by the new state legislative council, will replace the previous Water Corporation Law of North Kordofan State.

4.3.2 Natural Conditions

(1) Climate

Precipitation in North Kordofan State gradually changes from 50mm/year in the north to 500mm/year in the south, as shown in Figure 4.3-4. North Kordofan is the one of the most arid states in Sudan. As a result, it has fewer renewable water resources than the other states.

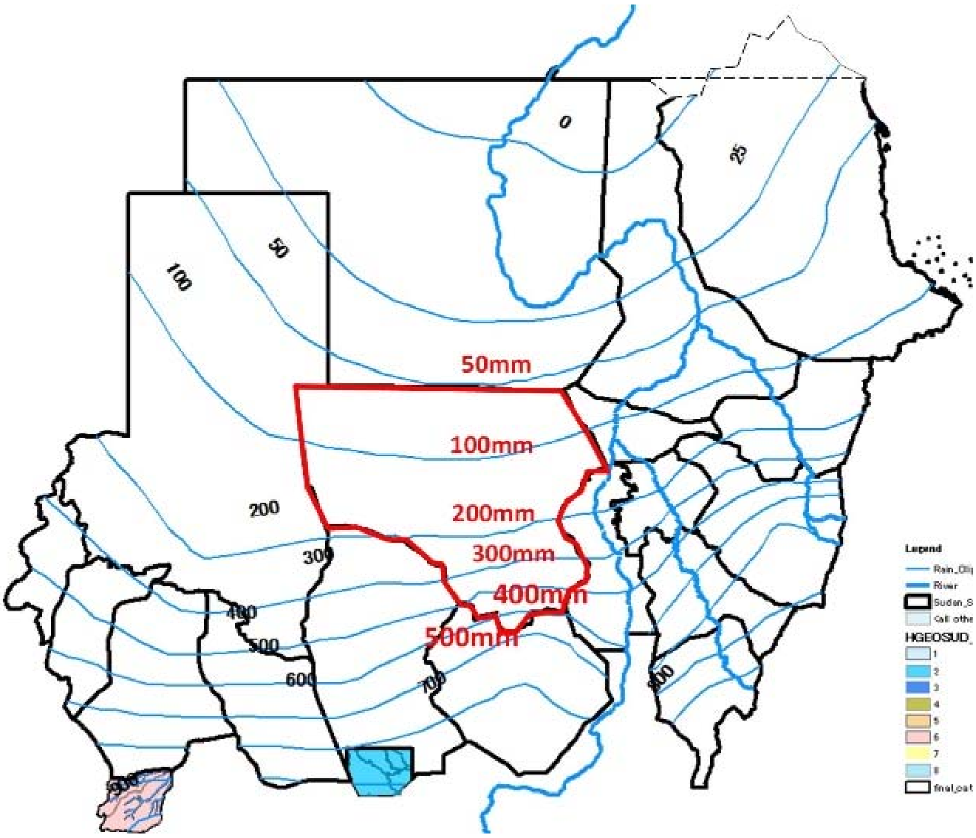


Figure 4.3-4 Annual Precipitation of North Kordofan State

(2) Topography

The topographic features of the area are shown in Figure 4.3-5. The highest point of elevation in North Kordofan State is 1,262 m and the lowest point is 251 m. The topography of North Kordofan State is very flat overall. Most of the state gently dips from southwest to northeast. However, the southernmost part of the state dips from the north to the south. This topographical configuration affects the wadi distribution in North Kordofan State.

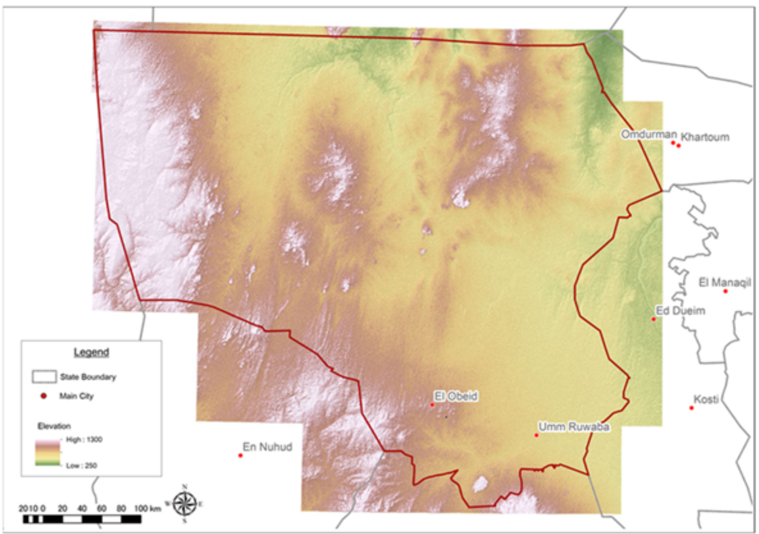


Figure 4.3-5 Land Elevation of North Kordofan State

(3) SW Resources

The river basin of North Kordofan State is shown in Figure 4.3-6. As shown in the figure, this river basin is divided into two areas below:

- Northern River Basin
- Abu Habil River Basin

The watershed dividing the aforementioned river basins extends from west to east in the southernmost part of North Kordofan State. El-Obeid is located near the boundary of this watershed, so El Obeid can effectively use the water resources of both the Northern River Basin and the Abu Habil River Basin.

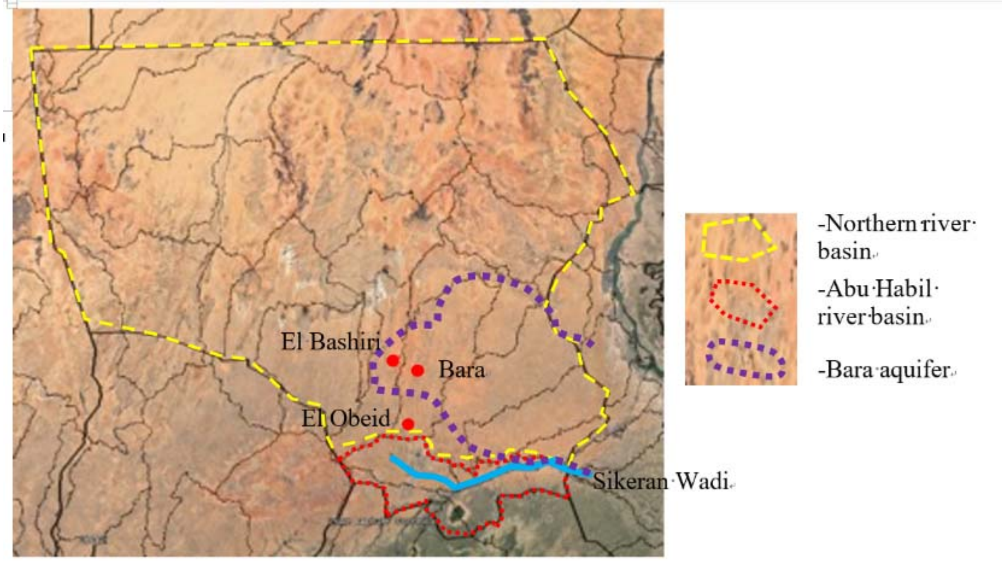


Figure 4.3-6 River Basin North Kordofan State

Satellite Image Source: Landsat

<u>Northern River Basin</u>

Wadis in the Northern River Basin generally extend from the south to the north, disappearing into the desert. Precipitation is very low in this region, and wadi flow is also scarce. There are livestock zones and rain-fed agricultural zones in the northern regions, where development is significantly delayed compared with other areas of North Kordofan State.

<u>Abu Habil River Basin</u>

Wadi Abu Habil, which is representative of wadis in Sudan, is located in the southernmost part of North Kordofan State. Abu Habil flows from the west to the east. There are some tributaries of Abu Habil within North Kordofan State. These tributaries experience a considerable amount of river flow in the rainy season, and they are used as a source of the urban water supply for El-Obeid and the other cities of North Kordofan State.

(4) GW Resources

The aquifer of North Kordofan State is classified into three (3) groups as below (see Figure 4.3-7):

- Basement complex
- Nubian sandstone
- Bara Aquifer

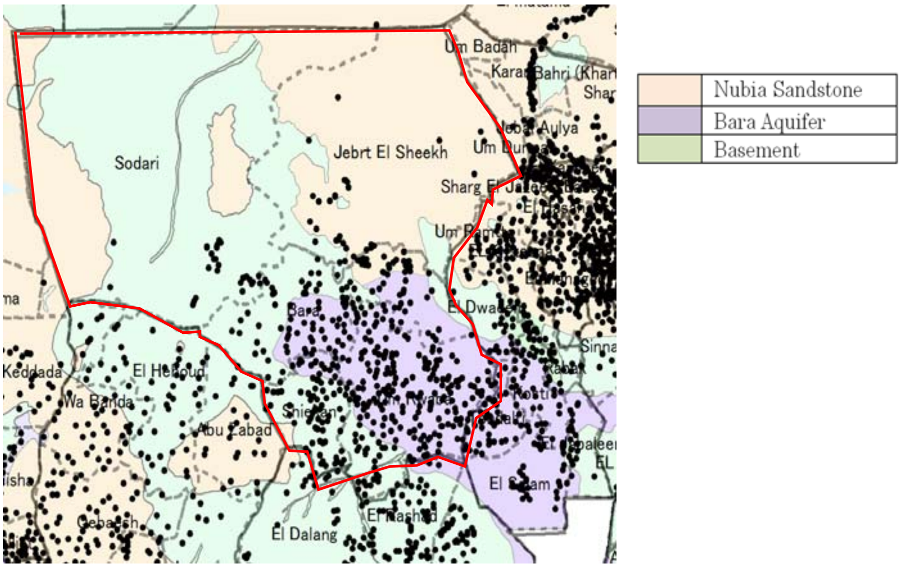


Figure 4.3-7 Distribution of Aquifers in North Kordofan

Basement Rock

Basement rocks (granite and metamorphic rocks) are distributed in the south of El-Obeid. Basement rock shows low permeability, which is not suitable for large-scale GW development. Therefore, wadi water is mainly developed in this region, and the wadi water of the tributaries of Abu Habil is stored in water-harvesting dams and hafirs in the south of El-Obeid, to supply water for urban and rural areas. The low permeability of the basement rocks has negative consequences in terms of GW development. However, this characteristic of basement rocks becomes a positive factor in the case of hafirs and water-harvesting dam construction, as water leakage from the bottom of the hafirs and dams is minor due to the low permeability. Moreover, topographic undulation is relatively rigorous in the basement rock area, which creates suitable conditions for the construction of water-harvesting dams.

Nubian Groundwater Basin (Nubian Sandstone)

The Nubian Groundwater Basin is located north of the Bara Sub-Basin. The Nubian Groundwater Basin experiences less precipitation than the Bara Sub-Basin. Reflecting this natural condition, the population is smaller in the Nubian Groundwater Basin than in other areas of North Kordofan State. As a result, this area is less developed than the other areas, and only the livestock zone is widespread. GW is the main source of water supply in this area, as wadis have not been developed. However, the GW development potential has not yet been assessed, therefore, GW development is also delayed overall.

Bara Groundwater Basin (Bara Aquifer)

The Bara Groundwater Basin comprises excellent aquifers that consist of sand layers with high permeability. Aquifers are divided into shallow areas (0 to 50m) and deep areas (160 to 300m) with a semi-permeable layer lying between the shallow and the deep aquifer. In this region, wadis are not fully developed due to the sandy soil of the wadi beds, which promotes the active infiltration of wadi water from the wadi beds into the ground. Similarly, the construction of water-harvesting dams and hafirs is not effective, due to the high permeability of the soil covering the ground surface of the dams and hafirs. The topography of the Bara Groundwater Basin is extremely flat, which is also unsuitable for the construction of water-harvesting dams.

Relationship Between the Population and Aquifer Distribution

As shown in Figure 4.3-7, it is very clear that the population is distributed unevenly in North Kordofan State. Many towns and villages are distributed within the Bara Sub-Basin area. In contrast, few towns and villages are distributed in the basement rock and Nubian sandstone areas, except for the southernmost part of North Kordofan State, where Abu Habil is located. This suggests that water can be more easily obtained in the Bara Sub-Basin than in the basement and Nubian sandstone areas.

(5) Water Issues in North Kordofan State

The water issues of North Kordofan State were analysed at the beginning of the pilot activity. Huge quantities of GW are used for many purposes, including domestic and irrigation use without GW monitoring, which will threaten sustainable GW use in the future.

The source of the water supply for El Obeid, the capital of North Kordofan State, is the GW in the North and SW in the South (see Figure 4.3-8). GW sources have issues regarding sustainability with large amounts of GW being pumped up from 40 deep wells in the Al Sidir Wellfield. However, the monitoring of the GW level was not carried out. The actual situation regarding the GW level is not known to date, although some researchers in universities have pointed out that the GW level of the Al Sidir Wellfield might be decreasing rapidly due to over-pumping.

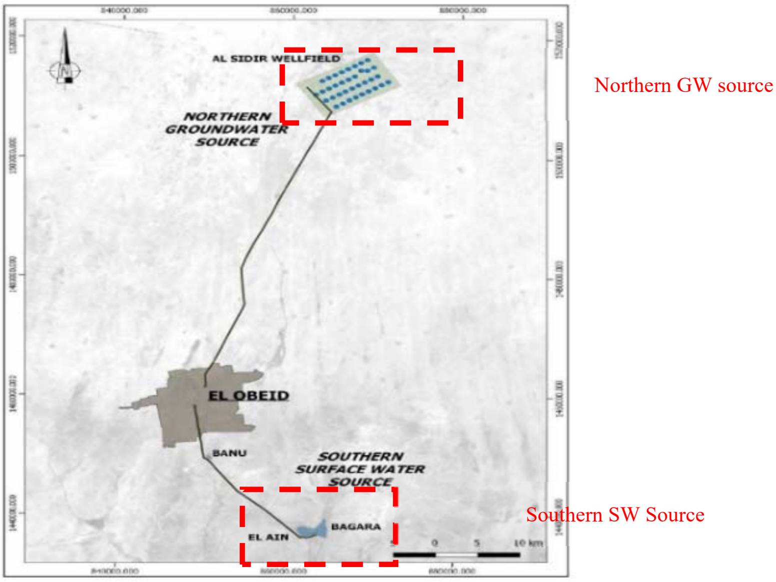


Figure 4.3-8 Water Sources for El Obeid

The GW level was observed from 2001 to 2013 (see Figure 4.3-9). According to the result of the observation, a drawdown of the GW level was observed during this period. This means that the GW level is decreasing at a rate of 1.5m to 2.3m each year, however, observation of the GW level has been suspended since 2014.

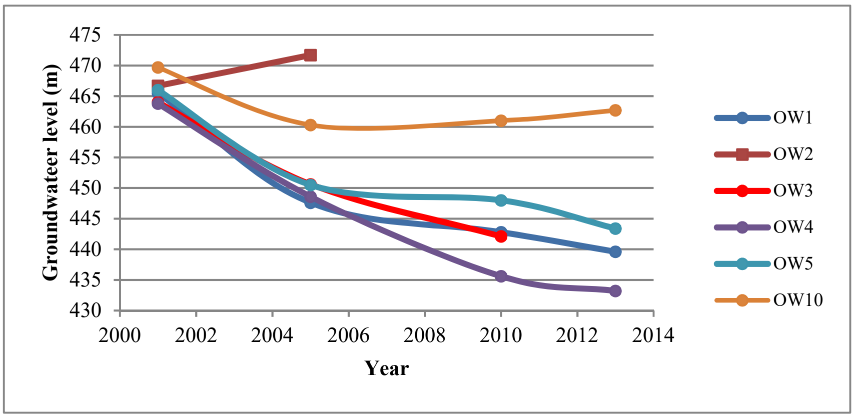


Figure 4.3-9 Monitoring Results of the Al Sidir Wellfield

Bara town, the capital of Bara locality, is located near the Al Sidir Wellfield and a great deal of GW is being pumped up for domestic and irrigation use from shallow hand-dug wells in Bara town. The drawdown of the GW level of shallow wells is assumed to be the result of over-pumping in the Al Sidir Wellfield. In general, the GW of the shallow aquifer will move to the deep aquifer, if large quantities of GW are pumped up from the deep aquifer (see Figure 4.3-11). Therefore, the GW level of the shallow wells in Bara town will decrease as a result of GW pumping from the deep aquifer of the Al Sidir Wellfield. Moreover, the drawdown of the GW level in the shallow wells of Bara town is due to over-pumping in many shallow wells within the town, as shown in Figure 4.3-10.

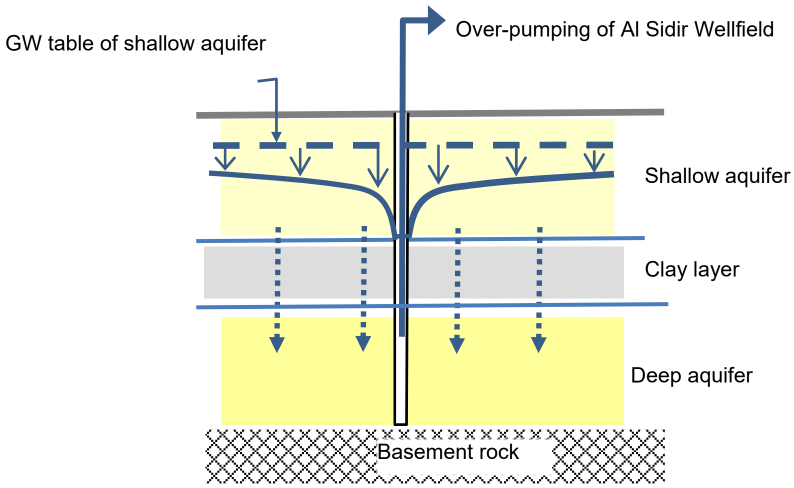


Figure 4.3-10 Well Interference in Bara Town

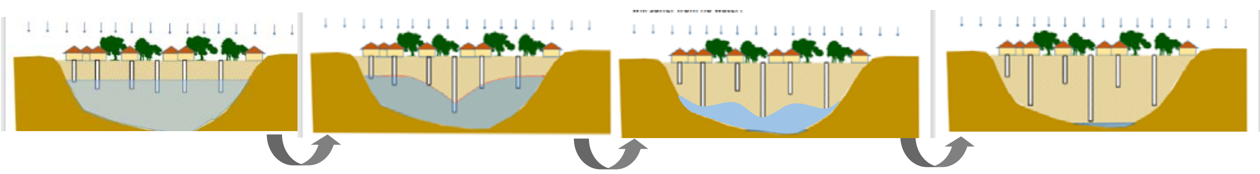


Figure 4.3-11 Land Elevation of North Kordofan State

<u>Analysis of Water Problems</u>

The water problems and the structure of the Bara area was analysed by the JPT, as shown in the problem structure (see Figure 4.3-12). Based on this initial analysis, the water issues of the area were confirmed through a series of workshops with stakeholders and water users.

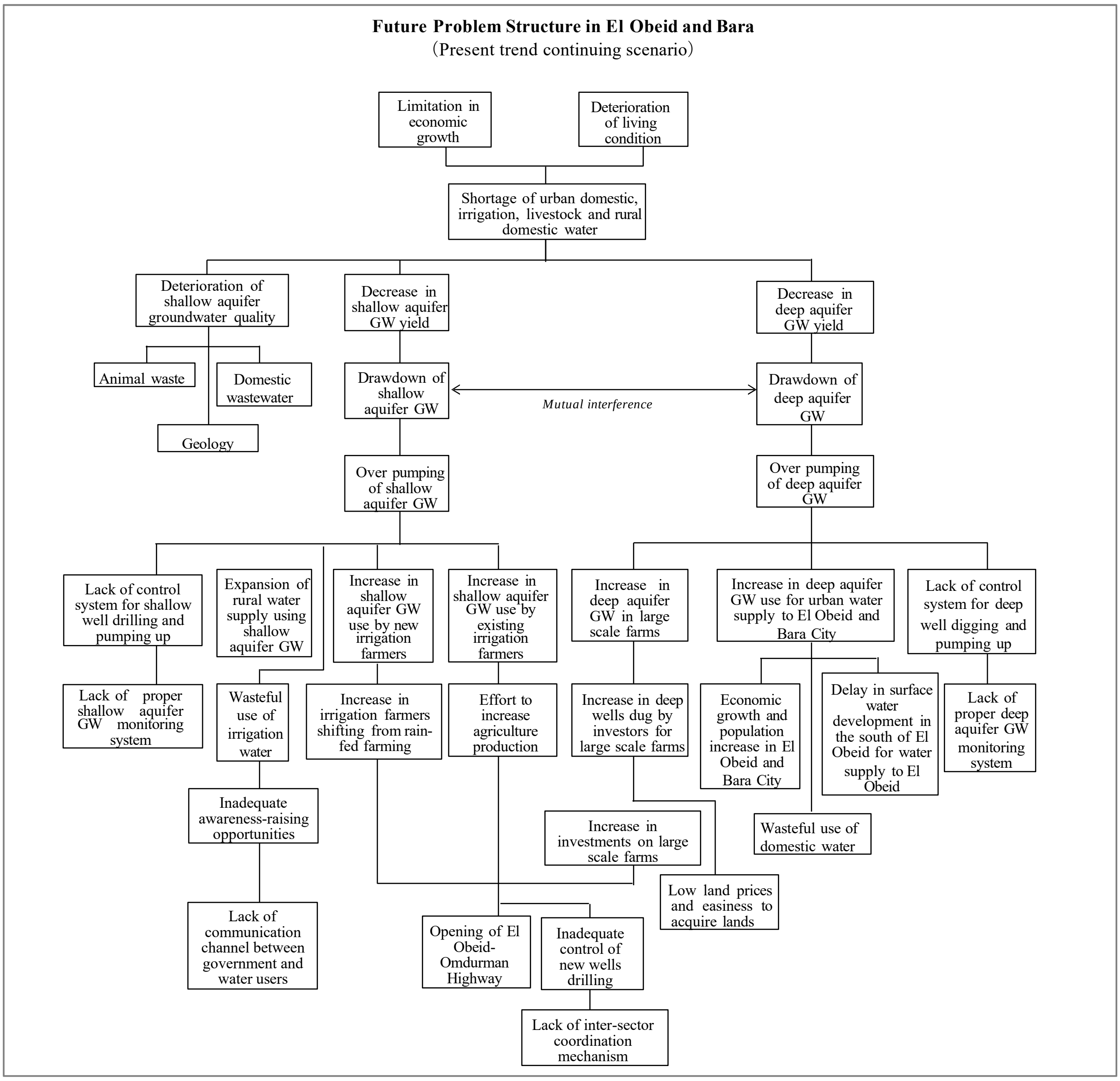


Figure 4.3-12 Structure of Water Problems in the Bara Sub-Basin

4.4 Overview of the Pilot Activities

4.4.1 Objectives and Selection of the Pilot Activities

The objectives of the pilot activities are the following:

- to evaluate the risk of GW depletion in the Al Bashiri Sub-Basin, identify the required actions to minimize such a risk and implement these on a pilot basis to assess their effectiveness
- to implement various water resources management activities in a mutually supportive manner under a model organizational structure for IWRM promotion
- to propose recommendations for promoting IWRM in North Kordofan and Sudan. based on the experiences of the pilot activities

The selected pilot activities are shown in Table 4.4-1 in relation to the outputs, the contribution to solving problems and the identified water problems in Bara: drawdown of shallow aquifer GW and deep aquifer GW and the deterioration of shallow aquifer GW quality. The process of selecting these pilot activities is shown in sub-section 4.4.2.

Table 4.4-1 Selected Pilot Activities in Relation to Water-Related Problems in Bara

Pilot Activity	Output	Contribution to solving the problem	Relevant Problem
Monitoring			
Groundwater Monitoring	Capture the situation of Groundwater level and share the results with SWRC	Provide data for technical analysis such as water balance analysis for assessing the need for controlling groundwater extraction amount	Shallow/deep aquifer groundwater drawdown
	Capture the situation of Groundwater quality and share the results with SWRC	Provide the scientific base for assessing the need for groundwater quality control	Shallow aquifer groundwater quality
Surface Water Monitoring	Capture the situation of surface water in Shikeran Wadi basin, and share the results with SWRC	Provide data for technical analysis to assess the water supply potential, the capacity to meet water demands in El Obeid and the possibility of reducing the deep aquifer groundwater supply From Al Sidir to El Obeid	Deep aquifer drawdown
Water Quality Monitoring	Capture the groundwater quality in Bara, and share the results with SWRC	Provide the scientific base for the need of water quality improvement	Shallow aquifer groundwater quality
Database creation	Store existing data and accumulate data collected by monitoring in a systematic manner and share the results with SWRC	Provide data for technical analysis and scientific base for the groundwater licensing system	Shallow aquifer drawdown
Groundwater licensing	Control the new well drilling and the groundwater extraction amount, and report to SWRC for advice	Control the amount of shallow aquifer groundwater extraction amount	Shallow aquifer drawdown
Water-saving irrigation	Reduce the amount of irrigation water use, and share progress and issues at SWRC for advice	• Reduce the shallow aquifer groundwater extraction amount • Increase crop yield • Reduce fertilizer cost • Reduce GW pollution	Shallow aquifer drawdown Shallower aquifer GW quality
Creation of SWRC structure	Provide a venue for information sharing, consensus-building and decision-making for all the Pilot Activities and related policies and programs to achieve sustainable use of Bara's groundwater resource.	• Increase the level of cooperation of well owners/users in controlling the shallow aquifer extraction amount and quality (vertical) • Mobilize relevant stakeholder organizations in encouraging water users for better control of groundwater resources (horizontal)	• Shallow aquifer drawdown • Shallow aquifer groundwater quality

In the following sections, the terms "groundwater license" and "well registration" are used interchangeably. They are closely correlated, as those wells which obtained a license are registered. When the pilot activities started in North Kordofan, "well registration" was used often, but later, when the MIWR's initiative was linked to the pilot activities, the term "groundwater license" also began to be used in relation to the 2016 Groundwater Act.

At the initial stage of the pilot activities, El Obeid and Bara were assumed to be the target areas for the pilot activities. A workshop was held with El Obeid water users to clarify their problems. It was subsequently agreed among the state C/Ps and the JPT that the pilot activities would focus on the Bara area, as the water problem in El Obeid itself is a huge and challenging task and involves mainly the water supply aspect rather than the water resources aspect. They judged that the Bara area has a higher possibility of taking advantage of the IWRM approach.

4.4.2 Selection of Pilot Activities

The selection of pilot activities was made during the following three stages from January to February, 2019:

- Preliminary selection by the North Kordofan C/Ps of the General Directorate of Water Resources under the MIUD and the General Directorate of Groundwater and Wadi (Kordofan office)
- Discussion within the TC on 10 February, 2019
- Final selection by the SC on 14 February, 2019

The TC and the SC were formally established as the supervisory bodies for the JICA IWRM Project activities by the North Kordofan State decree, dated 12 March, 2018. While the TC is chaired by the MIUD General Director in charge of water and responsible for technical discussion, the SC is chaired by the MIUD Minister and is responsible for decision-making. Both the SC and TC comprise members of the state ministries in charge of water, agriculture, forestry, environment and investment.

<u>Preliminary Selection of Pilot Activities by the C/P Team</u>

The pilot activities were preliminarily selected by the C/P team with the JPT's facilitation, following the steps shown in Figure 4.4-1 below:

Activities planned in 2019 Budget	Possible Problems Associated with the activity at:		IWRM-oriented solutions to possible problems	Relevance to IWRM Activities in Bara (high or low)	Time Frame (short, medium, long)	Relevant ministry, GD and organization
	Development Stage	OM Stage				
(Example)						
Drilling 54 wells	Low successful rate due to limited access to data	Drawdown due to over pumping	• Creation of an integrated database • Creation of a well registration system	High	Short-term	• GD Water Resources • GWW

(1) Refer to the existing document prepared by North Kordofan Government

(2) Identify problems associated with the 2019 planned activity

(3) Indicate IWRM-oriented solutions to the problems

(4) Assess relevant to IWRM activities in Bara

(5) Indicate time frame

(6) Indicate relevant office

Figure 4.4-1 Steps for the Preliminary Selection of Pilot Activities

Step (1): Listing of water-related activities in the 2019 budget of the North Kordofan government

Step (2): Identification of the problems in undertaking the planned activities, first hypothetical identification of problems referring to the results of the problem analysis conducted in Phase-1, followed by an assessment by the C/Ps considering the actual situation in North Kordofan

Step (3): Identification of possible solutions, especially IWRM-oriented solutions, to resolve those problems

Step (4): Assessment of the relevance of these solutions to Bara area

Step (5): Classification of the solutions by timeframe: short-term (1-2 years), medium-term (5 years), long-term (10 years)

Step (6): Identification of responsible ministry and general directorate

This approach of starting with the existing 2019 budget activity plan was adopted to create strong links between the planned activities by the North Kordofan government and the pilot activities to be implemented under the JICA IWRM Project. This approach would enhance the motivation of the C/Ps because the quality of their regular work would be improved, as they would engage in the JICA Project pilot activities. Through this process, these activities were found to be highly relevant to the Bara area and were classified as short-term actions as follows:

a) GW database creation
b) Hydrogeological survey
c) Monitoring
   c)-1 Shallow aquifer monitoring
   c)-2 Deep aquifer monitoring
   c)-3 GW quality monitoring
   c)-4 SW monitoring
d) Creation of well registration system
e) Promotion of water-saving irrigation
f) Improvement of investment approval process
g) Assessment of the impact of solar power introduction on the amount of GW use in water yards
h) Assessment of the impact of GW transfer from Bara to Mazroub, located in the basement rock area on the GW balance of Bara
i) Integration of water meter installation in water yards into the monitoring system
j) Improvement of El Obeid urban water supply
k) Water balance analysis in relation to the drilling of around 30 boreholes at Al Sidir and Bagara

<u>Screening at TC</u>

The TC meeting held on 10 February, 2019 discussed the preliminary list shown above. The TC agreed to remove some activities as follows:

- The "improvement of the investment approval process" was judged "not necessary", reflecting the view of the Investment Commission Officer that coordination is sufficient, despite the opposing views of other participants that the water issue had not been adequately assessed at the investment approval stage.
- The "assessment of the impact of GW transfer from Bara to Mazroub located in the basement rock area on the GW balance of Bara" was dropped because a technical study has already been confirmed.
- The "improvement of El Obeid's urban water supply" was not included because it is difficult to deal with such a major issue in one year, and the GWWD is already taking care of it.
- The "water balance analysis in relation to the drilling of around 30 boreholes at Al Sidir and Bagara" was not included because the drilling of wells at Al Sidir will not affect the total amount of GW extraction, and the extraction at Bagara is for stand-by purposes.
- The "technical review of Er Rahad Turda" was not included because (i) a study is planned to review the possibilities of vertical and horizontal expansion, (ii) geological fractures are not an issue, as they are covered with basement soil and (iii) the fluorine problem is found in a different watercourse.

The C/Ps estimated the costs of each of the activities in the preliminary list with the support of the JPT prior to the TC meeting. The screened pilot activities and their costs are shown in Figure 4.4-2 below.

Table 4.4-2 Short-Term Actions Selected by the Technical Committee

Candidate Activity	Budget (SDG)
1. Database creation	130,000
2. Hydrogeological survey	
3. Monitoring	
3.1 Shallow aquifer monitoring	438,000
3.2 Deep aquifer monitoring	135,000 (manual) 655,000 (automatic)
3.3 GW quality monitoring	726,500
3.4 SW monitoring	1,141,000
3.5 Assessment of the impact of solar system introduction on water use amount (to be integrated into monitoring)	30,000
3.6 Integration of water meter installation	None
4. Well registration system creation	Internal
5. Water-saving irrigation promotion	Need review
Total	(Manual) 2,600,500
	(Automatic) 3,115,500

<u>Approval by the SC</u>

The SC meeting held on 14 February, 2019 approved the TC's proposal with the addition of two issues: the establishment of an IWRM unit and the transfer of the operational responsibility of rural water supply systems to villages.

The Sudanese side requested an extension of the JICA Project period, so that JPT will be able to support the implementation of short-term actions by the Sudanese side. Establishing an IWRM unit was proposed by the TC due to the need for a unit responsible for managing all aspects of water resources management from a sustainability and comprehensive perspective. The state-level C/P group will need to be nominated to take charge of short-term action preparations and implementations, and this group will be the core of the IWRM unit once it is established. The IWRM unit will function as the secretariat for the North Kordofan State Water Council to be established in the future.

The transfer of the operational responsibility of rural water supply systems to villages was added as a result of a discussion within the SC. However, this subject was dropped from the list of short-term actions later in the SC meeting.

<u>Modification of Pilot Activities and Pilot Activities Implementation Structures</u>

A number of modifications were made to the list of pilot activities shown in

Table 4.4-2 as follows.

- The "hydrogeological survey" was dropped because the C/Ps considered that it would be better to concentrate on organizing the existing but scattered data, by creating a database rather than collecting new data through geological surveys.
- The "assessment of the impact of solar system introduction on the quantity of water use" was dropped

because it was found that the MIUD would not implement the solar system in Bara.

- The "integration of water meter installation" was dropped because it was later discovered that the North Kordofan government planned to install 2,000 water meters for the institutional water users in El Obeid, therefore duplication of similar activities should be avoided.
- The "establishment of the SWRC" was added after the United Nations Environment Programme (UNEP) withdrew its support in early 2020.

The pilot activities started under the initial implementation structure as shown in Figure 4.4-2. The four pilot activities were undertaken by the North Kordofan State C/P team with the support of the JPT. Although the establishment of the IWRM unit was approved by the SC, there was no substantial change and the C/P team continued undertaking the Project work under the same conditions. At this stage, only the four pilot activities were targeted and the creation of the SWRC was not included, as UNEP was supporting the North Kordofan government in relation to this issue. It was assumed that the pilot activities would be transferred to and continued by the SWRC after the JICA Project ended and once the SWRC was established,

Around one year after the initiation of the pilot activities, the implementation structure evolved to that shown in

Table 4.4-2. Following the withdrawal of support of the UNEP in the establishment of the SWRC, the JPT took on the support role and added the creation of the SWRC structure, including the official launch of the IWRM unit to the pilot activities. The problems shown in Figure 4.4-2 are significant issues observed by the stakeholders. The SWRC structure may be a solution to solving these specific problems by strengthening horizontal, inter-sectoral coordination and vertical, inter-hierarchical coordination. Adding this component to the pilot activities is critical to GW management in Bara. There should be a mechanism by which well owners and operators clearly understand the situation and future risk of Bara's GW and take the necessary measures to minimize the future risk of GW depletion. Containing the total extraction quantity of GW within a sustainable level is only possible with their cooperation. Since many of them are irrigation famers, the involvement of the General Directorate of Agriculture of the Ministry of Economic Production is essential.

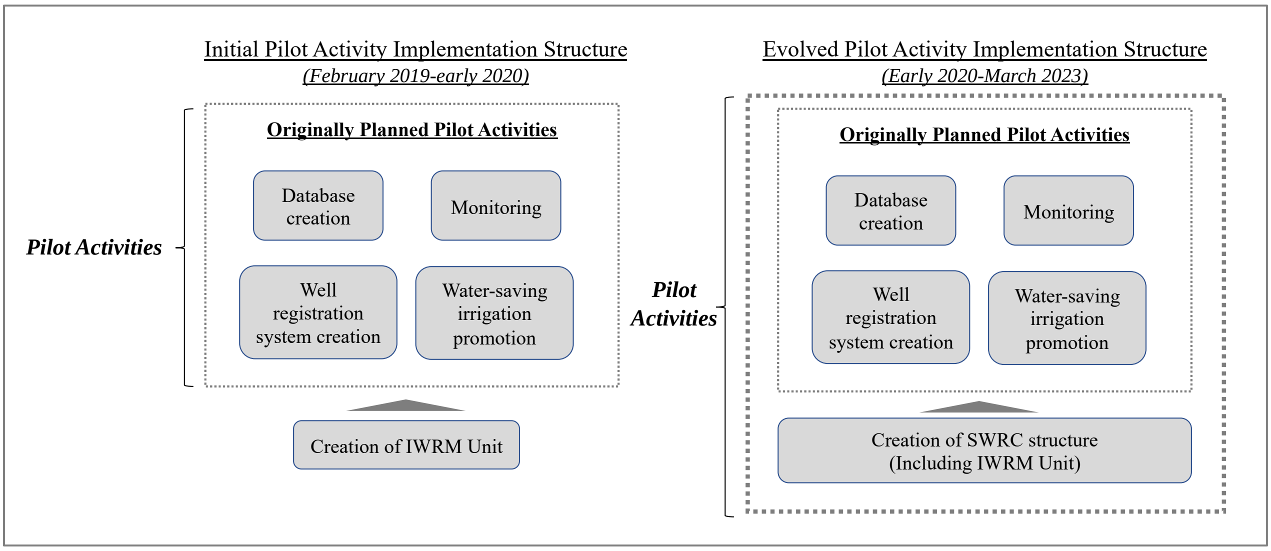


Figure 4.4-2 Implementation Structures of Pilot Activities

National Water Resources Council (NWRC)

The revitalization of the NWRC was added as as a subject of JPT's support for the MIWR C/Ps, when the 1995 Water Resources Amendment Act（"the Amendment" hereafter） was passed in August 2021. The MIWR C/Ps had been visiting North Kordofan State in order to experience the IWRM implementation on the ground, by participating in the pilot activities, when they were initiated in August 2019. They were expecting that their experiences in North Kordofan would be utilized effectively in the future to disseminate IWRM in other states in Sudan. The enactment of the Amendment in August 2021 provided a legal framework for promoting IWRM in Sudan. The MIWR C/Ps began to formulate an appropriate way of revitalizing and strengthening the NWRC structure with the support of the JPT and arranged their visits to North Kordofan with a clearer view of the future direction of IWRM dissemination in Sudan.

4.4.3 Establishment of Organizational Structure for IWRM Promotion

(1) SWRC

1) Background and Objectives

As explained in 4.4.2, support for the establishment of the SWRC was added to the pilot activities around a year after their commencement. The objective of the creation of the SWRC was to provide an opportunity for the state government to communicate with water users and coordinate the activities of different sectors to achieve better water resources management. The SWRC is especially needed for an area like Bara where the major water source is GW and a substantial amount of GW is extracted without any control. The people and the government have recently begun to comprehend the risk of GW depletion in Bara with some signs of a drawdown. Well owners and operators are using GW that they extracted themselves, both individually for irrigation purposes and as a community for domestic use. They are water users, but also water suppliers at the same time. For this reason, their involvement in GW resources management is essential. Since the largest proportion of GW is used for irrigation purposes, it is necessary for the MIUD in charge of water to cooperate with the General Directorate of Agriculture of the Ministry of Economic Resources in charge of agriculture to encourage irrigation farmers to use GW more carefully.

In the past, there has been no such mechanism in North Kordofan whereby the government and water users share technical information and cooperate with one another to improve GW management. The following activities were undertaken during the pilot activity to establish the SWRC:

- Review of the UNEP's proposal
- Preparation of a proposal to the governor indicating objectives, functions, membership, structure, frequency of meetings, office, budget, etc.
- Preparation of a proposal for the formal launching of the IWRM unit
- Guidance on meeting management (timing of meetings, determination of agenda, time management, etc.)
- Creation of a mechanism of SWRC-TC-WUC that would ensure vertical and horizontal coordination and according to which actions for improving GW management in Bara are taken by water users with the support of the SWRC, TC and the IWRM unit.

Details of these activities are shown below.

2) Chronological Development of the SWRC Initiative in North Kordofan

The establishment of an organizational structure for promoting the IWRM in North Kordofan proceeded in the following three stages.

- Period when UNEP was leading the initiative in establishing the State Water Council (April

2018-early 2020)

- Period when the JPT took over the initiative (early 2020 to February 2022)
- Period when the SWRC was formally established and started to function (February 2022 to May 2023)

The major events in each of these three stages are explained below:

2-1) UNEP's Initiative (April 2018-early 2020)

UNEP started to support the North Kordofan government in establishing a State Water Council following its similar experience in Kassala State. When the JPT started its activities in North Kordofan in June 2018, UNEP had already been supporting this initiative. Although UNEP and the governor at that time came to an initial agreement on the establishment of the State Water Council, UNEP suddenly withdrew its support unexpectedly in early 2020.

The organizational structure for implementing the JICA Project activities was specified by a state decree. A TC and SC were established to oversee and manage the JICA Project activities. The TC was responsible for sharing information among the technical level officers of the relevant state government officers, discussing technical issues and making proposals to the TC. The SC was responsible for making a decision based on the proposals of the TC, including budget allocation.

The JPT's policy during this stage was to support the UNEP initiative, while undertaking pilot activities with the assumption that the functions of the SC and TC for the JICA Project would be transferred to the State Water Council once established. Unfortunately, this transfer did not take place due to the withdrawal of the UNEP.

Table 4.4-3 summarizes the content of the proposal by UNEP on the establishment of a State Water Council.

Table 4.4-3 UNEP's Proposal on the State Water Council

1. Objective	Advisory body responsible for the better management of natural resources, especially water, and strengthening coordination between government institutions and international organizations
2. Functions	(i) Awareness raising of communities and beneficiaries (ii) coordination between sectoral institutions (iii) identification of strategic frameworks and development of general principles of natural resources management (iv) promotion of IWRM principles (v) knowledge building of the council (vi) development of policies and legislation related to natural resources, especially water, (vii) monitoring and evaluation of the council's activities (viii) coordination with other states and the Federal Water Resources Council
3. Membership (23 in total)	(Chair) Environmental Council (co-chair) Ministry of Physical Planning (Rapporteur) Ministry of Water Resources, Irrigation and Electricity (members) Ministry of Agriculture and Forestry, Ministry of Finance, Humanitarian Aid Commissioner, Ministry of Social Affairs, Ministry of Livestock, Water Association users, localities' representatives, Legal Department, Radio and TV Corporation, Legislative Council, universities' representatives, legal advisor in North Kordofan State, Civil Administration, international organization representatives, national organization representatives, youth, researchers, banks' private sector, mining

2-2) Preparation of the SWRC with the JPT's Support (early 2020-February 2022)

<u>Participatory Consensus-Building Process of the JICA IWRM Project</u>

The JPT decided to take over the role of UNEP in supporting the North Kordofan C/Ps with the establishment of a State Water Council.

The JPT's support at this stage took the form of undertaking the pilot activities under the implementation structure specified by the state decree with the TC and SC, as well as facilitating discussions between the state C/Ps and federal C/Ps on the desirable structure and operation of the SWRC. The term State Water Resources Council was used with the addition of "Resources" to avoid confusion with the SWC, or State Water Corporation, responsible for the water supply service.

Figure 4.4-3 below shows the concept of participatory consensus-building applied in undertaking the pilot activities. This process was pursued not only for effective implementation of the pilot activities, but also as a practice process ahead of the SWRC being formally established.

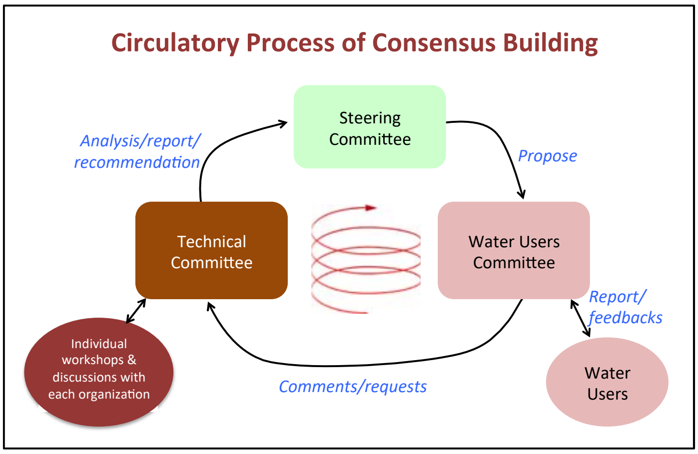


Figure 4.4-3 Participatory Consensus-Building Cycle

The consensus-building process is circulatory, as important issues regarding the IWRM are discussed and agreed upon by three important stakeholder groups and these occur in a circulatory manner: the WUC composed of representatives of water users, the TC mainly with technical officers, and the SC chaired by the MIUD Minister. Their functions are as follows:

WUC

- The WUC functions as a bridge between the state government and water users. The problems faced by water users and requests are transmitted to the state government through the WUC.
- In turn, messages and relevant information from the state government reach water users through the WUC.

TC

- Technical information related to water resources and accumulated by C/Ps with the support of the JPT is shared with representatives of the relevant state government ministries and directorates (agriculture, forestry, environment, investment, finance and economy, etc.). The findings from the implementation of pilot activities were shared, such as the results of monitoring and water balance analysis, database creation, the introduction of the GW license system and irrigation water saving.
- The TC reviews the messages and requests from the WUC and integrates them into their technical analysis.
- The TC makes a proposal based on the discussion among TC members and submits it to SC.

SC

- The SC makes a decision concerning the proposal submitted by the TC.

A successful example of this circulatory process can be found during the TC and SC meetings in February, 2019. Two separate meetings were held by the TC on 10 February and by the SC on 14 February. The TC members discussed and selected a set of pilot activities to be implemented as the JICA Project activity, the details of which are shown in Section 4.4. The TC proposed them during the SC meeting chaired by MIUD Minister at that time and held on 14 February, 2019. The SC approved the proposal of the TC and promised to allocate the required budget of 3.1 million SDG.

Proposal on SWRC Creation

The preparation of a proposal on the establishment of the SWRC, with the JPT's support, started in early 2020, when the UNEP withdrew its support. It continued until December 2020 when a proposal was submitted to the North Kordofan governor. All the discussion sessions took place remotely due to the travel restrictions imposed on the JPT experts as a result of the COVID-19 situation.

The UNEP's proposal was reviewed and modified, taking into account the experiences accumulated by implementing the pilot activities under the JICA's participatory consensus-building structure.

An outline of the proposal is presented in Table 4.4-4 below:

Table 4.4-4 Outline of the Proposal on SWRC Establishment

1. Objective	The SWRC aims to provide all the water related stakeholders with opportunities to share information, discuss important water issues and find solutions together, based on scientific judgement and the IWRM principles.
2. Mandates	(a) Raising the awareness of the communities and beneficiaries to improve the management of water resources, by introducing them to the concept of IWRM. (b) Coordinating the sectoral institutions working in the field of water and natural resources management in North Kordofan State and improving the links between governmental institutions and local communities, to promote the joint management of natural resources in all basins and wadis. (c) Defining strategic frameworks, setting general principles related to water resources management and creating a roadmap for improving water resources management within the state in a sustainable manner. (d) Contributing to providing coordination, support, advice and counsel on the rational management of water resources, based on engineering and technical analysis. (e) Reinforcing council knowledge so that it has the ability and influence to make decisions related to water, to move the wheel of sustainable development within the state. (f) Developing policies and legislation related to natural resources, especially water, and supporting the explanation of such policies, legislation, customs and standards, in particular, in the field of water resources management. (g) Following up on the monitoring and evaluation of activities related to water resources management. (h) Coordinating transboundary GW and SW resources with the state and other participating states, as well as with the Federal Water Resources Council. (i) Providing advice and technical support on licensing in relation to all forms of water, including GW and SW and transferring the application to the relevant authorities. (j) Responsibility for all the issues related to water in North Kordofan.
3. Structure	As shown below

The proposed structure of the SWRC is shown in Figure 4.4-4 below:

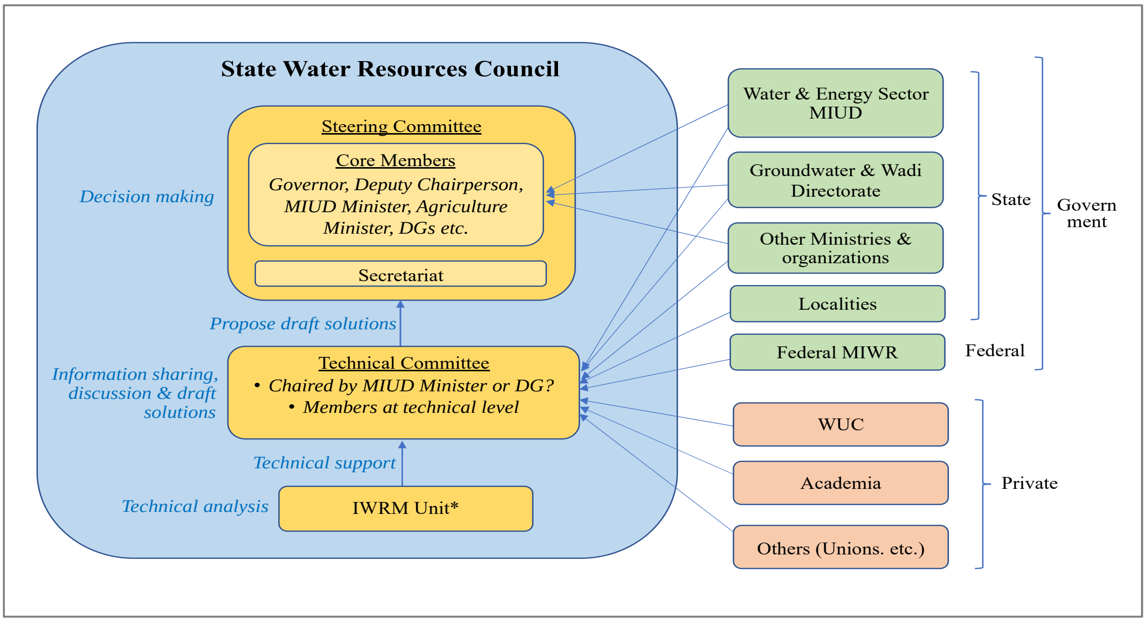


Figure 4.4-4 Proposed Structure of the SWRC

The proposed SWRC structure is characterized as follows:

- The SWRC has a multi-layer structure, similar to the JICA Project structure: SC, TC and IWRM unit. This whole structure is called the SWRC.
- The SC has the decision-making function, whereas the TC deals with technical issues at working level. The TC shares technical information, discusses technical issues and makes proposals to the SC in the same way as the JICA IWRM Project structure.
- This multiple-layer structure has been proposed, due to the effectiveness of a bottom-up approach, by which important, water-related issues are analysed at a technical level first, then brought up to a higher level for decision-making.
- The establishment of an IWRM unit is proposed. It is a permanent body undertaking regular work at the technical level and supports the TC and the SC. Its functions are described in detail later. The IWRM unit corresponds to the C/P group for the JICA IWRM Project.
- The WUC members will attend the TC on behalf of water users.

The proposed membership is shown in Table 4.4-5 below:

Table 4.4-5 Proposed Members of the SC and TC

SC	TC	
1. Governor, supervisor 2. Secretary General, deputy supervisor 3. Minister of Infrastructure and Urban Development, chair 4. Minister of Economic Production, co-chair 5. Head, Higher Environmental Council 6. Senior legal officer in N. Kordofan State 7. DG of the Water and Electricity Sector 8. DG of the Ministry of Economic Production	1. DG of the Water and Electricity Sector, MIUD, chair 2. DG of Agriculture in the Ministry of Economic Production, co-chair 3. Head, Higher Environmental Council (to be changed to a new name) 4. Representative of the Legislation Council 5. Representative of the Ministry of Economy and Finance 6. Representative of the Ministry of Social Affairs 7. Director of Groundwater and	10. Executive officer of Shikan locality 11. Executive officer of Bara locality 12. Representative of the University of Kordofan 13. Economic security officer 14. Pastoralist representative 15. Private sector representative 16. Director of Mining Sector 17. Representatives of the Water User Committees (2) 18. Director of the Livestock Department 19. Investment Commission

9. Director of Groundwater and Wadis at state-level	Wadis at state-level 8. Director of Water, Environment and Sanitation (WES) 9. Director of Rural Waters	20. Director of Forestry, Ministry of Economic Production

The difference from the JICA Project structure is that the governor and under-secretary, as the supervisor and deputy supervisor, respectively, participate in the SC. This arrangement was proposed in order to give sufficient weight to the SC, to enable smooth coordination across the different sectors.
The budget for 2021 was estimated to be SDG 19.4 million and has been included in the proposal.
The proposed IWRM unit will function in the way presented in Table 4.4-6 below:

Table 4.4-6 Functions of the IWRM Unit

Secretarial Functions	Technical Functions
• Printing materials, typing letters • Welcoming visitors • Preparing for meetings • Receiving issues from visitors and submitting them to the technical team of the IWRM unit • Coordinating meetings between the technical team of the IWRM unit, the TC and the SC • Sending of invitation letters to members • Linking with all the members of the WUC. Functioning as a focal point for water users	• Technical role including awareness, coordination, monitoring/evaluation • Connected to the TC and the SC of SWRC • Undertaking technical analysis: water level, water balance analysis, etc. • Creating a draft roadmap for IWRM promotion • Drafting policies and legislation • Giving advice and technical support to GW licensing

The TC and SC meetings held during this period are shown in Table 4.4-7 below. The TC and SC meetings under the JICA IWRM Project management structure were essentially held for the purpose of confirming the progress of the pilot activities, undertaken by the C/Ps with the JPT's support. The underlying concept was to support the North Kordofan C/Ps in developing their skills by summarizing the results of technical analysis and the progress of the pilot activities, preparing presentation materials, which are easy to understand for non-experts and making presentations. The state C/Ps undertook these works in preparation for the IWRM activities when the formal SWRC structure including the TC and the WUC are formally launched.

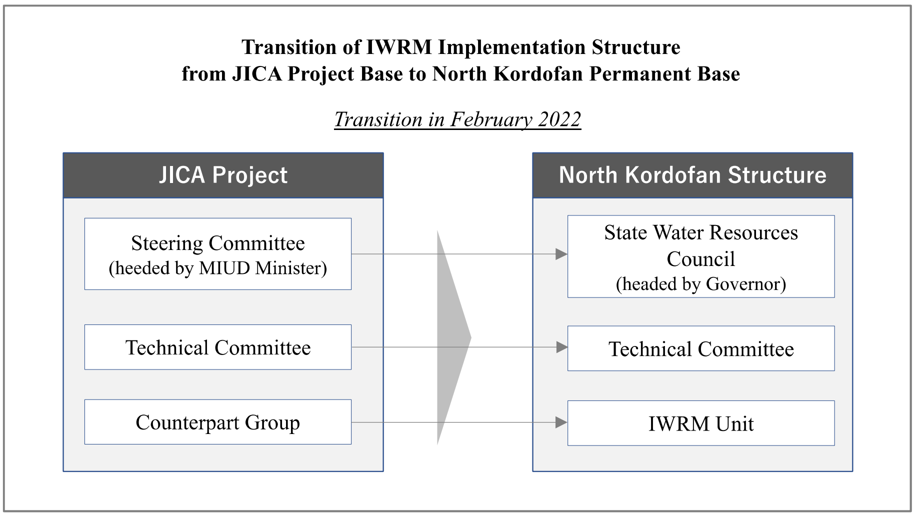
Table 4.4-7 SC and TC Meetings Under the JICA IWRM Project Management Structure

Date	Year	Type of Meeting	Main Agenda/Outputs	Remarks
12th July	2018	1st SC/TC	Activities plan for Phase 2 of JICA IWRM Project and discussions	Joint meeting
27th November		2nd SC/TC	Progress of pilot activities, status and prospect of consensus-building process, presentations and discussions on water issues, good practices of IWRM	Joint meeting
11th December		3rd TC	Consensus-building mechanism, water balance analysis, WUC, progress of baseline survey, environmental consideration in North Kordofan	
10th February	2019	4th TC	Selection of pilot activities	
14th February		3rd SC	Approval of pilot activities and budget	
3rd April		5th TC	Progress of pilot activities, schedule of the JICA IWRM Project and request by the	

			Sudanese side for its extension	
15th November		6th TC	Progress and schedule of the JICA IWRM Project, possibility of extension, outline of Progress Report 3, plan of activities from December 2019	Long interval due to social instability
26th November		4th SC		
6th February	2020	7th TC	Progress of pilot activities, schedule of the JICA IWRM Project, IWRM guidelines, functions and members of IWRM unit and WUC, schedule of pilot activities, environmental consideration and climate change, preparation of shallow well monitoring, topographic survey and wadi monitoring	
25th August	2020	8th TC	Progress Report-4 and presentations by C/Ps on pilot activities	Online
27th August	2020	5th SC		
9th November	2020	9th TC	Roles, structure and budget of SWRC, progress of GW monitoring, wadi monitoring, water quality monitoring and preparation of WUC	
9th December	2020	10th TC	SWRC (roles, membership, stakeholders, frequency of meetings, budget)	Proposed by the Sudanese side
11th March	2021	11th TC	Progress of the establishment of the SWRC, progress of the pilot activities, result of water balance analysis (over-pumping), solar disinfection (SODIS), African Development Bank (AfDB) aided water supply project	
18th March	2021	6th SC		
28th July	2021	12th TC/7th SC	Establishment of the SWRC, result of monitoring (instalment of automatic recorder), WUC meeting on 15 July, AfDB-aided water supply project, introduction of GW licensing pilot scheme, resolutions	Joint meeting
21st October	2021	13th TC	Establishment of the SWRC, monitoring results, water-saving irrigation proposed by the WUC and suggestions as to how the government can support the WUC, AfDB-supported water supply project (information on progress shared), progress of database creation, introduction of GW licensing pilot scheme, resolutions	

2-3) Formal Establishment of the SWRC (February 2022)

The SWRC and the TC were formally established in February 2022. Two decrees were issued on 20 February, 2022 by the North Kordofan government. Decree 13 stipulates the establishment of the SWRC, whereas Decree 16 establishes the TC. The term “Water Resources Council” is used in place of the “Steering Committee” in the proposal. The project-based, participatory, consensus-building mechanism under the JICA IWRM Project shifted to a permanent structure, constituting part of the North Kordofan government with relevant stakeholders as shown in Figure 4.4-5 below:



The membership, functions and frequency of meetings are determined as shown in

Table 4.4-8 below:

The set-up of the SWRC and the TC basically follows the proposal submitted by the C/P team. One important member was missing from the TC, who was the Director of Groundwater and Wadis from the Kordofan office; he was instrumental in the establishment of the SWRC and the TC. However, he was officially added to the TC in the first SWRC meeting held in April 2022. Despite the efforts of the North Kordofan C/Ps in preparing for the establishment of the IWRM unit, discussing its objectives, functions, activities, membership and office location, the establishment of the IWRM unit had not been formalized as of March 2023.

Table 4.4-8 Outline of Water Resources Council and TC Defined by Decree 13 and 16

	Water Resources Council	Technical Committee
Membership	(1) Governor (general supervisor), (2) General Secretariat (3) DG of MIUD (4) DG of Ministry of Production (5) DG of Finance and Economics Resources (6) DG of Water Sector (7) DG of Local Governance of North Kordofan (8) Manager of El Obeid Agriculture Station (9) Representative of the Legal Department (10) Manager of Bank of Sudan-El Obeid Branch (11) Secretary of Department of Zakat (12) Commissioner of Humanitarian Aid	(1) DG of the MIUD-Chief (2) DG of Ministry of Production and Economic Resources (3) DG of Water and Power Sector-member and rapporteur (4) Representative of the Ministry of Finance and Economy (5) Representative of the Employees in the Water Sector (6) Representatives of Rural and Urban Water (7) Representative of Pastoralists (8) Representative of the Private Sector (9) Representative of the Mining Sector in North Kordofan State (10) Representative of the Livestock Sector (11) Forest Director (12) Representatives of the Urban WUC (13) Representatives of the WUC
Functions	(1) Developing policy legislation related to natural resources, especially water (2) Providing coordination between sectors and institutions and improving links	(1) Preparing technical and evaluation studies for water resources in the state

	between government institutions and local communities (3) Defining strategic frameworks, setting general principles for managing water resources and creating a road map (4) Building on the knowledge of council members (5) Coordinating policy between the state and other states and with the NWRC (6) Following up on the monitoring and evaluation of activities related to water resources management (7) Approving studies and budgets for the council's programme and projects (8) Responsible for everything related to water in North Kordofan State	(2) Conducting engineering and technical analysis for water resources projects in the state (3) Developing a water map for the state and identifying areas of water fragility and water poverty (4) Raising awareness of communities and beneficiaries, and enhancing the role of women and youths to improve water resources management (5) Coordinating companies, the private sector and organizations tasked with social responsibility in the field of water (6) Preparing the budget for the programmes and activities of the Water Resources Council (7) Periodic monitoring and evaluation of the water resources in the state
Frequency of meetings	Twice a year	Four times a year

Source: Decree 13 and Decree 15 in 2022 in North Kordofan State

The SWRC and TC meetings during this period were held as shown in Table 4.4-9.

Table 4.4-9 SWRC and TC Meetings Under the North Kordofan Government Structure

Date	Year	Type of Meeting	Main Agenda/Outputs	Remarks
26th May	2022	1st SWRC/TC	SWRC and IWRM unit (background, objective and activities, membership, budget), report on WUC on 23 May, progress of NWRC revitalization preparation, plan of JICA IWRM Project activities of May 2022-March 2023 period, resolutions	• Joint meeting • Chaired by General Secretary
15th December		2nd SWRC/TC	SWRC/TC management, review of resolutions by previous SWRC, message to WUC (need to halve the pumping rate), measures to reduce the pumping rate (water-saving irrigation, GW licensing, conjunctive use of GW and SW), resolutions	• Joint meeting • Presided over by the state governor
7th March	2023	3rd TC	Completion of the JICA IWRM Project, findings and lessons from the JICA IWRM Project, proposal on resolutions, risk of GW depletion, official launching of IWRM unit, water-saving irrigation experiment, result of monitoring, introduction of GW licensing pilot scheme, support for WUC activities, final resolutions	Chaired by MIUD Director General for water
9th March	2023	3rd SWRC	Resolutions by 7 March to TC and request to SWRC and IWRM unit for training in Japan, Federal-State IWRM Partnership Committee meeting, JICA in Sudan, completion of the JICA IWRM Project	Presided over by the state governor

The emphasis was shifted to linking the outputs of the WUC, the TC and the SWRC under the new formal mechanism established in February 2022, with the establishment of the SWRC and the TC. It was also intended that good meeting management be achieved, such as the announcement of the meeting schedule well in advance, the practicing of good time management, ensuring that the meeting duration did not exceed two hours and the preparation of the minutes of meetings. The links between the SWRC, the TC and the WUC were intended to be strengthened by sending a clear message to the WUC and agreeing at TC meetings on the resolutions at the end of each TC meeting and developing them into requests to the SWRC on the part of the TC. The message from the state government to water users was "let's halve the amount of groundwater extraction!" which was prepared based on the conclusion of technical analyses that the GW in Bara will be depleted in the near future in the event that the current pumping rate continues. This message was transmitted by the state C/Ps to the WUC members at the WUC meetings. The WUC members then disseminated this message to ordinary water users.

The resolutions agreed at TC meetings and the requests to the SWRC at the first, second and third SWRC meetings are shown in Table 4.4-10.

Table 4.4-10 Resolutions and Requests Submitted by the TC to the SWRC

Resolutions at 1st SWRC Meeting

1. Issuance of state decree for establishing the IWRM unit
2. Budget allocation
3. Approval of the activities during the extension period (April 2022 to March 2023)
4. Information sharing on AfDB-supported water supply project
5. Addition of Meteorology Department as a member
6. Forestry preservation
7. Effective utilization of SW in the south
8. SWRC office
9. Possibility of emergency SWRC meeting
10. Development of understanding of SWRC members

TC's Resolutions and Requests to the SWRC at 2nd SWRC Meeting

1. The SWRC accepts the proposal from the message to water users at the next WUC, "Let's reduce the GW use by half!" The SWRC instructs the TC and the IWRM unit to continue communication with water users and to agree on a realistic approach through continuous dialogue to realize the target.
2. The SWRC accepts the report on the irrigation water-saving experiment. The SWRC ensures that the Ministry of Economic Resources will provide the necessary support for the experiment. The SWRC will consider the results of the experiment as soon as it has been completed.
3. The SWRC accepts the report on the GW licensing initiative. The SRWC instructs the relevant state authorities to start taking the required actions within the general framework indicated in the presentation.
4. The SWRC accepts the proposal on the conjunctive use of GW and SW. The SWRC instructs the TC and the IWRM unit to continue studying this concept toward its realization.

TC's Resolutions and Requests to the SWRC at 3rd SWRC Meeting

1. The TC will continue its activities even after the JICA Project ends in March 2023 to minimize the risk of GW depletion in Bara in the future.
2. The TC requests that the SWRC approves the following:
   - 2.1 Official launching of the IWRM unit in North Kordofan
   - 2.2 Ensuring that the General Directorate of Agriculture and the Agriculture Research Centre undertake a joint initiative with the IWRM unit to implement a second-round irrigation water-saving experiment and follow-up activities to disseminate the water-saving irrigation technique.
   - 2.3 Continuously allocating a budget for the following activities:
     - (1) Second-round irrigation water-saving experiment
     - (2) Monitoring of SW, GW and water quality
     - (3) Introduction of GW licensing system

(4) Support of WUC
2.4 Initiating discussions on the expansion of SWRC activities within the entire North Kordofan State

3) Findings, Lessons and Challenges for the SWRC-TC-WUC Structure

3-1) Findings

Level of Vertical and Horizontal Coordination

The findings concerning the level of vertical and horizontal coordination under the SWRC-TC-WUC structure are summarized below and shown in Figure 4.4-6:

- Vertically, coordination between the IWRM unit and the WUC has been good with the support of locality officers. The IWRM unit was successful in sharing the results of technical analyses, such as the risk of GW depletion and the need to reduce the amount of GW extraction. The locality officers played an important role in linking the IWRM unit and the WUC members by utilizing close networks with local residents. Awareness of WUC members increased significantly as a result.
- WUC members began to share the results of discussions at the WUC with ordinary water users. It was reported that certain communities started to shorten the time available for local residents to access the water supply, following the advice of the WUC to reduce the level of GW extraction. This is a successful example of information dissemination by the WUC and the resultant raising of awareness of the significance of GW at the ordinary people's level. The various opinions of water users were listened to and shared with the IWRM unit members at WUC meetings.
- Upward vertical coordination above the IWRM unit, on the contrary, has been rather one-way. The resolutions drafted by the IWRM unit for the SWRC meeting in December 2022 were submitted to the SWRC after being approved by the TC. There has, however, been no response from the SWRC since then. The resolutions agreed upon at the TC meeting on 7 March were presented to the SWRC, chaired by the state governor on 9 March. It is unclear whether or not the SWRC will respond to this. A hypothetical explanation for this one-way vertical coordination may be the top-down mentality of the government decision-makers, influenced for many years by a dictatorial political style.
- Important downward coordination between SWRC, TC and IWRM Unit is a decision by SWRC on budget allocation for IWRM Unit activities. This issue was included in the submitted resolutions, so remains to be seen.
- Horizontal coordination among the different sectors is positive at the level of the IWRM unit and at locality office level. The IWRM unit is characterized by a multi-sector membership covering the water, agriculture and environment sectors. The members have been cooperating while undertaking the pilot activities and applying their specialties. At the locality level, there has been close cooperation between the agriculture director, the water manager and the other relevant officers.
- Inter-sectoral coordination at the TC and SWRC levels has been rather limited. The TC meetings tended to become opportunities in which to express the general ideas of each participant regarding their areas of responsibility, rather than focusing on the pilot activities. One of the reasons for this is the inconsistency of the members attending the TC meetings. It was often the case that new attendees would raise questions previously discussed. Although the JPT has made an effort to guide IWRM unit members to manage the meetings effectively by drawing the attention of the participants to the pilot activities, it was difficult to improve the behaviour and way of thinking of the Sudanese

participants.

- Although a similar tendency was observed at SWRC meetings, discussions within the SWRC could be better managed with more focus on specific subjects, such as the resolutions submitted by the TC and budget allocation.

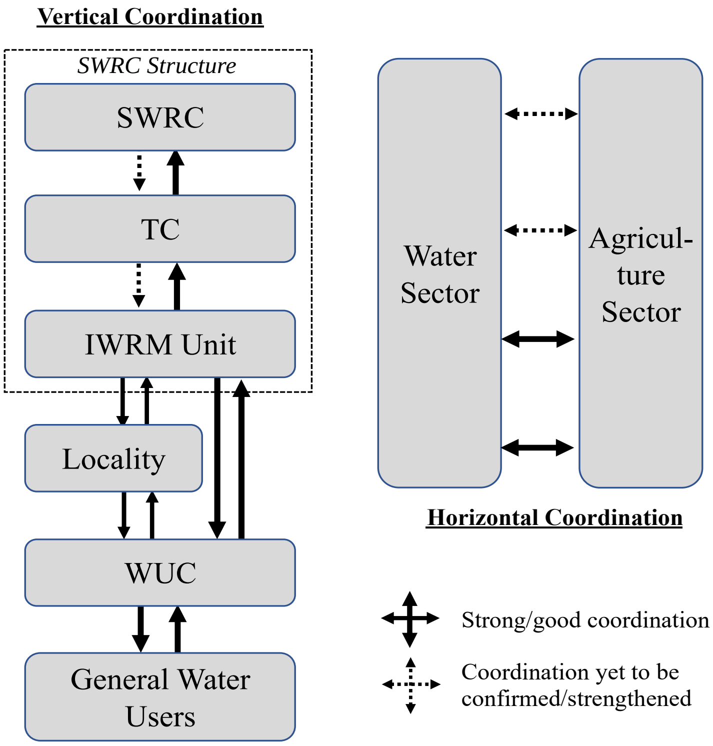


Figure 4.4-6 Level of Vertical and Horizontal Coordination

Preparation for the Establishment of an IWRM Promotion Structure

The process of preparing for the establishment of an IWRM structure for North Kordofan was found to be effective and could be replicated in other states. As explained in the previous section, the support initiative of creating an SWRC in North Kordofan was first led by UNEP and was subsequently taken over by the JPT, after UNEP withdrew in early 2020. It was not until two years later that the SWRC was formally established in 2022.

The JPT facilitated discussions among the North Kordofan C/Ps and the MIWR C/Ps regarding the basics of the new structure to be established, such as its objective, functions, organizational structure, membership and frequency of meetings. There were a number of important issues in the preparation of an IWRM structure as follows:

- It was necessary to define specific activities to be undertaken by the new structure, such as sharing information on monitoring and the results of water balance analysis. Defining solely the objective and functions, in general, does not ensure the sustainability of the initiative.
- The functions of continuous technical work, as well as regular meetings for sharing technical information and decision-making should be recognized, so that an appropriate structure suitable for each state can be designed. In the case of North Kordofan, these three functions were assigned to three different units: the IWRM unit for continuous technical work, the TC for regular information sharing and technical discussion including proposals to SWRC, and the SWRC for decision-making. Thus, a three-layer structure was created in North Kordofan, as shown in Figure 4.4-7.

There was a view among the federal C/Ps that only the SWRC was needed. In fact, the original proposal by the UNEP was also a single-layer structure. The North Kordofan C/Ps, however, considered it important to share information from the MIUD and other related ministries and to ensure sectoral coordination at the technical level before decisions were ultimately made by the SWRC.

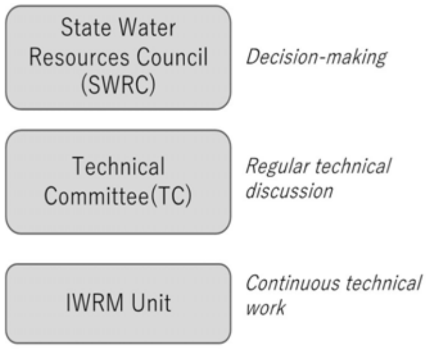


Figure 4.4-7 Three-Layer IWRM Structure in North Kordofan

- An important element of the North Kordofan initiative was the endeavour to create the IWRM unit. No meaningful discussion and decision-making would be possible within the TC and SWRC without sufficient collection and analysis of technical data and proposals for action, based on technical analysis. There may be options depending on the condition of each state. In the event that a technical unit exists, which can carry out sufficient analytical work for the TC and the SWRC, a new unit like the IWRM unit would not be required. In the case of North Kordofan, the IWRM unit was intended to be created to ensure sufficient technical work and sector-wise coordination at the daily working level, by involving officers in charge of other sectors such as agriculture and the environment.
- There was a heated discussion on who should chair the SWRC. One view was that the MIUD minister should chair the SWRC, whereas the opposing view was that the governor should chair it. There are pros and cons in relation to these two options. If the MIUD minister chairs the SWRC as in the case of the JICA IWRM Project in which the MIUD minister chaired the SC, it would be easier to convene SWRC meetings. However, there may be a limitation in the coordination function across different sectors, as the MIUD minister's responsibility covers the water sector but does not go beyond it. The Minister of Economic Resources, for example, is responsible for the agriculture sector, the most influential sector with regard to water. If the governor chairs the SWRC, on the contrary, his authority would cover all the sectors, so the coordination function would be fully effective. The governor, however, is usually extremely busy and convening SWRC meetings may not be easy. This point was made by the former JICA IWRM Project Director, who was familiar with the failure of the NWRC in the 1990s. One of the reasons for the failure, according to him, was the inability of the MIWRE minister at the time, who was also the chairperson of NWRC, to make himself available for the NWRC meetings, due to his heavy workload as minister.

  In the case of North Kordofan, an intermediate compromise option was selected. The MIUD director general would chair the SWRC, whereas the governor would preside as the general supervisor. The effectiveness of this arrangement was in evidence towards the end of the JICA IWRM Project in March 2023.

<u>Establishment of the WUC and its Involvement in the TC</u>

An important characteristic of the IWRM promotion structure in North Kordofan is the creation of a WUC and its involvement with the TC. This initiative was found to be highly effective, therefore it is recommended that this be replicated in other states. The idea is to create a channel of communication between water users and the North Kordofan government. The problems and requests of water users can reach the state government through the WUC, whereas the results of the technical analysis of water conditions in the target area and messages from the state government can be transmitted to water users through the WUC. The actions taken by the state government as well as water users can be improved by this kind of mutual communication.

In the case of the Bara area, the awareness of water users, especially irrigation farmers, of the value and limitedness of GW was greatly enhanced by the sharing of technical information at the TC and WUC meetings. The water users were informed of the result of the water balance analysis, conducted by the IWRM unit with the assistance of the JPT, and the risk of GW depletion in the event that the current rate of GW extraction continues.

Operation of the IWRM Promotion Structure

The SWRC-TC-IWRM unit only started to operate in April 2022 after the official establishment of the SWRC and the TC in February 2022. The IWRM unit is ready to be launched but is waiting for a formal announcement by state decree. The North Kordofan C/Ps, who will constitute the main body of the IWRM unit once it is established, are currently playing the role of the IWRM unit (as of March 2023).

The original intention of a circulatory consensus-building process, as explained in Figure 4.4-5, is now in evidence.

3-2) Lessons

The lessons learnt concerning the SWRC-TC-WUC structure are as follows:

- Meeting management could have been focused on previously. When supporting the North Kordofan C/Ps, the initial focus was giving them opportunities to summarize the results of the monitoring and technical analysis and other subjects, preparing presentation materials and making presentations. On occasions, the TC meetings lasted for more than four hours and the participants were leaving before the end of the meeting. The state engineers tended to discuss the technical details in depth, resulting in long presentations. After the SWRC and the TC were officially established in February 2022, the JPT started to give guidance on meeting management, such as restricting the meeting agenda to a maximum of two hours. Earlier attention to meeting management could have resulted in an improvement of the meeting management capabilities of the state C/Ps.
- The social and cultural background of decision-making in Sudan could have been analysed. It was towards the end of the JICA IWRM Project that a top-down mentality was found to exist, especially at the decision-making level of the state government. A local person highlighted the general tendency of the Sudanese government officers to speak up in the meeting and to talk about their own issues, rather than to contribute to reaching an agreement on the prepared meeting agenda. A JPT expert, experienced in TC and SWRC meetings, observed that no conclusion seemed to have been reached at the end of the meetings, however, according to the participants, a conclusion had been reached. There may be a unique Sudanese way of reaching an agreement, different from that of the Japanese. All these phenomena have their own cultural background. Clarification of such a cultural background, if at all possible, may have provided better guidance for the state C/Ps matched to the local way of thinking and behaviour.

3-3) Challenges

The following challenges remain concerning the SWRC-TC-WUC structure:

- Awareness of the state-level decision-makers needs to be raised to ensure the sustainability of the pilot activities. The formal establishment of the SWRC and the TC in February 2022 indicates the significant awareness of the North Kordofan decision-makers of the need for such a mechanism. Their awareness should be further raised to have a better understanding of the SWRC-TC-WUC mechanism at the operation stage. The voices and requests from the bottom, such as the WUC and the IWRM unit should be heard, and responses should be given. This two-way communication between the top and bottom will nurture a sense of trust in the state government and create a more favourable environment, ensuring better cooperation between the state government and the water users. Awareness-raising should be conducted by a bottom-up approach on the part of the IWRM unit and by the MIWR and the NWRC once it is revitalized.

- The pilot activities have proven that water users are the strongest driving force within the SWRC-TC-WUC mechanism. Continuous efforts by the state government are needed to expand the impact of the pilot activities to cover a wide area. The water users are those who are most affected by the depletion of GW, and are therefore the most keen among all the stakeholders to prevent such a situation. All the activities like monitoring, water balance analysis, database creation, water-saving irrigation and GW licensing should be aligned to help the water users prevent the depletion of GW. All the activities should be continued and expanded based on this concept.

(2) Establishment and Operations of the WUC

1) Background and Objectives

The top-down approach was taken for a long time in Sudan and the government made important decisions, while disregarding the opinions of the water users, as they were not considered important players in water resource management. Although there were cases when international donors or NGOs established a well management committee at village level or the government set up a water user association to distribute water from a large-scale SW irrigation scheme, such as the Gezira scheme, there was no guideline or framework as to how the government should organize water users from a wider area, listen to their opinions and work with them to manage their water resources and facilities.

The Project aimed to establish a committee composed of water users, namely, the WUC and to hold regular meetings in order to link the government and water users and establish an environment in which both can work together in water resource management. The WUC plays a pivotal role in the IWRM consensus-building structure in North Kordofan. Due to the unique characteristics of the Bara area with rich GW resources, well owners and operators should be part of the GW resources management mechanism.

The Project planned that the government would disseminate information relating to water resources in the target area, listen to the concerns and requests of water users and discuss actions to be taken by water users and the government. In turn, the WUC was also expected to discuss similar issues with ordinary water users. It was also planned that communication and relations between the government and the WUC would be improved through WUC activities, as the government was not usually trusted by citizens. due to the political history in Sudan.

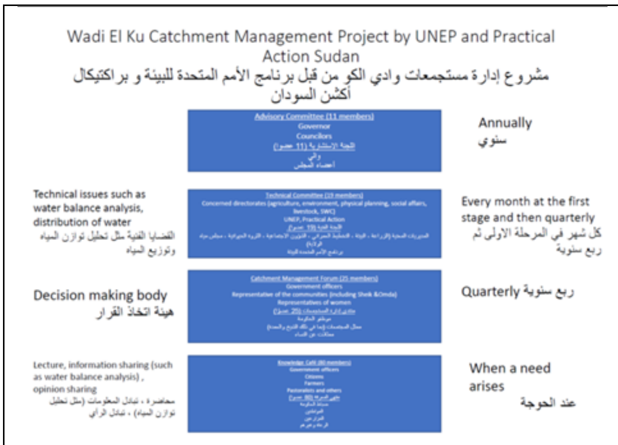
According to the baseline survey, most of the respondents answered that there is abundant and unlimited water in the Bara Aquifer. The WUC could be an important channel through which the government could disseminate accurate information and change the way of thinking of the water users.

2) Chronological Development of the WUC Initiative in North Kordofan

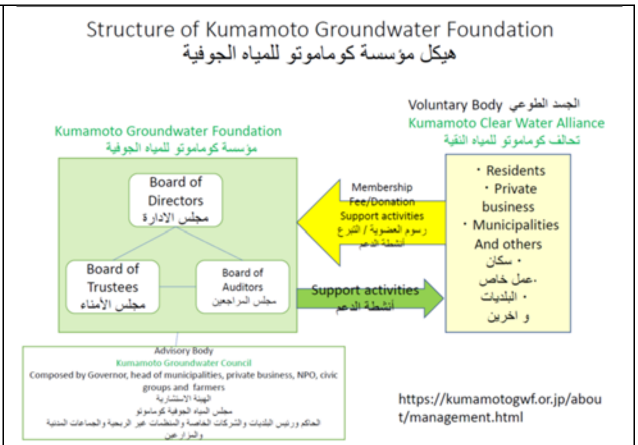
The Project established the WUC in 2020 to create a mechanism linking the government and water users at state level, so that the water users could participate in water resource management with the government. The Project had six WUC meetings by March 2023 as explained below:

(a) Preparation for the 1st WUC Meeting

During the pandemic, the Japanese experts started sharing experiences and examples of institutional arrangements from other water projects in Sudan and Japan with the C/Ps online, so that these cases could be reflected in the institutional framework of the WUC and the SWRC.



Example of Wadi El Ku management project (UNEP project in Darfur)



Example of Kumamoto, Japan

Figure 4.4-8 Shared Example of the Institutional Arrangements

Sudan was transitioning to a democratic country and many organizations, such as the popular committees, unions by occupation and the women's union, linked to the former regime, were dissolved. This change prompted the project team to discuss in detail who and which organization should be invited to join the WUC as a representative. The Forces of Freedom and Change (FFC) was selected, because this group had played a great role in the revolution since 2019 and there are many sub-groups under the FFC. The project team expected that the FFC could link women, youth and other groups under the FFC with the WUC.

(b) 1st WUC Meeting in November 2020

The project team held the 1st meeting with water users to establish the WUC covering the Al Bashiri Sub-Basin in November 2020. The Japanese members could not travel to Sudan from March 2020 due to the pandemic, so the experts participated in the meeting online from Japan.

The 1st WUC meeting was held in two places, Bara town and Al Bashiri (a village in Al Kheiran) for the convenience of the participants and also to reduce the number of participants, so as to comply with COVID-19 restrictions.

Around 50 people participated in the WUC meeting at Bara town. The participants included well operators of the monitoring wells targeted by the Project, representatives of the water committees of the water yards, the executive officer[3] and related departments in the locality, the DG of the MIUD and the state and federal C/Ps. The executive officer of the locality was very active and led the discussion.

[3] The head of localities in the executive wing. Previously, the commissioner, a political appointee, was the head of the localities. The positions of commissioner have become vacant due to the transition period.

1st WUC in Bara Town

Around 40 people from the Al Kheiran area participated in the WUC in Al Bashiri. The participants included the well operators of the monitoring wells, targeted by the Project, representatives of the water committees of water yards, a traditional leader (Omda), the FFC, teachers, the executive officer and related departments in the locality, the DG of the MIUD and the state and federal C/Ps.

The agenda of the 1st WUC meeting is shown in the next table.

Table 4.4-11 Agenda of the 1st WUC Meeting

	Topic
1	Quizzes and presentation on the basic knowledge of GW
2	Purpose of shallow well monitoring (GW)
3	Presentation on the JICA Project
4	Why we need the WUC
5	Shallow well monitoring (water quality)
6	Irrigation agriculture

To help the participants understand the GW situation, the Project prepared a quiz-style presentation in which the project team posed questions and asked the participants to select their answers from a list of two or three choices, as shown in Figure 4.4-9. This quiz format was very effective and increased the interest and participation of the participants. The project members learned from the answers and reactions of the general public that they did not even have basic knowledge of GW.

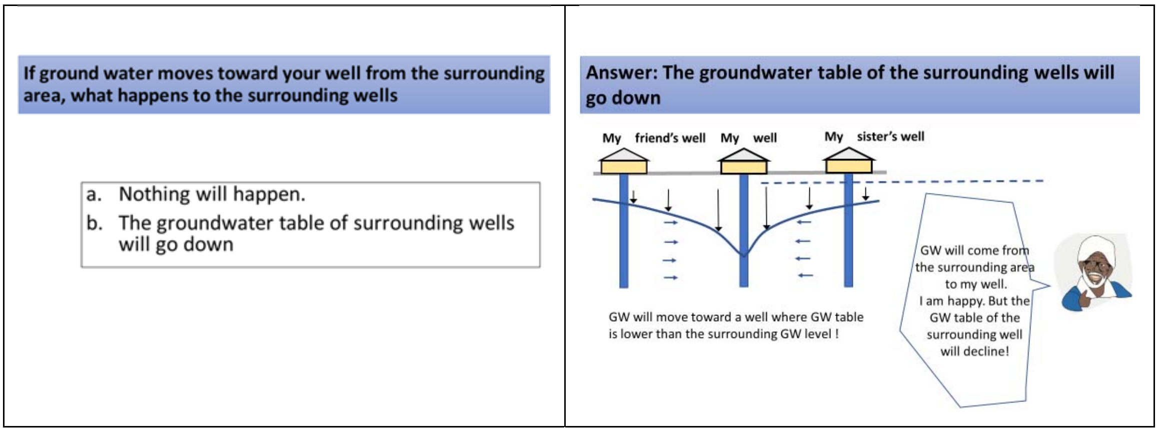


Figure 4.4-9 Quiz on GW

The participants raised many questions and comments in response to the presentations of the project team, as shown in the table below. Since some of the participants came from areas outside Bara town and Al Kheiran, those people were unaware that GW was declining, while the participants from Bara town and Al Kheiran were worried about uncontrolled new well drilling. The participants expressed concerns about water quality and the farmers wished to understand how they could use irrigation water wisely.
The purposes of establishing the WUC, which were explained to the water users, are presented in Table 4.4-13.

Table 4.4-12: Questions and Comments Relating to the 1st WUC Meeting

Category	Questions and Comments from Participants
GW level	It seems that the water level in the wells is not affected by pumping. Why do water levels recover quickly?
	There is a general consensus that if the water table decreases, then it acceptable to drill another hole beside it and the water will fill up again.
Water recharge	We learn that the use of renewable water from rain is important. We also know that forests enhance rainfall and recharge, so there should be vegetation and measures to protect the forest (by a forest officer).
Water balance	There is a need for an accurate analysis of water in the Al Kheiran area.
Control of water use	How do you limit the amount of water used for domestic, irrigation and pastoralist purposes?
Control over the drilling of wells	In the El Kheiran region, there has been considerable expansion in the drilling of private wells. What is the solution to this problem?
	What is the role of Bara locality regarding the uncontrolled drilling of wells?
Water quality	Does solid waste pollute the GW?
	Can we use chlorine to purify the water?
	Is the use of organic fertilizers dangerous?
Expectations from farmers	JICA should provide farmers with highly technical equipment (considered feasible)
	We request that the Project provide new irrigation techniques to rationalize the use of water
WUC	The WUC in El Kheiran village should be separated from Bara town.

Table 4.4-13: Purposes of the WUC

1	To be a hub for better communication between the government and water users, and to promote the participation of water users in water resource management. i) The government can disseminate information and data regarding water resources, which ordinary water users do not have. Without sufficient knowledge, water users will not follow government guidelines. The government can also propose its policies and decisions. ii) Water uses can convey their requests and concerns to the government.
2	To prevent conflict at a later stage by consulting water users at an earlier stage on government policies and development projects.

The project team and participants of the 1st WUC meeting nominated 20 members for the WUC, as shown in the table below. These were made up of irrigation farmers, including a women's group, private wells along with an Omda (traditional leader) and a FFC member. The C/Ps and the participants decided to include six government officers in the WUC to support water users and to ensure the smooth operation of the WUC. Irrigation farmers have already formed the irrigation farmers' committee covering Bara town and Al Kheiran. This committee has worked with the government to coordinate and provide a subsidy for fuel for the irrigation wells. The irrigation farmers in the WUC also belong to this irrigation farmers' committee, as well as belonging to a small irrigation farmers' committee/group in their specific area. According to the interviews carried out by project members, not all these irrigation committees/groups are functioning well.

There were geographical limitations when selecting the members. Although, there are 63 villages in Al Bashiri Sub-Basin, there are no paved roads and access from most of the villages to Bara town is not easy. Moreover, if a representative was selected from each village, the WUC could become too big to manage. For this reason, the project team decided that members would be selected from the two major water-using areas, namely, Bara town and Al Kheiran.

Table 4.4-14 Original Members of the WUC

Non-Government Members	Government Members
Fourteen water users (eight from Bara town and six from Al Kheiran） Bara ● FFC（1） ● Women's representative (1) Note: a representative from a women's irrigation association ● Irrigation farmers (3) ● Owner/operators of private wells in the town (3) Al Kheiran • Irrigation farmers（6） Note: One member is an *Omda* (traditional leader in Sudan)	Six governmental officials from Bara locality 1. Executive officer 2. Bara water manager (project state C/P） 3. Director of Agriculture（project state C/P） 4. Representative from the Ministry of Justice 5. Representative from Economic Security 6. Representative from the Health Department

(c) 2nd WUC Meeting in July 2021

The 2nd WUC meeting was held in July 2021 in the presence of the Japanese members. The original plan was to invite not only WUC members but also a wide range of other water users, in order to provide a broad range of information on water resources. However, due to COVID-19, only WUC members were invited and the number of government officials attending was also limited. The meeting was held in Bara town only on this occasion. A total of 24 people attended the meeting, including four members from Bara town, five members from Al Kheiran, seven governmental officials from Bara locality, as well as federal and state C/Ps.

The 2nd WUC meeting discussed four topics, shown in Table 4.4-15:

Table 4.4-15 Agenda of the 2nd WUC Meeting

	Topic
1	Monitoring results of participatory shallow well monitoring and water quality
2	Changes in participatory monitoring (introduction of self-registered water meters and participatory monitoring of water use)
3	Method of disinfection of drinking water using solar energy (SODIS)
4	Selection of WUC representatives to attend the SWRC and their roles.

The result of shallow well monitoring, which demonstrated a decrease on average of 0.36m from the start of monitoring to the present, was explained. Moreover, it was clarified that the current pumping rate was approximately twice the safe pumping rate in Bara town based on the monitoring results. Since the WUC members have experienced GW decline in their wells, they raised many questions regarding the monitoring results and commented on sustainable use in the future. Regarding irrigation water use, the participants perceived that they were wasting irrigation water and stated, "we know we are giving more water than the crops need, but what can we do to conserve water?"

The results of the water quality analysis tests conducted by the project members in Bara town were explained. E. coli and high concentrations of NO3 were detected in the shallow GW in Bara, and domestic wastewater was mixed with shallow GW, resulting in GW contamination by organic matter. Therefore, the Project introduced SODIS as a solution to this problem.

In the 2nd WUC meeting, many questions relating to the new AfDB water transfer project[4] from Al Bashiri were raised by the participants, and the project members provided the relevant information.

Regarding the selection of representatives to participate in the SWRC (TC), the project team suggested that one person be selected from Bara town and one from Al Kheiran. However, the WUC members wished to select those who could express their opinions firmly at the SWRC, therefore, two irrigation farmers were selected from the Al Kheiran region. One is a headmaster of a primary school, and one is a lecturer in a college. These two individuals participated in the TC in late November for the first time and actively spoke to oppose the AfDB project on behalf of water users in their area.

(d) 3rd WUC Meeting in May 2022

The 3rd WUC meeting was held in May 2022 with 24 participants (seven non-governmental WUC members, two officials from Bara locality, federal and state C/Ps, and Japanese experts). This meeting had been postponed for over half a year, following a political disturbance in which the military arrested the prime minister and other ministers in October 2021, on the very day the project team planned to hold the 3rd WUC. This political disturbance affected the operation of the WUC, and the decision was made by the project team not to invite the FCC member to the 3rd WUC meeting, due to the declining activity of the FCC and the worsening relationship between the FFC and the state government. The project members expected to invite nomads, women and youth representatives through the FFC, but this was not possible.

The 3rd WUC meeting discussed five topics in the next table.

Table 4.4-16 Agenda of the 3rd WUC Meeting

	Topic
1	Progress of monitoring
2	Irrigation agriculture: the concept of establishing the correct amount of irrigation water, the possibility of excess water use of the current traditional irrigation method
3	Trial of GW license in Bara

[4] The AfDB planned a project to convey GW from Bara to Al Mazroub, 90 km west of Bara. The AfDB first conducted an environmental assessment, but the AfDB proceeded with the project without disclosing the results sufficiently to the residents in Bara.

4	Progress of AfDB project
5	Improved memberships, functions and activities of WUC

The meeting ended prior to discussing topic No.5, as it was time for the participants to catch the bus to return home, therefore, we were unable to discuss this issue.

In reaction to the long-term decline in GW levels, highlighted as a result of monitoring, the WUC members asked questions and suggested countermeasures. In this regard, the participants again requested that JICA provide equipment and other assistance for drip irrigation to save water. The project members responded that there was an opportunity to save water using the traditional irrigation method, before introducing drip irrigation, and called for interested farmers to cooperate in a water-saving experiment planned by the project members. Five farmers expressed their willingness to participate in the experiment.

The participants asked for further information on GW licensing and the project team assured them that this would be explained in subsequent meetings. The interest of the participants in the AfDB project was still high and they were opposed to the project.

3rd WUC Meeting

(e) 4th WUC Meeting in August 2022

The 4th WUC meeting was organized in August 2022 with 21 participants. Only four non-governmental WUC members attended as the others were attending a meeting to discuss farm boundary issues at the start of the agriculture season. However, the two representatives who attend the SWRC were present. The FFC member was not invited on this occasion since the political situation had not improved.

The discussions during the 4th WUC meeting are shown in the following table:

Table 4.4-17 Agenda of the 4th WUC Meeting

	Topic
1	Report on the last SWRC meeting by the representatives of WUC
2	Presentation and discussion on the structure, roles and activities of the WUC
3	Presentation and discussion on the saving irrigation water experiment

The WUC members, inspired by the knowledge obtained in the WUC meetings to date, formed the Natural Resources Management Committee (NRMC), (refer to the table below) to manage their natural resources. The NRMC held its first meeting, with over 200 people representing all the villages in Al Kheiran, a few days before the 4th WUC meeting, to discuss the AfDB project. The participants came to the conclusion that they were opposed to any future re-examination of the AfDB and sent an official letter to the departments concerned.

Table 4.4-18 Members and Objectives of the NRMC

Number of members	277 including 19 members as executive members from the Al Kheiran area. There are no female members.
Objective of NRMC	To conserve and protect the various natural resources in the area, for instance, water, forests and minerals. The impetus for the creation of the NRMC was the AfDB project, aiming to supply the Al-Mazroub area with water from the Al-Kheiran area.

Since the 4th WUC meeting was held immediately after this NRMC meeting, much of the WUC's time was devoted to the topic of the AfDB project. Once again, discussion on the future structure, roles and activities of the WUC was not finalized. The WUC members basically agreed to the proposal on the structure, roles and activities of the WUC, suggested by the project members. They were to hold a meeting with the other WUC members to discuss and report the results to the project team subsequently.

Regarding the irrigation experiment, the project members explained the plan for the saving irrigation water experiment. The project team proposed that farmers decrease the amount of irrigation water each time. However, the farmers were opposed to this idea and preferred to change the irrigation frequency. It was finally agreed to revise the experiment plan after obtaining basic information, such as the irrigation methods of the target farmers.

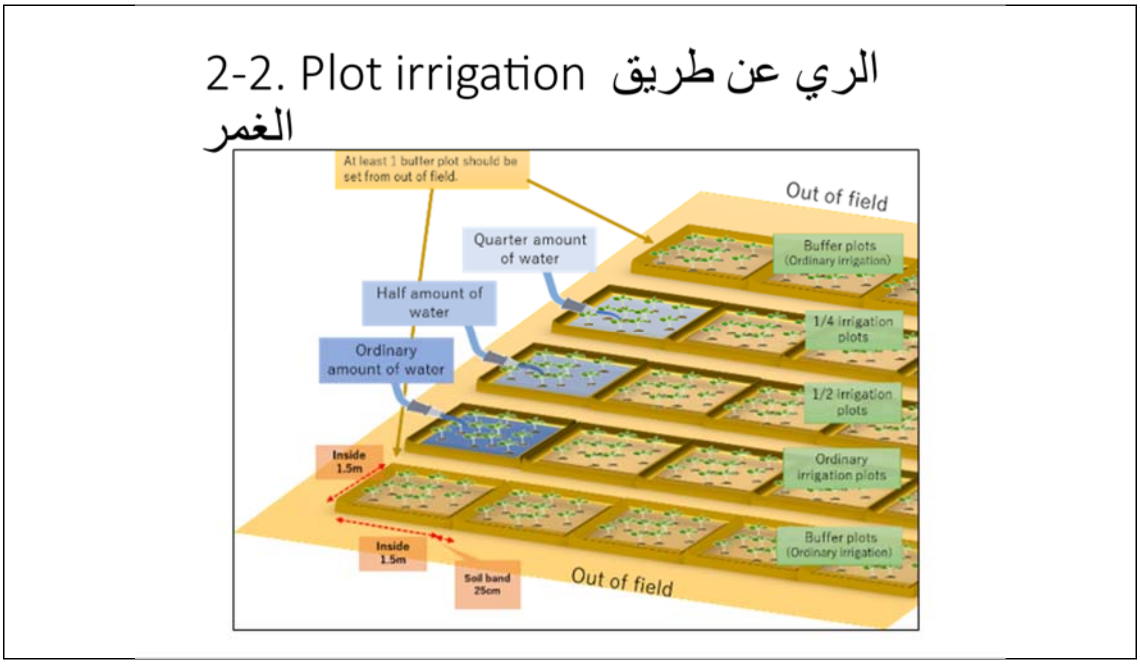


Figure 4.4-10 Irrigation Experiment Plan Presented by the Project Members

(f) Telephone Interview Targeting WUC Members

The federal and state C/Ps, instructed by the Japanese members, conducted a telephone interview with almost all the WUC members, including the governmental members, between the 3rd and 5th WUC meetings, as the project members had not had sufficient time for discussion with WUC members in the WUC meetings. The purposes of the interview were 1) to listen to the opinions of the WUC members regarding the need to add new members, 2) to ascertain whether they had shared the information obtained in WUC meetings to the people around them and 3) to establish which roles they would like to take on.

In relation to question 1, some members stated that it was better to include the youth and female members or an Imam (religious figure in mosques), while others were opposed to adding a female member as in their view, women were not involved in irrigation. Others maintained that the number of current members was sufficient.

With regard to question 2, most of the members have shared information gained in previous WUC meetings with the community members in their area or the government staff in the locality office. The channels of information sharing are many, such as the markets, the mosques, community meetings or simply chatting with neighbours or aquicultural groups.

Some of members said that they understood the mechanism of GW and had come to know why the GW level was decreasing. They knew that water level of their wells was decreasing, although they did not why. One member, who is a caretaker of a community well, reduced the hours of water provision for his neighbours because he had learned of the importance of saving water in the WUC. Due to the information supplied by the project team, the NRMC was established in August to deal with the AfDB project.

The following responses were given to question 3, i) raising the awareness of people regarding water sources and their situation, ii) saving water especially for irrigation purposes, including the introduction of modern irrigation, modern equipment and methods and iii) providing drinking water.

The project members learned that information provided by them has been shared widely by the WUC members as had been planned when the WUC was established. Regarding the roles played by the WUC, the WUC members and the project members have the same understanding.

(g) 5th WUC Meeting in December 2022

The 5th WUC meeting was held in December 2022 with four non-government WUC members, six officers from Bara locality as well as the state and federal C/Ps and the Japanese members.

The 5th WUC meeting discussed the topics in the next table:

Table 4.4-19 Agenda of 5th WUC Meeting

	Topic
1	WUC's role and structure
2	Proposal from the North Kordofan government ～*Let's reduce the water use by half!* ～
3	How can we control GW use? 3.1 How to reduce irrigation water use? ～ progress of Participatory Irrigation Water Saving Experiment ～ 3.2 GW licensing 3.3 Conjunctive use of GW and SW

Regarding the role and structure of the WUC, the project members reminded the participants of the expected roles and necessary positions of the WUC. The WUC members have basically the same understanding of the functions of the WUC as the project members. These are to conserve water resources in a scientific manner, to communicate ideas to water users for decision-making and implementation, and to communicate between the government and water users. The WUC members did not reach a conclusion in the 5th WUC meeting regarding the roles and structure of the WUC. They explained that the difficulty surrounding the discussion of membership and the structure of the WUC was the fragile political and social situation over the past few years in Sudan. They agreed that they would have a meeting the following week to decide on this and to confirm it in writing.

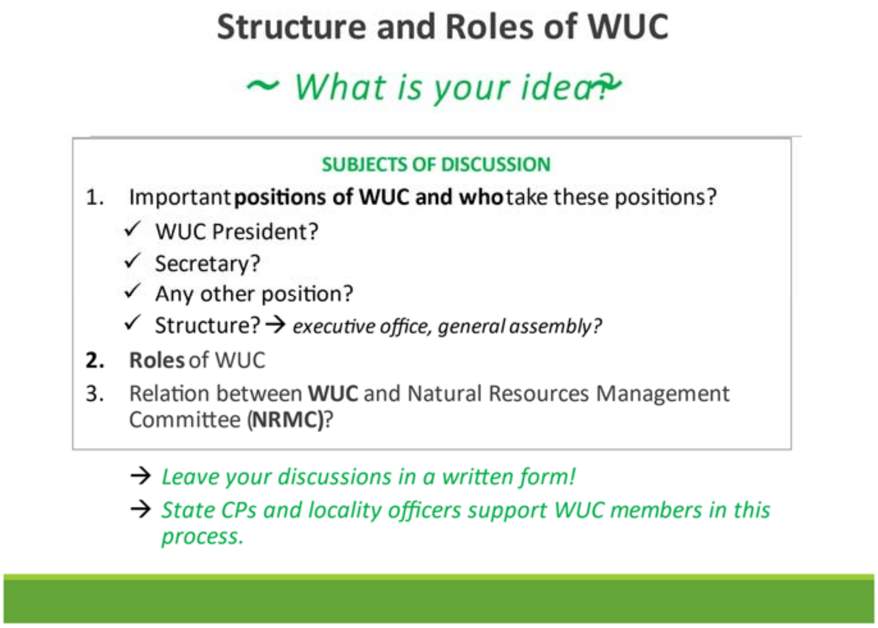


Figure 4.4-11 Presentation Slide on the Structure and Roles of the WUC

The meeting also discussed the division of roles and cooperation between the WUC and NRMC. It was confirmed that the NRMC covers all the natural resources, while the WUC covers water only. Both committees will share information and cooperate with one other, as they have some of the same members under the NRMC and the WUC.

In the following presentations, No.2 and No.3, the project team tried to deliver a clear message and propose practical actions on how to reduce water use for the first time. The project members have made efforts to give water users information and data on GW and has highlighted the fact that the GW is declining. Therefore, this is the second stage in which the government and the WUC discuss how to react to this crisis together.

The WUC members raised many comments and questions regarding how to save irrigation water and the process of GW licensing, such as, “we need further guidance and support from the government and the project team to save irrigation water” and “it will be difficult to explain the GW licensing process to farmers who are not highly educated. This may need to be combined with other supportive measures to promote the licensing system”. It was agreed that further explanations and discussions will be scheduled between the WUC members and the C/Ps in relation to GW licensing, in order to start trial licensing targeting the WUC members.

The 5th WUC meeting was concluded by agreeing to three resolutions as follows:

- Discussing the organizational structure and role of the WUC within the next two-week period
- Initiating the discussion of measures to halve water use
- Holding the next WUC meeting in February 2023

(h) 6th WUC Meeting in February 2023

The 6th WUC meeting was held in February 2023 and included 10 non-government WUC members, six officers from Bara locality, three state and two federal C/Ps and one Japanese member. The four core positions, namely chairperson, vice-chairperson, secretary and accountant of the WUC were selected within the committee before the 6th meeting and the chairperson made a call to the WUC members to ask them to attend the meeting. Therefore, attendance was increased compared to previous meetings.

Members of the 6th WUC meeting discussed the topics in the following table:

Table 4.4-20 Agenda of the 6th WUC Meeting

	Topic
1	Confirmation of the structure and role of the WUC
2	Presentation on the results of the irrigation experiment
3	Presentation on the updated safe yield
4	Presentation on the water quality test
5	Presentation on next steps after the Project

Firstly, the core positions and roles of the WUC were confirmed by the attendees. The roles that the WUC play are 1) connecting water users with government, 2) raising awareness of water users, 3) identifying the problems and issues that concern water users and 4) exchanging information between water users, the government and the relevant official bodies.

The WUC members discussed how the WUC would operate and which activities the WUC would carry out. These discussions were chaired by the chairperson and the following decisions were made:

- ✓ A meeting will be held every three months in the agriculture meeting room at Bara. Information will be shared with the members during the regular meetings and the WUC will use media to disseminate information.
- ✓ The WUC will consider the expansion of membership by creating small sub-committees under the umbrella of the WUC so that the WUC can include representatives from other villages and operators of wells for drinking water.
- ✓ The WUC will carry out the following activities:

  A) Awareness-raising. Currently, the main theme is irrigation water reduction, but it is also necessary to provide information to water users of drinking water.

  B) Implementation and expansion of water-saving irrigation. At the request of the NRMC and the WUC, a meeting was held in January with the directorate of agriculture, the governmental banks and private companies to discuss the financing of the introduction of drip and sprinkler irrigation. Some farmers have already introduced drip irrigation and sprinkler irrigation a few months ago. The WUC, along with the NRMC, will analyse the results of these new modern techniques and will select the optimal irrigation method for farmers to apply. The WUC will also continue the agricultural experiment to reduce the amount of water used for irrigation.

  C) Cutting mesquite trees. The WUC will negotiate with the government to cut down mesquite trees which consume large amounts of water and plant gum Arabic or lemon trees instead.
- ✓ The governmental members in the WUC will remain within the WUC for some time to support the implementation of the activities.

The members understood the second presentations relating to the agriculture experiment and the third presentation on safe water yield. One member stated that he would like to explain to others who over-irrigate how to save water, based on the results of the experiment.

Carrying out the water quality test was a request from the WUC during the last meeting, so that the results of the quality test conducted in February were explained. No.3 exceeds the Sudanese standard in several wells. The WUC members were worried about the contamination of water by fertilizers and agricultural chemicals, so they requested that the government perform the test regularly.

Finally, the project members asked the WUC members about the changes and lessons learned after they had organized the WUC. Their answers were as follows:

- ✓ The knowledge gained at the WUC changed our way of thinking. We now understand the system and the quality of GW. The NRMC was established based on this knowledge. We used to think that GW was unlimited, but we have come to understand that it is a limited resource and that it is necessary to manage it for the future.
- ✓ Natural resources are usually managed by traditional leaders, some of whom are close to politicians. Therefore, it is important for ordinary water users like us to have an organization like the WUC.
- ✓ By gathering water users within the WUC and NRMC, it has become possible to gain bargaining power with the government and the private sectors.
- ✓ Within the JICA Project, information was shared only with WUC members, but it would have been better to target more people.
- ✓ We would like to visit other areas, such as Kassala, to learn how to deal with the declining GW.

After the meeting, the WUC members started a discussion to change non-active members. Some members will be replaced in the future. The WUC members have also agreed to include a forest officer from Bara locality in the WUC. He supported the WUC members when they had the first NRMC meeting and started attending the WUC from the 4th WUC meeting.

3) Findings, Lessons and Challenges of the WUC

3-1) Findings

<u>Establishment of the WUC and Its Functionalization as a Hub</u>

The project members established the WUC in November 2020 and six meetings were held by the end of Project period. Due to the pandemic and political turmoil in Sudan, WUC meetings could not be held as frequently as planned in 2020 and 2021. However, four WUC meetings were organized in the last year. Planned activities, such as information sharing of water resources, collating the concerns and requests of water users and discussing the actions to be taken by water users and the government were carried out in the six WUC meetings.

The C/Ps have learned how to set agendas and explain technical issues on water resources simply to water users and also how to communicate with water users. For the WUC members, these were good opportunities to learn about the current situation and future prospects of water resources, and the members have recognized the significance and usefulness of the WUC. Both sides have started a discussion on how to save water since December 2022 and it is expected that the WUC will act as a forum for both to discuss how to manage water resources.

The roles and activities of the WUC were decided upon and confirmed in the 6th WUC meeting. The four core positions, with the names of the selected persons, as well as details relating to the operation and activities of the WUC were written in a document by the C/Ps after the 6th WUC and distributed to the WUC and the TC members in the TC meeting held in March, so that the WUC could be recognized as an official body and everyone concerned could understand the function of the WUC.

<u>Raised Awareness and Actions Taken on Water Resources Through Information Sharing of the WUC</u>

As the results of the telephone interviews and the responses of the WUC members in the WUC meetings show, the WUC members clearly understood about the mechanism, as well as the current state and future analysis of GW in Bara. This is because, firstly, they have experienced a decline in the GW level and secondly, the project team made an effort to deliver presentations which were simple and easy to understand. In the WUC meeting, WUC members also expressed their concerns about uncontrolled well construction and the expansion of irrigated farmland. They indicated their support for the introduction of GW licensing and highlighted their expectations for water-saving irrigation, since they share the deep concern of the project team as a result of the information shared. They also mentioned in the 6th WUC meeting that they used to think that GW was unlimited, but that they had come to understand that it is a limited resource and that it is necessary to manage water for the future. This raised understanding level will facilitate cooperation between the government and the water users, enabling them to take action together to manage water resources. One state C/P maintained that the government did not have a means of disseminating information relating to GW and raising the awareness of people. The establishment of the WUC provided the government with a channel through which to disseminate information and communicate with water users. The information shared in the WUC has been disseminated to other water users and has already led to the following actions by WUC members and other water users. One member, who is the caretaker of a public well, reduced the hours of provision of water to neighbours because he had learned of the importance of saving water. The WUC members initiated the establishment of the NRMC mainly to manage the AfDB project and to protect water and other natural resources. The WUC along with the NRMC have started negotiating with the government, banks and private companies to introduce modern irrigation equipment, such as drip irrigation and sprinkler irrigation. Some of the farmers have already installed the equipment and the WUC and the NRMC will analyse the results later. Having collective bodies, such as the WUC and the NRMC gives them power to negotiate and take action by coordinating with the government and the private sectors, etc. The members of the WUC are also members of the NRMC and one of the members of the WUC is the chairperson of NRMC. Therefore, both committees work closely and share information. Providing information with scientific data is very important and the WUC meetings have raised the awareness of WUC members and other water users, and facilitated their actions on water resources.

Start of the Cooperation Between the SWRC (TC) and the WUC and the Building of Trust

Two representatives were selected in the 2nd WUC meeting to attend the SWRC (TC) meeting in July 2021, and they have attended the SWRC since then. They have spoken on behalf of the WUC and water users in SWRC, and they have also informed the WUC members about the discussions within the SWRC. This cooperation and cycle of discussion or consensus-building has built relationships, to some extent, between the government and citizens despite the fragile political and social environment in Sudan. The participation of water users in the decision-making processes of the government, through the SWRC in the case of the JICA IWRM Project, could lead to transparency of decision-making within the government and trust building on both sides. This, in turn, it can promote cooperation between the government and water users to consider countermeasures and take action together. Another example is that the state government has started inviting NRMC and WUC members when they have a meeting concerning the AfDB project. The government has learned that it is necessary to involve water users from the planning stage.

However, the SWRC and the WUC have not yet reached the level of formulating concrete action plans by setting certain indicators and timeframes. Although the message, "Reduce water use by half" was conveyed from the SWRC to the WUC, time was limited to draft a concrete plan.

Consistency with the Water Strategy

The project activities to establish and promote the WUC are consistent with the water strategy. The water strategy lists the following as challenges: lack of gender perspective, limited participatory and accountable water resources' governance and lack of community participation and transparency of decision-making in water resources management. Future plans include organizing local water users' organizations at basin level, an improved governance of institutions by promoting the participation and support of water users including women and conducting social awareness campaigns.

Having a model and adhering to the lessons of the WUC within the Project constitutes valuable experience for the government in terms of creating user organizations at basin level and integrating them in the decision-making processes and future actions in a transparent manner.

3-2) Lessons

Need for Intensive Discussion at an Earlier Stage

The WUC members thought that the WUC was set up as a government initiative and that they were just guests, which prevented them from discussing the organizational structure of the WUC independently. On the other hand, the WUC members created the NRMC with a clear structure, which included over 200 members. The project members should have allowed more time to discuss the structure of the WUC at an earlier stage. Taking the NRMC as an example, once water users understand the significance and purpose of the organization to be created, they can make their own decisions regarding the selection of representatives and the organizational framework.

Low Attendance of WUC Members

The number of members who attended the WUC meeting decreased over time, although the core members always attended. One of the reasons for this was that the project members did not inform the WUC members of the dates of meetings sufficiently in advance, consequently, the WUC members were not available on the dates of meetings. This was because the project members could not decide on the date due to coordination difficulties with the executive officer of Bara locality, as well as other important meetings taking place among project members and the state government. The attendance rate improved by the 6th WUC meeting, as the chairperson of the WUC contacted the other members to ask them to attend the meeting. The WUC members started taking ownership when selecting the core positions, which could improve the situation.

Presence of a Government Officer Who Has an Association with the Water Users

The director of agriculture in Bara locality, one of the state C/Ps, was key in the creation and operation of the WUC for the Project. He had an association with the irrigation farmers before the project and knew the farmers well, in particular, the active figures. He assisted the project members regarding who t should be invited for the 1st WUC meeting and made phone calls to invite members to the WUC meetings. The water manager of Bara town also knew the private wells and had a connection with the well operators, who were also members of the WUC. It is important to find such a government officer who knows the water users and the specific area.

3-3) Challenges

Absence of Organizations and Persons Representing Water Users

With the exception of irrigation farmers, there are no organizations or representatives that represent water users in Bara. The project members discussed the inclusion of women and young people, representatives of rain-fed farmers and pastoralists/nomads, who are significant in the target area, and local traditional leaders in the WUC. With the fall of the previous regime in the 2019 revolution in Sudan, the popular committees, women's unions, farmers' unions, pastoralist unions and other organizations connected to the previous regime have been disbanded, and new organizations are in the process of being created by the government or by the autonomous activities of the local residents, which makes it difficult to select organizations and representatives to be included in the WUC. The FFC, which played a significant role in the revolution, was included as a member of the WUC established by the project members. Since there are women's and youth groups under the umbrella of the FFC, communication with these groups was expected through the FFC. However, the relationship between the government and the FFC deteriorated because of the incident in October 2021. To date, the project team has not been able to encourage youth and women sufficiently to participate. Since nomads move seasonally, it is difficult to select representatives and have them participate in the WUC on a regular basis.

Limited Representatives in Terms of Areas

The WUC was started with regional representatives from Bara town and Al Kheiran only, in order to manage the members more easily, but it is necessary to consider whether additional representatives from other villages in the Al Bashiri Sub-Basin should be included in the future. The WUC members have started discussions to expand the membership by creating sub-committees so that the WUC can accommodate additional representatives, such as well operators for drinking water and other villages within the Bara Aquifer.

(3) NWRC

1) Background and Objectives

The NWRC was established in 1995 following the enactment of the Water Act of 1995; three sessions were held initially but it has been dormant until now. The issue of the NWRC has occasionally been discussed by the JPT and the federal C/Ps since the start of the JICA IWRM Project. Its revitalization was, however, perceived only as a vague future possibility. The NWRC issue became an important agenda when the Amendment was passed in August 2021. The federal C/Ps and the JPT came to an understanding that the NWRC and the Water Resources Technical Organization (WRTO), as the technical working body for the NWRC, could constitute the organizational framework for promoting IWRM in Sudan. The federal C/Ps and the JPT started to discuss specific ways in which to revitalize the NWRC, following the Amendment and based on the recognition that the revitalized NWRC should contribute to promoting IWRM in Sudan by supporting state initiatives to establish SWRCs. The NWRC is presented in this section as a means of supporting the establishment and operation of the SWRC in North Kordofan. The objective of supporting NWRC revitalization was, thus, recognized as the establishment and strengthening of the organizational structure to disseminate IWRM throughout Sudan.

The establishment of the WRTO IWRM unit was also discussed by the MIWR C/Ps. Its objective is to function as the ground-level working force for IWRM dissemination throughout Sudan. The MIWR C/Ps who participated in the JICA IWRM Project are assumed to be core members.

With this understanding, the following activities were undertaken.

- Facilitation of discussions by the MIWR C/Ps to conceptualize the revitalization of the NWRC
- Facilitation of discussions by the MIWR C/Ps on ways to supplement the weakness of the 1995 Water Resources Act Amendment which does not include state representatives as NWRC members
- Facilitation of discussions by the MIWR C/Ps regarding the creation of the WRTO IWRM unit
- Support of the MIWR C/Ps in making presentations to the MIWR decision-makers
- Support of the MIWR C/Ps in preparing and hosting the "Federal-State IWRM Partnership Committee" meeting in March

2) Chronological Development of NWRC Initiative

The JPT supported the MIWR C/Ps in promoting the revitalization of the NWRC in consideration of its importance in promoting IWRM throughout Sudan.

"The Water Resources Law 1995 and its amendment in the year 2021 ("the Amendment hereafter")" provides a legal framework for IWRM promotion in Sudan. This law was enacted in 1995 and three sessions of the NWRC were held subsequently. The NWRC, however, became dormant for a long time, mainly due to a lack of commitment from the MIWR leaders. An amendment was made to the law followed by government approval and a public announcement in August 2021. The major points relevant to the promotion of IWRM in Sudan, especially the provisions concerning the NWRC and the WRTO, are summarized in Table 4.4-21 below. The WRTO, which is the C/P organization for the JICA IWRM Project, serves as a permanent technical body to support the NWRC in various technical issues.

Table 4.4-21 NWRC Defined by the 1995 Water Resources Amendment Act

1. Members	(i) Minister of Irrigation and Water Resources as chair, (ii) Ministry of Defence, (iii) Ministry of Foreign Affairs, (iv) Ministry of Justice, (v) Federal Court of Judgement, (vi) Ministry of Agriculture and Forestry (vii) Ministry of Energy and Oil, (viii) General Intelligence Service and Environment.
2. Functions	(i) Approval of general policy on water resources, (ii) approval of a long-term federal programme for the optimum and balanced use of water resources with certain priorities, (iii) decision-making on shared water resources with other countries and the building of a foundation of cooperation with international organizations, (iv) periodical review of legislation related to water resources and the provision of recommendations as necessary, (v) encouragement of scientific research into water resources and (vi) creation of specialized committees to assist in the performance of the NCWR's duties
3. Concerns	(i) General supervision of the withdrawal of water from the Nile, non-Nilotic rivers and other streams, GW, distribution and use of water and protection of water from pollution, (ii) establishment of the granting of licenses for the withdrawal of water, allocation of water and its optimal allocation, regulation of the use of water for various purposes, maintaining the records of water used in irrigation projects and determining water use.
4. Frequency of meetings	Twice annually
5. Functions of the WRTO	(i) Formulating general policies on water resources and submitting them to the NCWR for approval, (ii) inspecting water facilities and recommending maintenance to the relevant authorities, (iii) developing a long-term federal programme for water resources and submitting it to the NCWR for approval, (iv) preparing studies and research on water resources and development plans, (v) supervising the programmes and agreements on water resources shared with other countries, (vi) assessing current and future water needs and recommending the appropriate management, (vii) presiding over the Sudanese side in the Joint Permanent Technical Commission for the Nile Waters, (viii) recommending the revision and updating of water legislation, (ix) representing Sudan in the field of cooperation and negotiation with regional and international organizations related to water

	resources and (x) any other competencies and authorities necessary for performing its duties.

A serious shortcoming of the Amendment was the non-inclusion of state representatives in the NWRC. The original Water Resources Act, prepared in 1995, included these representatives, but the Amendment did not. Without state representation, it will be difficult for the NWRC to capture the water resources' conditions on the ground accurately.

To overcome this shortcoming, an additional mechanism to link the NWRC with the 18 states in Sudan was proposed by the JPT and agreed by the MIWR C/Ps.

A committee titled, "Federal-State IWRM Partnership Committee ("Partnership Committee" hereafter)" has been proposed to be established under the NWRC. Figure 4.4-12 below shows the position of the Partnership Committee in relation to the NWRC, the WRTO and each state.

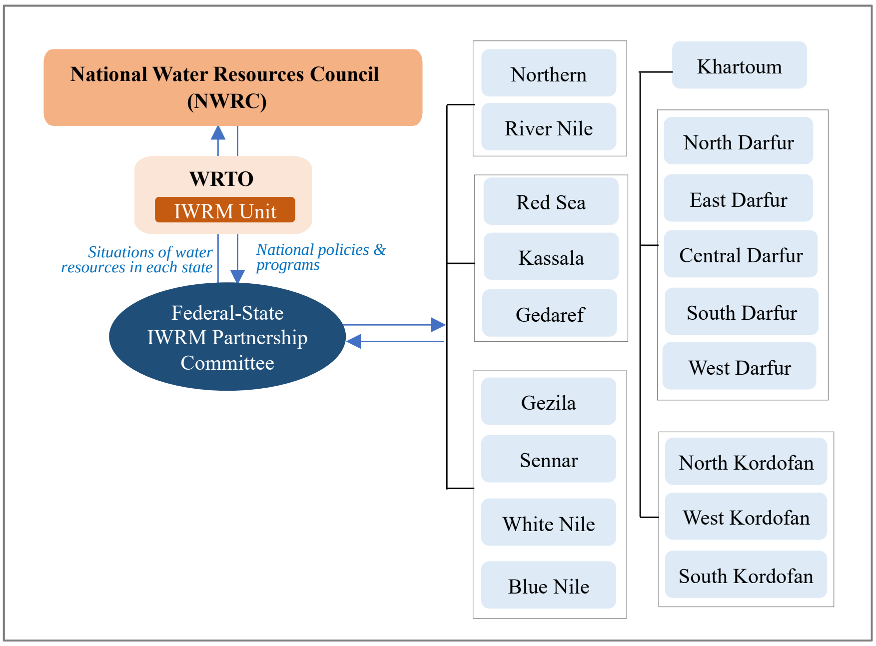


Figure 4.4-12 Federal-State IWRM Partnership Committee

The Partnership Committee meets regularly, usually twice annually, corresponding to the NWRC meetings. The Partnership Committee is attended by the representatives of all 18 states in Sudan and the WRTO officers. The attendance of the NWRC members is subject to further consideration. In the event that NWRC members do not attend the Partnership Committee, the WRTO will report the result of the Partnership Committee meeting to the NWRC later.

The Partnership Committee functions as a means of sharing information relating to the water resources' situation in each state with the WRTO and the state representatives. The WRTO is able to disseminate information on federal policies and programmes to the state representatives. By ensuring this information-sharing process, the federal government will be able to prepare policies and programmes based on accurate knowledge of the water resources' situation in each state. Likewise, each state is able to send information and messages to the federal government through this channel and is in a better position to align its activities with national policies.

The first Partnership Committee meeting was held on 15 March, 2023 at the Grand Hotel in Khartoum from 9:00 to 16:00 and sponsored by the JPT. Its agenda is shown in Table 4.4-22 below:

Table 4.4-22 Agenda of the First Federal-State IWRM Partnership Committee Meeting in March 2022

Agenda	Sub-Subject	Duration/Time	
		Duration	Time
1. What is IWRM?	1.1 Definition of IWRM 1.2 Previous efforts in Sudan 1.3 NWRC initiative in 1990's	30 minutes	9:15:9:45
2. JICA Project Experience in North Kordofan	2.1 State Water Resources Council (SWRC)	10 minutes	9:45-9:55
	2.2 Water Users Committee	10 minutes	9:55-10:05
	2.3 IWRM Unit	10 minutes	10:05-10:15
Breakfast (10:15:11:00)			
3. Reports by state representatives on water situation in each state	17 states	10 minutes for each state →10*17= 170 minutes	11:00-14:05 (including 15-minute coffee break)
Coffee/tea break (14:05-14:20)			
4. Way forward	4.1 Revitalization of NWRC/ -Committee/IWRM Unit	20 minutes	14:20-14:30
	4.2 NWRC and SWRC		14:30-14:40
5. Discussion/wrap-up	-	30 minutes	14:40-15:10

The meeting was attended by a total of 62 participants including 18 state representatives, all the general directors of the water corporations or the directorate in charge of the water sector, 17 directors of various general directorates of the MIWR, two JICA IWRM Project C/Ps from North Kordofan, four participants from donors and academia, nine employees from the JICA Sudan office and the JPT, two representatives from the media and others.

The meeting proceeded as follows under the chairmanship of the WRTO chairman:

- Opening speech by the MIWR minister
- Presentation on the definition of and previous experience in IWRM in Sudan by the JICA IWRM Project Manager
- Presentation by two North Kordofan C/Ps for the JICA IWRM Project focusing on the experiences of North Kordofan in introducing IWRM, supported by the JICA IWRM Project
- Presentations by the 18 state representatives on the problems, challenges and solutions in the water sector of each state
- Presentation by a MIWR C/P within the JICA IWRM Project on the way forward involving the NWRC, the Federal-State IWRM Partnership Committee and the WRTO ITWM Unit
- Discussions and wrap-up by the JPT

The presentations and discussions revealed that there are many problems similar to those faced in Bara, while there are other types of problems in Bara which are less serious. Table 4.4-23 below presents the problems raised by the state representatives, broadly grouped into "considerable problems", which are the problems directly affecting water resources and supply services, and "background problems", which are background factors, affecting water resources and supply services more indirectly.

Table 4.4-23 Water-Related Problems Pointed Out by the Representatives of 18 States

Category	Specific Problems Pointed Out by State Representatives
Phenomenal Problems	
Logistic issues	• No laboratory for water quality testing • No vehicles for monitoring • Inadequate funds • Low salaries • Shortage of employees • Poor work environment • Low commitment of technicians • Unstable power supply
Facilities, equipment	• Lack or inadequacy of spare parts • Collapse of water stations • Drawdown of GW, drying up of GW basin • No adequate Nile water stations • Cessation of federal projects • Absence of water filtration plants • Facilities damaged by the community or pastoralists • Inadequate number of hand pumps • Poor maintenance and rehabilitation • High cost of equipment and tools • No automatic recorders for GW • Collapse of wells • Lack of drilling machines and labour • Damas trees destroying water pipes
Operation	• High operation costs • Limited access in the rainy season
Background Problems	
Vertical/horizontal coordination, cooperation	• No coordination among water users • Neglect of community participation • Lack of coordination among organizations • No specific body to integrate water users • Weak relationships, management and coordination
Organization	• Unclear separation of responsibilities • No clear management and technical relations • Duplications of roles and responsibilities • Crossing of decisions • No rural water directorate • Inadequate independency of the water corporation from the state government
Demand side issue, cost recovery	• Water tariff is too low to cover operation and maintenance costs • High water consumption • Significant consumption of water through the use of AC • Water users not saving water • Considerable GW use by investment
Information management	• Poor information management • Limited monitoring • No updating of database • No continuous monitoring
Laws and regulations, policy	• No decree on well operation • Limited legislation • No legislation or water management • Inactive regulations resulting in uncontrolled drilling • Inactive legislation regarding GW licensing • Absence of legislation and laws • No water policy

State-federal relations	• Limited connection between federal and state water corporation • Ineffective application of national and state water policy • Poor coordination between state and federal bodies • Ineffective federal system in terms of decision-making • Inactive role of the NWRC • Lack of federal cooperation
Social and cultural	• Problems caused by pastoralists • Continuous conflicts • IDPs and refugees • Migration through conflict • Political instability
Environmental	• Pollution by sewage and pesticides • No awareness of hygiene • Pollution due to mining and contamination by mercury • Unorganized mining • Asbestos used in water pipes • Climate change
Technical approach, capacity development	• Inadequate studies and limited modern technology • Lack of scientific knowledge • No conjunctive use of water • No outside training • Lack of training • Huge gap in the technical level between senior officers and junior officers • Lack of technology transfer • Lack of qualified officers • No commitment to hydrological studies • No outside training for SCADA

Note: The information shown above is extracted from simultaneous interpretation, therefore should be regarded as general remarks.

Many kinds of water-related problems, identified in Table 4.4-23, indicate the following points:

- The problems identified this time are similar to those identified in Phase 1 of the JICA IWRM Project in the 2016-2017 period. The magnitude of the problems, however, seem to have worsened since then due to recent political, social and economic instability.
- There are different levels and kinds of problems. The "phenomenal problems" are mainly on the supply side and these problems limit the supply capacities of facilities. The financial problem is the root cause, therefore, normalization of the political and economic situation will result in more availability of funds, which will solve these problems significantly.
- Many of the background problems are primarily related to the demand side. Of these challenges, the pilot activities of the JICA IWRM Project in North Kordofan addressed the issues of vertical and horizontal cooperation and coordination, demand side control, information management, laws and regulations, state-federal relations, the technical approach and capacity development. The combination of these approaches, named the "Bara IWRM Model" in the JICA IWRM Project, made an impact in Bara.
- The level of IWRM would differ from region to region, depending on the situation of water resources and water use. The Bara IWRM model approach could be replicated where shallow aquifer GW is used, whereas different styles and levels of the IWRM approach would be needed in the basement rock area, in the Nubian sandstone area and in other areas with different natural characteristics. The experience of IWRM in other states, for example, in West Darfur, can enrich the IWRM models which could be applied in Sudan.

- In essence, certain objectives are common to all areas. One is the need for a technical approach. All the decisions should be made based on scientific judgment. Another is the need to involve water users in the water resources development and management process. These are most affected by water problems, therefore, are the most keen to solve those problems. They are the core driving force for better water resources management.
- A high expectation was observed among the participants for the continuation of the Partnership Committee and a simple questionnaire survey is being conducted to establish the participants' evaluation of the Partnership Committee meeting, their expectations for its continuation and the ideas of the state representatives with regard to the establishment of the SWRC and the WUC.

3) Findings, Lessons and Challenges

Since the NWRC has not been convened since the enactment of the Amendment in 2021, there are challenges rather than findings and lessons. The following are the remaining challenges:

- The present organizational capacity of the WRTO is not strong enough to undertake the functions to support the NWRC, which were newly defined by the Amendment. The IWRM Project proposed the establishment of the WRTO-IWRM unit to strengthen the organizational capacity of the WRTO. This proposal should be put into practice swiftly by the MIWR.
- The Federal-State IWRM Partnership Committee should be formally established as part of the NWRC mechanism.
- The MIWR should take action promptly to request that NWRC member organizations select official representatives to the NWRC, so that the first NWRC meeting since the Amendment can take place as soon as possible.

4.4.4 Enhancement of Monitoring Activities

(1) Background and Objectives

Although the monitoring of GW and SW in the Non-Nile area is the mandate of the MIWR's General Directorate of Groundwater and Wadi, monitoring activities have been inactive since the 1990s, when the federal government adopted the decentralization policy. The General Directorate of Groundwater and Wadi from the Kordofan office has received insufficient support from Khartoum, especially financial support, and has not been able to undertake monitoring activities.

The overall purpose of monitoring is to establish a GW and SW monitoring system and to sustainably manage the monitoring data in a database. The data will then be used for the purposes of consultation and policy-making for the sustainable use of the Bara Aquifer in a consensus-building/policy-making system led by the SWRC and the WUC. The following sections explain SW, GW and water quality monitoring.

(2) SW Monitoring

2-1) Background and Objectives

The MIUD had a plan to stop using GW from the Al Sidir wells to supply water to El Obeid and to replace it with SW from the Sikeran Wadi. The JPT assessed the sustainability of the water supply solely from Sikeran Wadi to El Obeid using the available data. The preliminary results showed that replenishment from the Al Sidir Wellfield was still necessary. It was decided to conduct a more detailed analysis, including the observation of the long-term flow rate of the Sikeran Wadi to assess this option more accurately.

2-2) Procedure and Outputs of SW Monitoring

<u>Workflow</u>

SW monitoring was undertaken according to the steps shown in Figure 4.4-13.

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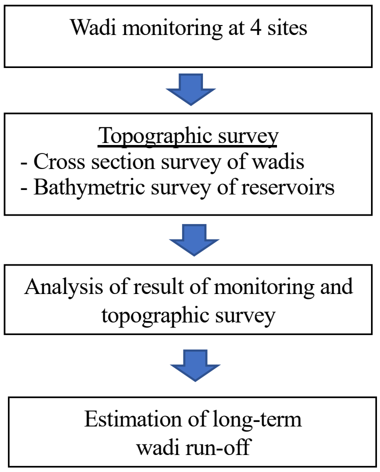

Figure 4.4-13 Procedure for SW Monitoring

<u>Locations and Monitoring Work</u>

SW monitoring has been carried out at four locations since the rainy season in 2019 as shown below:

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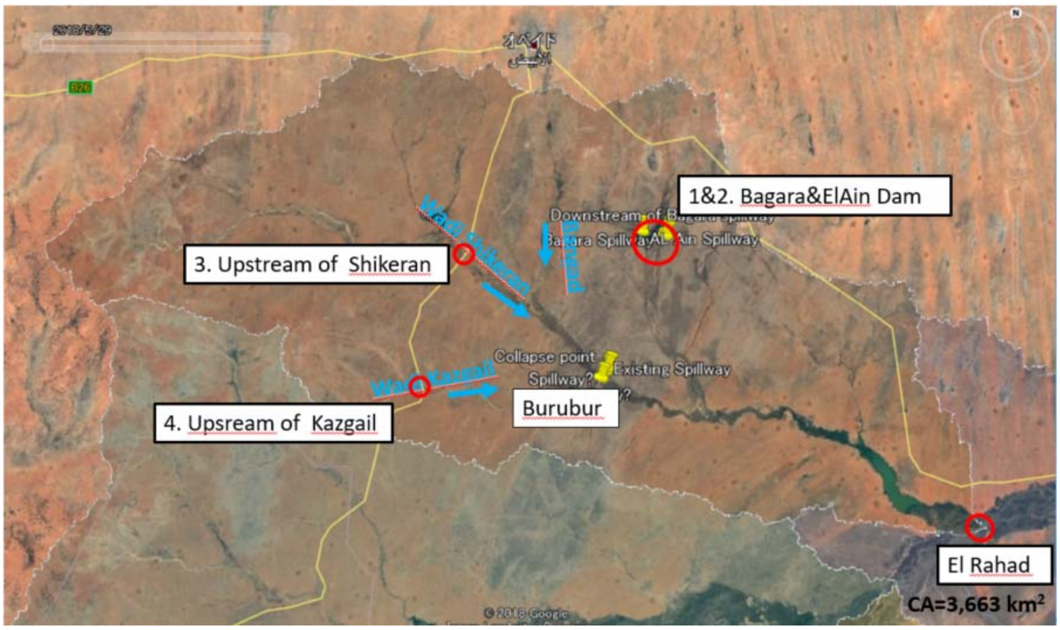


Figure 4.4-14 Locations of SW Monitoring

An outline of the SW monitoring is shown in Table 4.4-24.

Table 4.4-24 Outline of SW monitoring

Item	Content
Period	August 2019 to October 2023, for four seasons.
Location	Four sites at a) El Ain Dam, b) Bagara Dam, c) Wadi Shikeran and d) Wadi Kazgail (see to)
Measurement item	Water depth at each monitoring point
Measurement method	Reading by the staff

Measurement frequency	Hourly
Implementation system	Four teams (one team: one hydrologist and two laborers)

Topographic Survey on SW Monitoring

The topographical survey was carried out at the monitoring point by the Sudanese C/Ps in March 2020 to create primary materials for monitoring data evaluation. Figure 4.4-15 presents the photographs of the bathymetric survey.

Figure 4.4-15 Photographs from the Bathymetric Survey

Cross-Sectional Survey

The cross-sectional survey was implemented at 4 sites: i) Wadi Shikeran, ii) Wadi Kazgail, iii) spillway of the El Ain Dam and iv) and spillway of the Bagara Dam. The cross-sectional survey made it possible to understand the cross-sectional shape of the river and the specifications of the spillway of each reservoir.

Bathymetric Survey at the Reservoirs

A topographic survey of El Ain Reservoir, with two hafirs and Bagara Reservoir with seven hafirs within the total surveying area of 2.0 km^2 was carried out by the Sudanese C/Ps. As a result, the current capacity of both reservoirs was understood. A comparison of the current capacity and design capacity at each reservoir is summarized in Table 4.4-25.

The survey results show that El Ain and Bagara Reservoirs have already lost 29% and 48% of their original storage capacities due to sedimentation. This result is valuable and will be critical when studying the sustainability of the El Obeid water supply from the Al Ain and the Bagara Reservoirs in the future.

Table 4.4-25 Comparison of Existing Capacity and Design Capacity

Site	(1) Current Capacity	(2) Design Capacity	Ratio for Available Capacity=(1)/(2)
Al Ain Dam and Hafirs	2.35MCMm^3	4.5MCM	52%
Bagara Dam and Hafirs	6.37MCMm^3	9.0MCM	71%
Total	8.73MCMm^3	13.5MCM	65%

Calculation of Wadi Flow Discharge

The flow discharge is calculated from the flow velocity and the flow area.

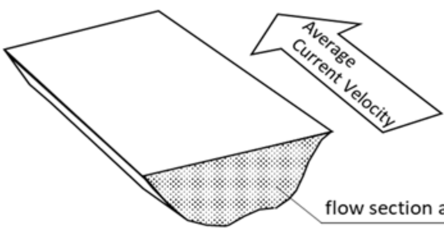
Q=A・V

where,

Q: flow discharge (m^3/s)

A: cross-sectional area of flow（m^3）

V：average flow velocity(m/s)



The flow discharge is estimated based on the observed water level and the head-discharge (H-Q) curve.

Observed water depth H(m) ⇒ H-Q Curve ⇒ Estimated flow discharge Q(m^3/s)

The H-Q curve is created by the Manning formula. The flow discharge is estimated from the observed water depth and the HQ formula.

Calculation of River Discharge into the Reservoir

The reservoir inflow is calculated by the formula below. Its concept is shown in Figure 4.4-16.

Inflow into the reservoir = Storage volume change + Outflow + Water intake for water supply
+ Evaporation from the reservoir

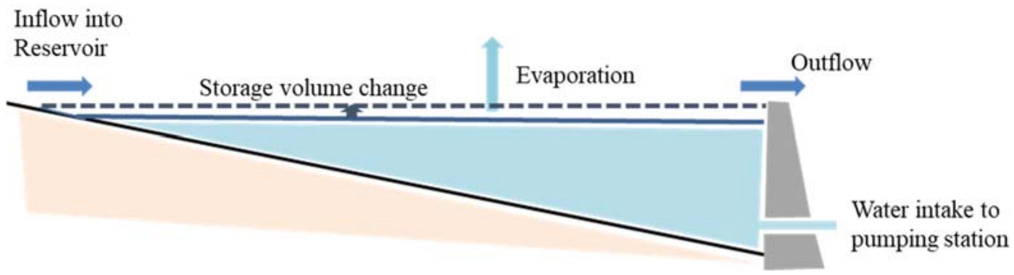


Figure 4.4-16 Water Balance of Reservoir

Calculation of Outflow from the Reservoir

The overflow calculation formula of the crest of the overflow is the same as the overflow formula for the weir. The following method is applied to the standard crest of the overflow of dams.

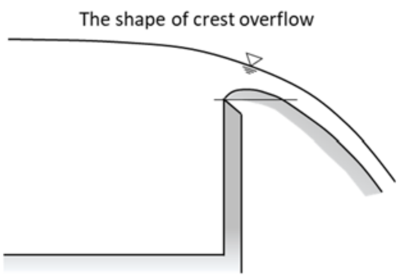
$Q = CBH^{3/2}$

where, Q: overflow (m^3/s)

H: overflow depth based on the highest crest point of the overflow (m)

C: discharge coefficient

B: overflow width (m)

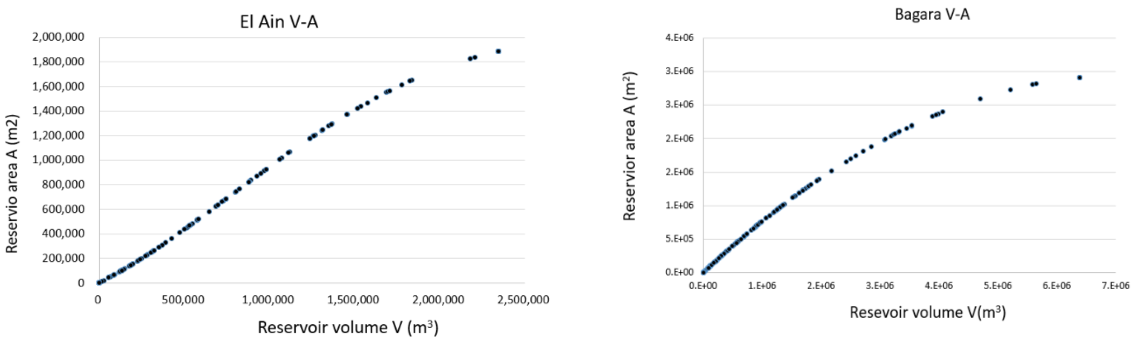


Evaporation from Reservoir

The evaporation from three reservoirs was estimated using the relationship between the volume (V) and the surface area of the reservoir. The V-A curve is shown in Figure 4.4-17.

Daily evaporation (m^3/day) = surface area of reservoir (m^2) × 0.007 (m)

Those curves were made based on the bathymetric survey of the Bagara and El Ain Reservoirs, which was implemented by the Project in 2020. The V-A curve of the Burubur Dam is not shown in Figure 4.4-17 because the Burubur Dam is a group of hafirs not a dam in reality. Therefore, it is easy to calculate the surface area of the dam and it is not necessary to show the V-A curve.



El Ain Bagara

Figure 4.4-17 V-A Curve of the Two Reservoirs

Result of Rainfall-Runoff Analysis Based on Monitoring Results

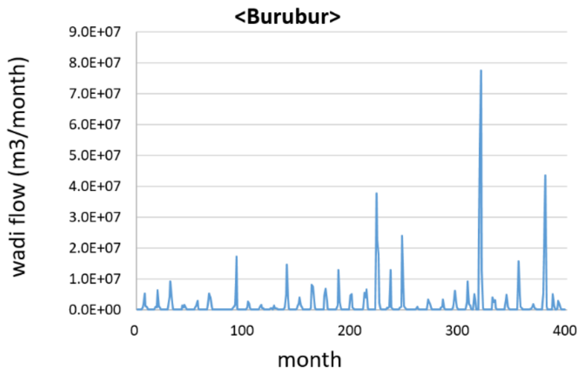
The runoff volume and ratio at each monitoring site during the monitoring period are shown in Table 4.4-26. Based on the initial estimation of flow discharge between 2019 and 2020, the runoff ratio at each monitoring point during the monitoring duration is 1% to 9%.

Table 4.4-26 Runoff Ratio at Each Monitoring Site in 2019 and 2020

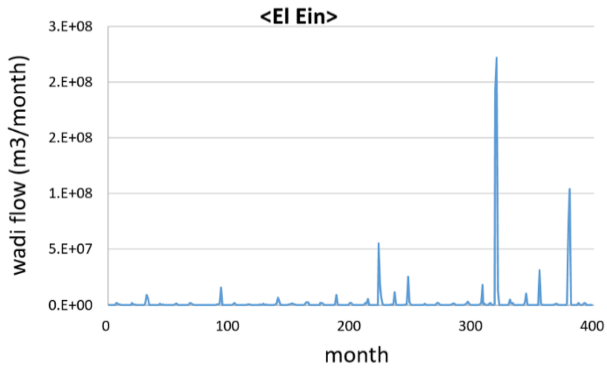
Site	El Ain Dam		Bagara Dam		El Sekaran Station		Rayash Station	
Year	2019	2020	2019	2020	2019	2020	2019	2020
(1) Catchment area (km^2)	93.8		168.3		1179.44		160.36	
(2) Rainfall	98.5	256.9	139.3	370.5	90.5	-	-	-
(3) Rainfall volume (MCM)	9.24	24.09	23.44	62.35	106.74	-	-	-
(4) Runoff volume (MCM)	0.57	1.39	2.26	3.36	1.28	-	-	-
(5) Runoff ratio	0.062	0.058	0.097	0.054	0.012	-	-	-

The results of monitoring were analysed to improve the accuracy of the parameters of the simulation model, SHETRAN. Then, the wadi discharge of three reservoir sites was analysed using historical rainfall data from 1980 to 2014. The analysed discharge is shown in Figure 4.4-18.

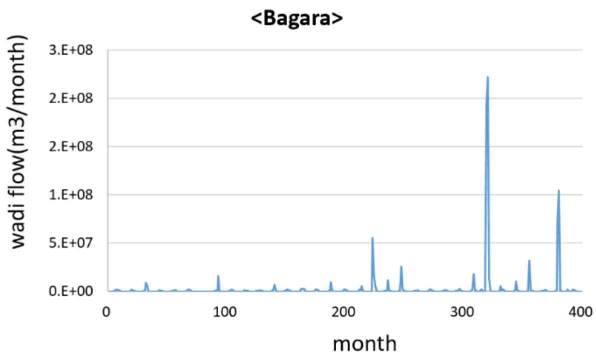
Throughout the four years (2019-2022) of wadi monitoring, the wadi flows of the three reservoirs in the Sikeran Wadi were observed. The observations were used to validate the parameters of SHETRAN, a long-term, rainfall-runoff analysis model. Using the improved parameters, wadi flows were calculated from rainfall data over the past 32 years. The flow rates were used to analyse the water balance of the three reservoirs. From the results, the sustainability of the water supply from the three reservoirs to El Obeid was evaluated. Based on this result, an optimal ratio of water supply from the three reservoirs to El Obeid was estimated, based upon which the possibility of the conjunctive use of SW and GW to supply to El Obeid was analysed.



Burubur Dam



El Ein Reservoir



Bagara Reservoir

Figure 4.4-18 Wadi Discharge for 32 Years (397 Months) at Three Reservoir Sites

2-3) Findings, Lessons and Challenges

Wadi Observation System

The SW monitoring system, established during the pilot activities, should be formalized and activities continued, capitalizing on the experiences of the JICA IWRM Project. During the four years of monitoring, an observation system for wadis has been established. Specifically, the system includes observation sites, methods, observers and the costs and method of covering the costs of the workers. Wadi monitoring is conducted by the SWRC's IMRM unit staff, who are also hydrological engineers from the Ground Water and Wadies Directorate (GWWD) and the MIUD. Wadi monitoring will be conducted at the site by the workers, and methods for staffing and mobilizing workers have been established. The majority of the wadi's monitoring costs are incurred by hiring local workers and providing vehicles and fuel for the workers to travel to the site. These costs are to be included in the SWRC budget.

Flexible Operation Depending on Budget Availability

Wadi monitoring is more expensive than other types of monitoring. This is due to the large number of workers required to conduct the observations. In addition, the monitoring work is concentrated during the three months of the rainy season, which requires workers to camp at the observation sites, a factor which increases costs. Therefore, during the years when the state government's budget is low, the Project should only be implemented during a portion of the three-month rainy season to accommodate the budget. Monitoring is still worth continuing even at a lower level. Considering the purpose of monitoring, this should be continued at a minimal level when the budget is small.

(3) GW Monitoring

1) Shallow Aquifer Monitoring

Many hand-dug shallow wells exist in the Bara area, and a large volume of GW is extracted from shallow aquifers. Shallow aquifer monitoring was conducted in two ways: first by participatory monitoring from March 2020 to September 2021, followed by monitoring by automatic recorders, installed in October 2021.

1-1) Participatory Shallow Well Monitoring

The objectives of participatory monitoring are as follows:

i. To make water users aware of the finite nature of GW resources and the need for water conservation through monitoring by the water users themselves.

ii. To calculate the GW recharge rate based on the monitoring results, determine the safe pumping rate of the wells, compare the safe pumping rate with the current pumping rate and assess the risk of GW depletion of the shallow aquifer. If the current pumping rate is greater than the safe pumping rate, it is necessary to reduce the pumping rate.

The JPT selected candidate wells for shallow GW monitoring in September 2019, considering their locations to be representative of GW levels covering the entire project area. The state C/Ps and the JPT visited all the candidate wells and investigated the conditions of wells to judge whether they were suitable for participatory monitoring. They finally selected 60 wells as shown in Figure 4.4-19.

The selected wells for participatory monitoring are grouped into three types, as shown in Table 4.4-27: irrigation wells, water yard wells and private wells in Bara town. Figure 4.4-20 presents the photographs of participatory monitoring. Figure 4.4-21 shows the structure of typical shallow wells.

Table 4.4-27 Outline of Monitoring Well

Type of Well	Number of Wells	Result of Site Survey
Irrigation wells	20	The candidate wells were selected form the list of existing wells of the MIUD. The state C/Ps visited each well and checked whether it was possible to measure the GW level. If it was not possible to measure the GW level of the wells, other wells were found near the original wells.
Water yards wells	20	
Private wells of Bara town	20	

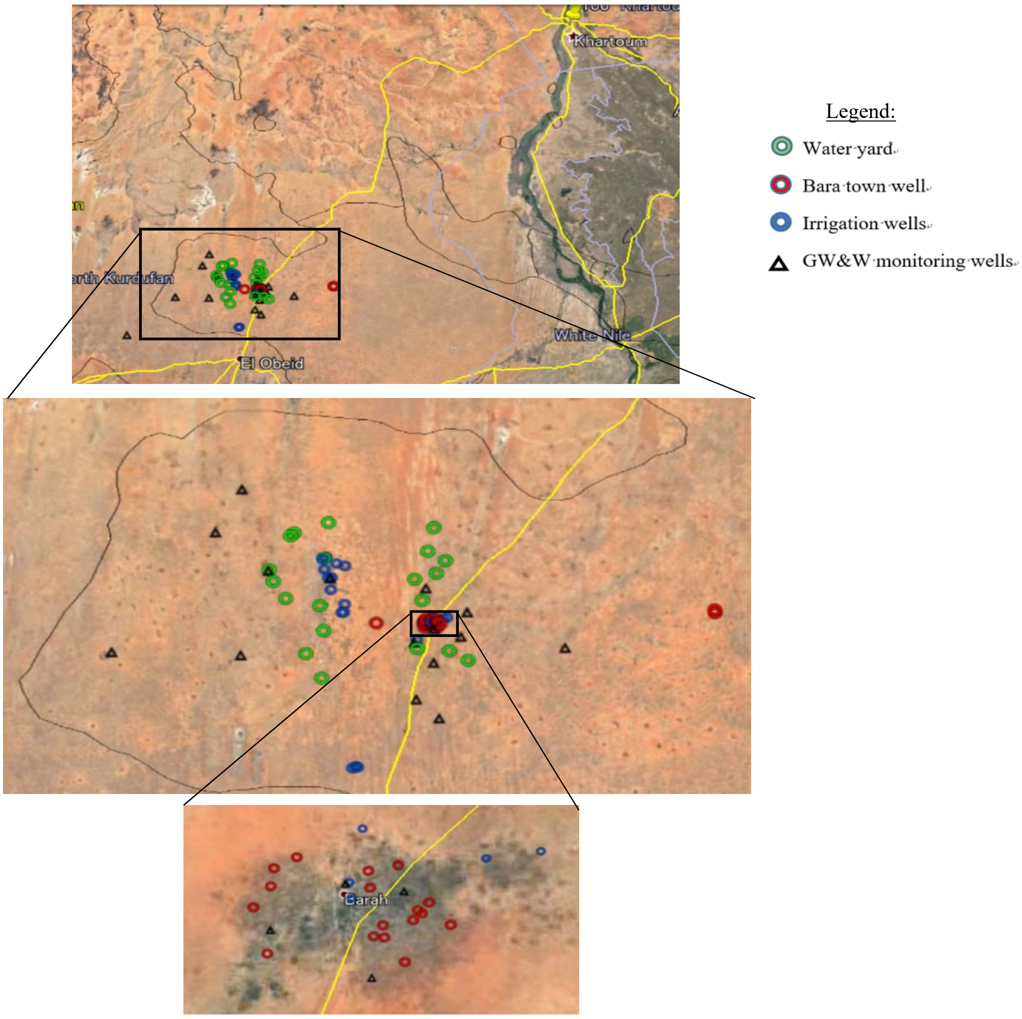
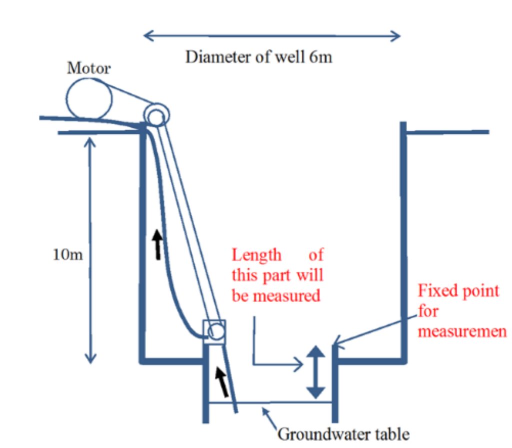


Figure 4.4-19 Locations of 60 Wells for Participatory Shallow Well Monitoring

(Instruction on methods of monitoring work)

(Private well in Bara town)

Figure 4.4-20 Photographs of Participatory GW Monitoring in Bara Town



Schematic section of well

Photo of well

Figure 4.4-21 Typical Structure of Shallow Wells

The state C/Ps started the collection of monitoring data in April 2020. Many more water users than expected joined and supported the monitoring works at the beginning of the monitoring process. Although the JPT experts could not visit Sudan due to COVID-19, the monitoring works started at almost all the monitoring wells. The collection of monitoring data has, however, been suspended since the middle of April 2020, due to the restriction of movement and the lack of vehicles as a result of COVID-19. The state C/Ps resumed the collection of monitoring data in July 2020, when the number of COVID-19 infections had started to decline.

As a result of the GW recharge analysis, based on the participatory monitoring results, the GW recharge was estimated to be between 30mm and 60mm per year in Bara town. Using these data, the safe yield of the wells in Bara town was estimated. The safe yield, defined as the amount of GW extraction that does not result in a depletion of the GW, was estimated to be 41m^3 per well per day on average in Bara town. The current average yield of the wells is 80m^3 per well per day in Bara town, which is almost twice the estimated safe yield. The drawdown of the GW level in the shallow wells was observed at 0.37m on average in Bara town during the monitoring period. The GW level of Bara town will continue to decline in the event that current pumping levels continue.

1-2) Shallow Well Monitoring by Automatic Recorders

Installation and Monitoring Results

Ten automatic GW recorders for the shallow aquifer were arranged and installed with the JPT's support between 2021 and 2022. The automatic recorders have been operated without any issues in the Bara and Al Bashiri areas. Their locations are shown in Figure 4.4-22.

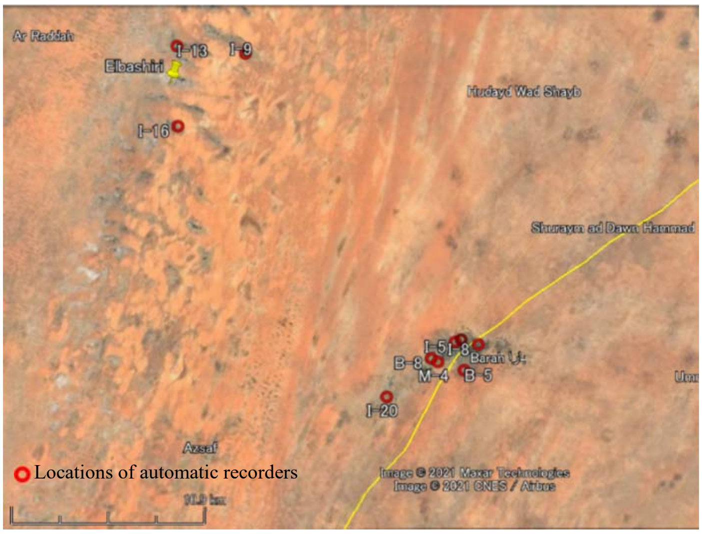
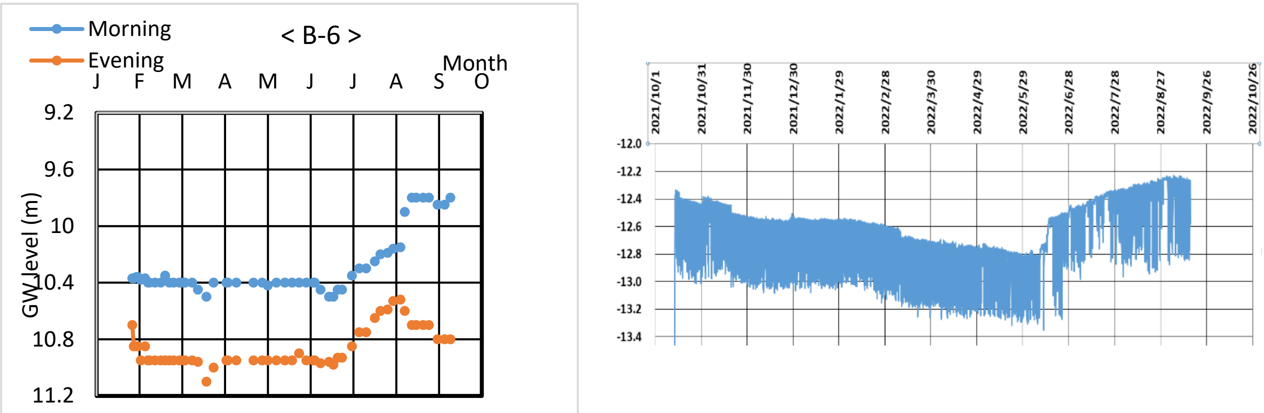


Figure 4.4-22 Locations of Automatic Recorders

The results of the participatory monitoring and monitoring by automatic recorders are compared in Figure 4.4-23.



Participatory Monitoring Automatic Recorder Monitoring

Figure 4.4-23 Results of the Participatory Monitoring and Automatic Recorder Monitoring

The pattern of the fluctuations in GW levels is similar in relation to participatory monitoring and monitoring by automatic recorder, as shown in Figure 4.4-23. GW levels gradually decrease during the dry season and begin to rise with the onset of the rainy season. There is also no significant difference in the range of GW fluctuation between the wet and the dry seasons as regards each monitoring method. In both cases of participatory monitoring and automatic recorder monitoring, the fluctuations between seasons is 0.6m. The number of wells showing similar results is, however, very small. On the other hand, all the wells with automatic recorders show similar results. This fact indicates the higher reliability of automatic recorders.

Based on the aforementioned results, the state C/P team and the JPT agreed to terminate participatory monitoring and to switch to monitoring by automatic recorders. A comparison of the results of participatory monitoring and automatic recorder monitoring revealed that if the well users are committed to monitoring, participatory monitoring can be comparable to automatic recorder monitoring in terms of the accuracy of the monitoring results.

Safe Yield Estimated Based on Automatic Recorder Monitoring

The state C/Ps had limited knowledge of the way in which to calculate GW recharge, therefore, the JPT provided guidance on how to define and calculate GW recharge.

GW recharge is estimated from the monitoring results and may be calculated using the following equation:

GW recharge (mm/year) = Maximum difference in GW level between rainy and dry season × porosity of aquifer

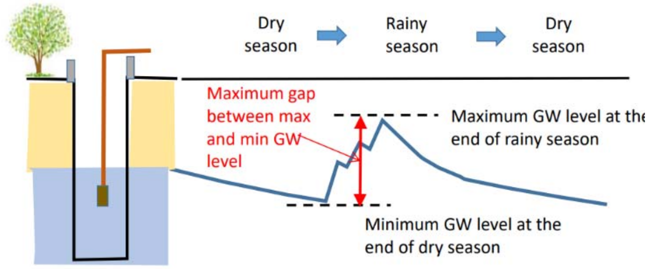


Figure 4.4-24 Relationship Between GW Recharge and Monitoring Results

The results are presented in Table 4.4-28 below. The GW recharge was estimated to be 14mm per year on average, based on the monitoring results of the automatic recorders.

Table 4.4-28 Result of Monitoring by Automatic Recorders

Well No.	Max. Difference of GW Level (cm)	Porosity of Aquifer	GW Recharge (mm/year)
B-5	20	0.05	10
I-8	57	0.05	28
I-13	20	0.05	10
I-16	18	0.05	9
M-4	23	0.05	12
Average	28	0.05	14

According to Table 4.4-28, GW recharges, estimated by the results of automatic recorders, varied widely by well; the average is 14mm per year. The GW recharge estimated by participatory monitoring was 20mm per year, therefore, the two estimated values are similar. Since the results from the automatic recorders are considered to be more accurate, 14mm per year was used as the GW recharge amount for estimating safe yield. Based on the calculated GW recharge rate and the structure of the wells in Bara, the safe yield of the wells was estimated to be 39m^3 per well per day. It was found that the current pumping rate from the wells in the Bara area is approximately twice the safe yield. The state C/Ps communicated these results to the well users at the WUC and proposed the slogan, “Let's cut the pumping rate in half”. This proposal was accepted by the WUC members at the WUC. Recognizing the relationship between over-pumping and declining GW levels, the WUC members were receptive to the reduction target. The results were presented to the TC, and the state government agreed to provide support to the WUC. The contributions of the water balance analysis are as follows:

- The state C/Ps learned how to calculate GW recharge and understood the mechanism of GW decline and the concept of safe yield.

- The state C/Ps set reduction targets for pumping from irrigation wells and encouraged irrigation well users to set reduction targets in the WUC. The WUC responded by cooperating with a water-saving irrigation experiment, demonstrating their awareness of water conservation.

1-3) Findings, Lessons and Challenges of Shallow Well Monitoring

Findings

- Well users in the Bara area took part in participatory monitoring for one year and realized the finite nature of GW resources and the need to conserve water. The original purpose of participatory monitoring was achieved. The wells in the pilot activity area, however, were generally not suitable for participatory monitoring and as a result, much of the monitoring was inaccurate.
- Observation frequency was different from well to well, depending on the motivation of the well users. Some well users observed the GW levels every day and others, less frequently, such as once a week or once a month. The frequency of monitoring clearly shows the motivation of the well users concerning participatory monitoring. Around 5% of water users were observing the GW daily.
- The accuracy of the participatory monitoring differed from well to well. Some wells show clear fluctuations of the GW levels daily and seasonally, while others show no fluctuations of GW levels over several weeks or even several months. It is unusual that GW levels show no daily or seasonal fluctuation. Only 15% of the monitoring results indicated a seasonal fluctuation of GW levels. The factors to explain this result would include the motivation of well owners, the difficulty in measuring the GW level in centimetres, the limited time of farmers who are busy with farming work and the limited knowledge and training available for monitoring,

Lessons

- The selection of wells could have been carried out more carefully in consideration of the physical structure of the wells. It is more difficult for the water user to measure the GW levels safely in the case of wells with a large diameter compared with those with a small diameter. Moreover, it is difficult to measure the GW level in multi-diameter wells, as shown in Figure 4.4-25.

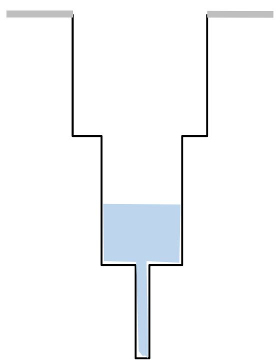


Figure 4.4-25 Structure of Multi-Diameter Wells

Wells for monitoring should be selected based on technical possibility and sustainability. Wells with a smaller diameter like less than 1.5m or those with a single diameter are appropriate for participatory monitoring.

- Wells with highly motivated water users should have been selected. The motivation of well users, however, cannot be confirmed at the outset, therefore, the continuous support of the state C/Ps is essential. It is practical to continue participatory monitoring for a certain period, then the monitoring wells with positive results should be selected, based on the accuracy and frequency of the monitoring. Monitoring should then be continued at those selected wells.
- Although the state C/Ps and the JPT agreed to shift the objective of participatory monitoring from measuring the GW level to measuring the pumping rate, when the automatic recorders were installed, this did not happen, largely due to the difficulties caused by COVID-19. Observation of the well pumping rate is much easier than observation of the well water levels. Well users only need to record the start and stop times of operation of the electric pump. In addition, since the pumping rate is almost constant, monthly observation would suffice.

Challenges

- Water users need support to continue with their monitoring, taking into account the aforementioned background factors. The state C/Ps should support the water users, patrol all the monitoring wells and collect the monitoring records. They should talk to the water users and collect records from them, and in so doing, motivate the water users to continue the monitoring work. Unfortunately, the state C/Ps could not visit the water users regularly at the start of the monitoring due to COVID-19. Therefore, regular contact between the state C/Ps and the water users was interrupted from the outset, and certain water users did not continue with the monitoring work.
- Resuming participatory monitoring to measure the pumping rate should be considered. An accurate estimate of the total pumping rate, based on the participatory monitoring in Bara would enable a water balance analysis with higher accuracy.

2) Deep Aquifer Monitoring

Issues to be Solved

GW levels in the deep aquifer in the target area are declining. The target area is providing water to El Obeid by pumping GW from the Al Sidir wells, and although a large amount of GW is pumped from the Al Sidir Wellfield, the GW levels in the wells have not been observed. The wells are being operated in a situation where the relationship between the amount of water pumped and the GW level is unknown. In other words, pumping continues without any awareness of the sustainability of the current pumping rate. To eliminate this risk, GW level monitoring of the Al Sidir wells should be conducted to determine the amount of water pumped and the status of the decline in the GW level. Based on this relationship, an appropriate amount of pumping should be proposed to eliminate the risk.

Content of Monitoring

The monitoring of wells in the Al Sidir Wellfield was completed in March 2020. Four deep boreholes were drilled by the MIUD at a 300m depth similar to the monitoring wells. The location of the monitoring wells is shown in Figure 4.4-26. The cost of drilling monitoring wells is very expensive, so the wells are expected to be used effectively. This seems to be the first attempt in Sudan to drill such deep wells specifically for monitoring work. This drilling indicates the acute awareness of the necessity of monitoring the GW level in the Al Sidir Wellfield. The JPT started monitoring the GW level of the monitoring wells from April 2020.

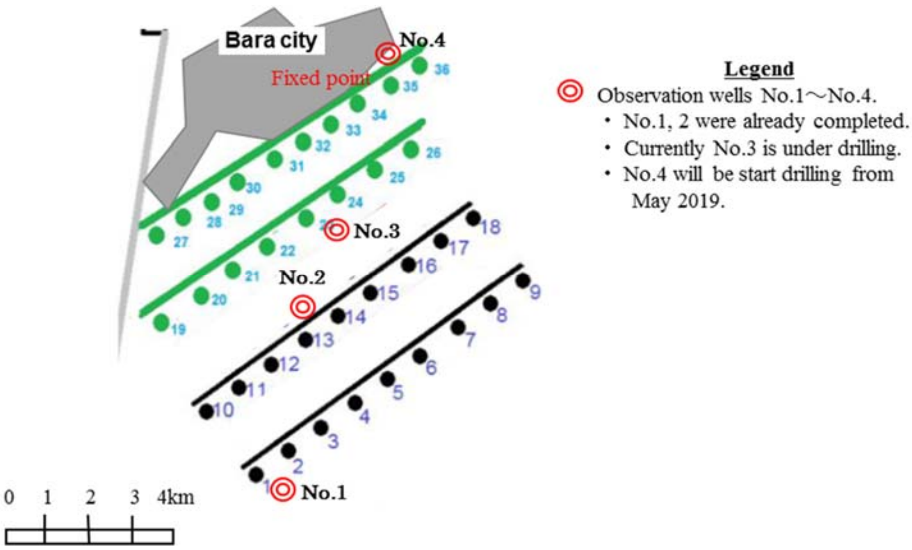


Figure 4.4-26 Layouts of the Wells in the Al Sidir Wellfield

The four monitoring wells are located in a line passing through the centre of the wellfield. Therefore, the GW level of the wellfield, affected by well interference, can be observed in the four monitoring wells.

(No.1 Monitoring well)

(No.4 Monitoring well)

(Top of the monitoring well)

Figure 4.4-27 Monitoring Wells of the Al Sidir Wellfield

Figure 4.4-28 shows the results of GW level monitoring of the Al Sidir Wellfield from February 2020 to April 2021. The results of the monitoring do not show a clear trend of the lowering of the GW level as a whole. In fact, the GW level of AL-1, AL-2 and AL-3 rose slightly (see Figure 4.4-28).

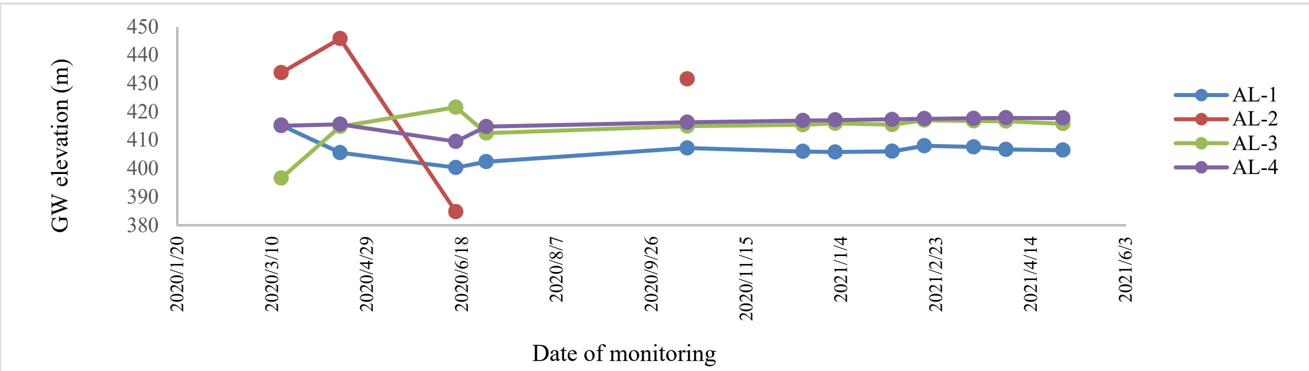


Figure 4.4-28 Results of the Monitoring of the Al Sidir Wellfield from February 2020 to April 2021

The reason is that there are 40 production wells in the Al Sidir Wellfield. Thirty of the 40 production wells are usually in operation, and these 30 wells are controlled with short-time rotation. The four monitoring wells are spread out across the entire wellfield. The GW level of the monitoring wells will go down when the production wells near the monitoring wells are in operation. On the contrary, the GW level of the monitoring wells will rise when the production wells near the monitoring wells are not in use. According to the results of the monitoring programme, it is expected that the pumping rate of the production wells will have been gradually reduced. The GW level of the monitoring wells is sensitive to changes in the pumping rate of the production wells. Therefore, it was concluded that a monitoring frequency of once a month was not sufficient. Consequently, the installation of GW level recorders is desirable.

3) GW Quality

Issues to be Solved

It has long been noted that the shallow well GW in the Bara area is contaminated. The state C/P, with the assistance of the Japanese experts, investigated the quality of well water in Bara town.

According to the survey results in Bara town in February 2020, the private wells in Bara town are actually used for almost the same purposes as the public water supply. The water quality of the GW in the Bara private wells, however, was not monitored, as the water supply by private wells is not regarded as a public water supply. The private wells in Bara town are shallow, hand-dug wells, therefore the water quality of the wells is considered to be contaminated by domestic wastewater.

Activities

The state C/Ps supported by JPT analysed the water quality of the shallow wells in Bara town, which are the target of GW level monitoring. According to the survey results in Bara town in February 2020, the private wells in Bara town are actually used for almost the same purposes as the public water supply. The water quality of the GW in the Bara private wells, however, was not monitored, as the water supply by private wells is not regarded as public water supply. The private wells in Bara town are shallow hand-dug wells, therefore the water quality of the wells is considered to be contaminated by domestic wastewater.

The state C/Ps collected the water samples from the shallow wells of Bara town, which are focus of the monitoring of GW levels, and analysed the water quality in relation to NH_4, NO_2, NO_3, total dissolved solid (TDS) and pH. From the results of the water quality analysis, the concentration of NO_3 exceeded the WHO guidelines in more than half of the target wells. It was fully expected that many wells would be contaminated with NO_3, caused by organic substances and affecting the drinking water. According to the results of the water quality analysis on coliform bacteria, the correlation between coliform and NO_3 was identified. Therefore, the cause of high levels of NO_3 was considered to be contamination by domestic wastewater. SODIS, which can kill coliform bacteria by sunshine, was proposed by the JPT as a simple and effective measure to solve this problem. The aforementioned water quality analysis was proposed and implemented by means of strong initiatives organized by the state C/Ps.

Countermeasures

Based on the results of the water quality analysis, the state C/P, with the assistance of the JPT, examined the countermeasures to water pollution. The following measures were considered:

i. To start a public water supply from the deep wells in the town of Bara.
ii. To encourage HH to improve the quality of well water by boiling or SODIS before use.

According to the MIUD engineer in charge, the deep GW in the Al Sidir wells is already supplying water to El Obeid, and there is insufficient water to supply Bara town. Although measure (ｉ) above is a drastic measure, it requires time and considerable investment. Therefore, for the time being, we have decided to adopt the method described in (ii) above, and the state C/P will appeal to the residents through the locality office and the WUC to take measures in this regard.

Water Quality Monitoring System

The MIUD has a water quality analysis laboratory with several experts. There is a water quality expert among the state C/Ps, who is in charge of water quality analysis in Bara town. When the state government was unable to obtain laboratory reagents due to financial difficulties, the JPT brought chemical test papers and the necessary equipment for on-site water quality analysis from Japan, which the C/P used to conduct the on-site water quality analysis. The MIUD has not conducted water quality analysis since Bara's water supply is not a public water supply. However, the pilot activity was the first step towards regular water quality analysis in Bara town and the provision of information to water users.

4.4.5 Application of Monitoring Results for Water Balance Analysis

(1) Issues to be Solved

In the project area, the lowering of shallow and deep GW levels is an issue (see Figure 4.3-12). A GW management plan was developed as a long-term solution to this problem. The cause of the GW level decline is excessive GW pumping. The decline in shallow and deep GW levels can be controlled by reducing the amount of GW pumping. In order to reduce GW pumping, reduction targets must first be presented to water users. Reducing shallow GW pumping requires reducing the amount of water used for irrigation in Bara. On the other hand, to reduce deep GW pumping, the pumping in the Al Sidir Wellfield must be reduced. Without providing reduction targets for each of these, it is impossible to create a reduction plan. Therefore, the first step is to define GW pumping reduction targets. The following procedures are used to calculate the GW reductions:

- Determine the current and future amount of GW used in the target area.
- Predict the reduction in GW levels if current GW pumping continues.
- Calculate the amount of GW pumping (safe pumping) that will allow for sustainable GW use.
- Compare current and future water demand to the safe yield, and if water demand exceeds the safe yield, set a reduction target for the portion of water demand that exceeds the safe yield.

Planning Procedures

The following procedures were used to analyse the water balance and establish reduction targets for lowering the GW level.

i. The current water balance is determined and a reduction target for GW pumping is set. The quantity of alternative wadi development water corresponding to the amount of GW reduction is also presented.
ii. The water balance for the target year of 2035 must be identified and a reduction target for GW pumping set. The amount of alternative wadi development water corresponding to the quantity of GW reduction will be presented.

(2) Current Water Balance and GW Pumping Deduction Target

The C/Ps, supported by the JPT, conducted a water balance analysis of the current status of the target area. The JPT recognized issues in the water balance and proposed measures to resolve them as part of a water resources management plan.

<Selection of Target Area for Water Balance Analysis>

This JICA Pilot Project is aimed at GW conservation and the sustainable use of GW resources in the Bara Aquifer. The GW basin targeted by this analysis is shown in Figure 4.4-29.

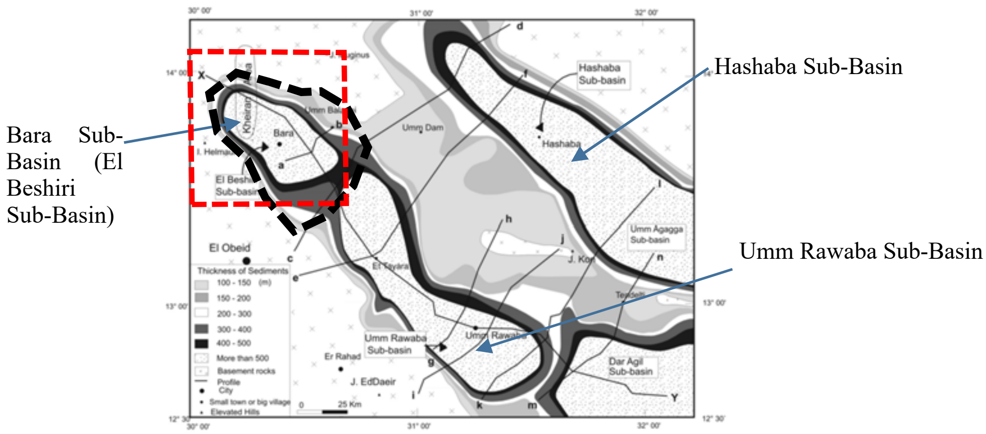


Figure 4.4-29 Bara Groundwater Sub-Basin of North Kordofan State

Source: Aquifer Systems in Kordofan, Sudan: Subsurface Lithological Model, Osman A Abdalla Osman A Abdalla

The Bara Basin covers a vast area of North Kordofan State. The Bara GW Basin is divided into three sub-basins (see Figure 4.4-29), which are the Bara (El Beshiri), Umm Rawaba and Hashab Sub-Basins. The three sub-basins are connected but are considered independent from a hydrogeological viewpoint. The pilot project area is located in the Bara Sub-Basin (El Beshiri Sub-Basin), as shown in Figure 4.4-30. Therefore, the Bara Sub-Basin was the target of this analysis; hereinafter the Bara Sub-Basin will be called "Bara Bain" in this report.

The target of the pilot activity is located in the Bara Basin within the Bara Aquifer. This area is mainly located in Basins No.92 and No.102 (see Figure 4.4-30) and provides the water supply for the state capital, El Obeid. However, El Obeid also receives SW from Basin No.88. GW development in the Bara Aquifer is closely related to SW development in No.88 Sub-Basin, so the No. 88 Sub-Basin is also included in the analysis.

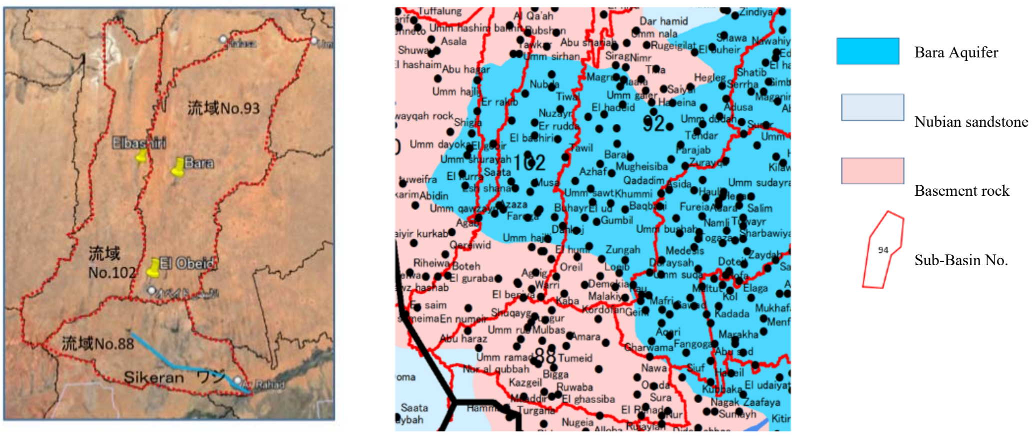


Figure 4.4-30 Target Sub-Basin for Water Balance Analysis

The geological classification of the three aforementioned sub-basins and the number of villages they contain are shown in Table 4.4-29.

Table 4.4-29 Overview of Sub-Basin Included in the Water Balance Analysis

Sub-Basin No.	Aquifer	Basin Area		Village Number
		km^2	% of each Sub-Basin	
88	Basement	3,533	96	32

	Nubian sandstone	143	4	0
93	Basement	1,941	20	23
	Bara Aquifer	5,161	41	62
	Nubian sandstone	1,204	12	14
102	Basement	1,941	23	20
	Bara Aquifer	5,161	62	41
	Nubian sandstone	1,204	14	12

Source: JPT

<Estimation of Water Demand>

Urban Population and Water Demand

The target sub-basin consists of cities and villages. Two cities, El Obeid and Bara town, have known populations. The urban population is shown in Table 4.4-30 and Table 4.4-31.

Table 4.4-30 Population and Water Demand of El Obeid

Population		Water Demand (m^3/day)	
2016	2035	2022	2035
418,725	727,439	500,000	655,000

Table 4.4-31 Population and Water Demand of Bara

Population		Water Demand (m3/day)	
2022	2035	2022	2035
16,800	29,200	672	1,480

Village Population

The average population of villages in the target sub-basins was estimated and water demand was estimated from the distribution of villages. Based on the statistical data of North Kordofan State, 3,000 people (in 2022) and 5,400 people (in 2035) were estimated as the average population of villages in the target sub-basins. The population of the three target sub-basins is shown in Table 4.4-32.

Table 4.4-32 Population of Rural Area of Target Sub-Basin

Sub-Basin	Number of Villages	Population	
		2022	2035
No.88	32	96,000	172,800
No.92	73	219,000	394,200
No.102	45	135,000	243,000
Total	150	450,000	810,000

Water for Livestock

Statistical data on village population and livestock types/numbers were analysed. Data on standard water consumption (ℓ/day/head) for livestock species were obtained and analysed. The statistical analysis revealed the following facts:

a) The village population and number of livestock are highly correlated.

b) The village population and livestock water consumption are highly correlated.

The relationship between a) and b) above is shown in Figure 4.4-31.

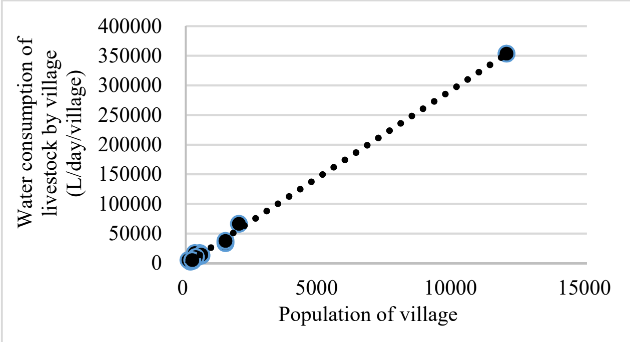


Figure 4.4-31 Relationship Between Village Population and Water Demand of Livestock

The relationship in Figure 4.4-31 presents the number of wells that correspond to the relationship between the village population (X) and the water consumption of livestock in the village (Y).

$Y=29\times X+1,583$

Using this relationship, livestock water consumption was estimated from the village population. The domestic water demand and livestock water demand in the target area are shown in Table 4.4-33.

Table 4.4-33 Water Demand for Domestic Use and Livestock

Items	2022	2035
Domestic Use	3,000 people ×30(ℓ/day/capita)=90m^3/day	5,400 people×60(ℓ/day/capita)=324m^3/day
Livestock	3,000 peopll×29(ℓ/day/head)=87m^3/day	5,400 people×29(ℓ/day/head)=157m^3/day
Total	147m^3/day	373m^3/day

Irrigation Water

Statistical data on the number of farms and the pumping rate in the target area were analysed. The correlation between the number of farms (gardens) and the number of wells was analysed and was found to be highly correlated (see Figure 4.4-32).

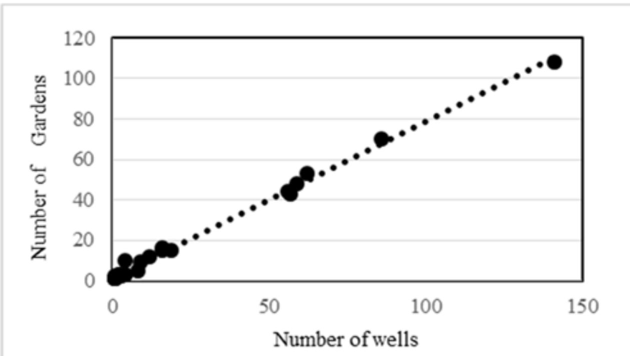


Figure 4.4-32 Relationship Between the Number of Wells and the Number of Farms

Since there were no data available regarding the location of farms, the distribution of farms was surveyed from satellite images, and the results are shown in Table 4.4-34.

Table 4.4-34 Distribution of Farms by Satellite Image

Area	Number of Farms[1)]	Total Area of Farms[2)]	Total Pumping Rate[3)]	Pumping Rate of a Well[4)]
Bara town	213	1.02km^2	12,600m^3/day	60m^3/day
Al Bashiri	262	1,23km^2	17,200m^3/day	66m^3/day

1) Based on statistical data from the Ministry of Agriculture
2) Estimated from sanitary photographs
3) Calculated based on the estimated water consumption of vegetables by Cropwat of the Food and Agricultural Organization (FAO)
4) Estimated and calculated as one well per farm, based on the relationship in Figure 4.4-32.

Based on the results of the participatory monitoring conducted by the JPT, the average pumping rate of wells in the Bara and Al Bashiri areas was calculated to be 80m^3/day. There is no significant difference between this value and the value of the pumping rate of one well shown in Figure 4.4-33, therefore, it can be concluded that the results of this analysis are reliable.

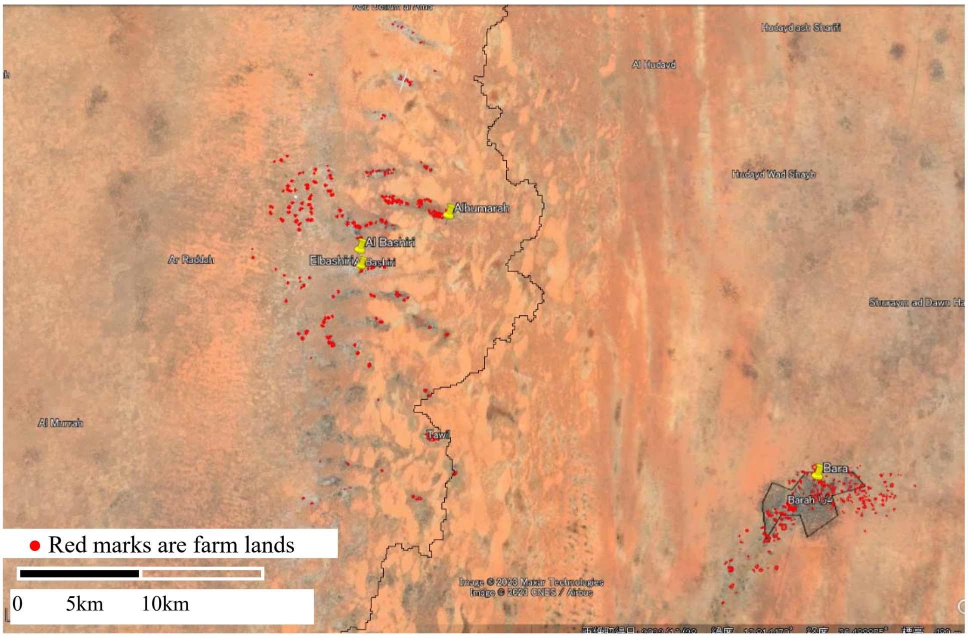


Figure 4.4-33 Distribution of Farmlands in Bara Town and the Al Bashiri Area

Conclusion of Water Demand Analysis

The results of the water demand analysis described above are summarized in Table 4.4-35.

Table 4.4-35 Water Demand of Target Area

Sub-Basin No.	Number of Villages	Rural Water Supply (m^3/day)		Water Consumption of Livestock (m^3/day)		Water Consumption by Irrigation (m^3/day)	
		2016	2035	2016	2035	2016	2035
88	32	2,880	10,368	2,784	5,024	0	0
92	73	6,570	23,652	6,351	11,432	12,600	22,680
102	45	4,050	14,580	3,915	7,047	17,200	30,960
total	150	13,500	48,600	13,050	23,490	29,800	53,640

<GW Balance Analysis>

The water balance analysis is performed based on the results of water demand and the water resource potential.

GW Model for the Project Area

The GW model was created to analyse the GW balance of the Bara Basin. The purpose of this simulation is to ascertain the magnitude of the drawdown of the GW level, based on the current water use.

GW Model

The area covered by the model is shown in Figure 4.4-34. The outline of the model is explained in Table 4.4-36.

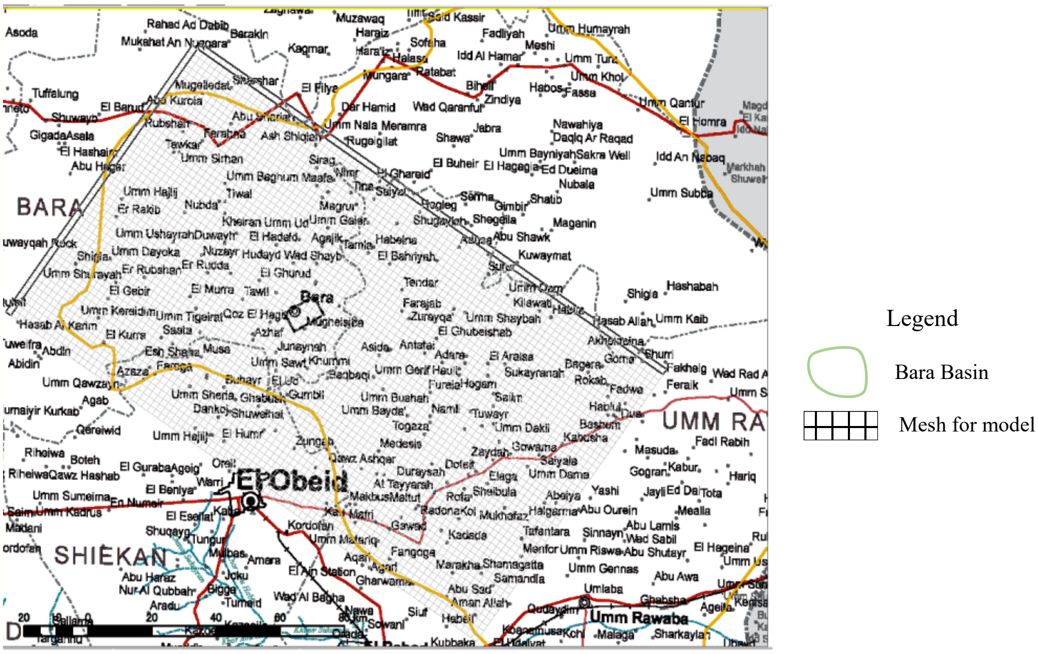


Figure 4.4-34 Area Covered by the Model

Table 4.4-36 Outline of Simulation Model

Item	Content
Number cells	102×64=6,528 cells
Size of cells	500m to 2,000m
Aquifer structure	-1st layer : shallow aquifer (depth :0-50m) -2nd layer : semi-confined aquifer (depth: 50 -150m) -3rd layer : deep aquifer (depth:150-300m)
Parameter of aquifer	-1st layer : 1.72m/day (10^{-3}cm/sec) -2nd layer : 0.00086m/day (10^{-7}cm/sec) -3rd layer : 0.86m/day (10^{-4}cm/sec)

Model Parameters

The model structure and hydraulic parameters of the model were created by referring to the existing studies. A summary of the model parameters is shown in Table 4.4-36.

GW Recharge

The GW recharge of the Bara Basin was analysed from the monitoring result. According to the results of the analysis, GW recharge in Bara Bain is estimated at 14mm/year.

Distribution of Wells

Shallow wells and deep wells were included in the model, based on water demand analysis.

Results of Analysis

The drawdown of the GW level was analysed over a 60-year period at the centre of the Al Sidir Wellfield, as shown in Figure 4.4-35. The GW level has been declining for a long period of time. The drawdown of the GW level of the Al Sidir Wellfield was around 32m in the centre of the Al Sidir Wellfield for 20 years, that is, a drawdown rate of 1.6m/year.

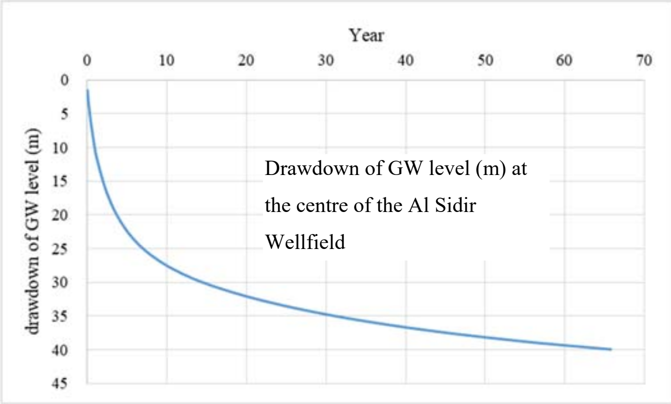


Figure 4.4-35 Drawdown of the GW Level in Al Sidir Wellfield

There is a possibility that the drawdown of the GW level in the Al Sidir Wellfield will be faster than the forecasted rate, and some deep wells will dry up.

Furthermore, there are many shallow, hand-dug wells in Bara town that are pumping huge amounts of GW. The depletion of the GW level of the shallow aquifer is very complicated, therefore, an analysis of shallow aquifer is explained in detail in “4.4.5 Application of Monitoring Results for Water Balance Analysis”.

Irrigation wells in Bara town have had an influence on one other causing a dramatic depletion of the GW level. There is no regulation to control such excessive well pumping, which is resulting in the rapid depletion of GW year on year.

<SW Balance Analysis>

There are three existing reservoirs, i) Bagara, ii) Al Ain and iii) Burubur Dam in the Sikeran Wadi Basin (see Figure 4.4-36). Water from the aforementioned three reservoirs is conveyed to El Obeid. The water balance of the three dams was analysed.

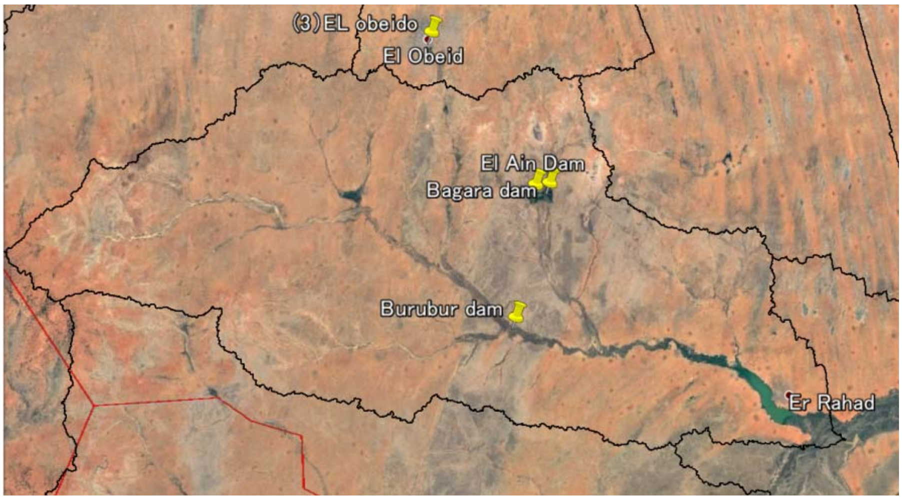


Figure 4.4-36 Location of Water Development Facilities Within the Sikeran River Basin

Discharge of Three Reservoirs

The wadi discharge at the sites of three reservoirs was observed by wadi monitoring from 2019 to 2022. The results of the monitoring were analysed to improve the accuracy of the parameters of the simulation model, SHETRAN. Then, the wadi discharge of three reservoir sites was analysed using historical rainfall data from 1980 to 2014.

Water Balance of the Burubur Dam

The schematic water balance of the Burubur Dam is shown in Figure 4.4-37.

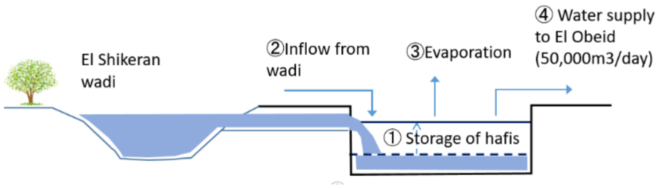


Figure 4.4-37 Image of Water Balance of the Burubur Dam

Storage of Burubur Dam today (m^3) = ① water storage of the Burubur Dam yesterday (m^3) + ② inflow into dam today (m^3) + ③ evaporation from dam today (m^3) + ④ water consumption from dam today (m^3)

Water Balance of the Bagara and El Ain Dams

The schematic water balance of the Bagara and El Ain Reservoirs is shown in Figure 4.4-38.

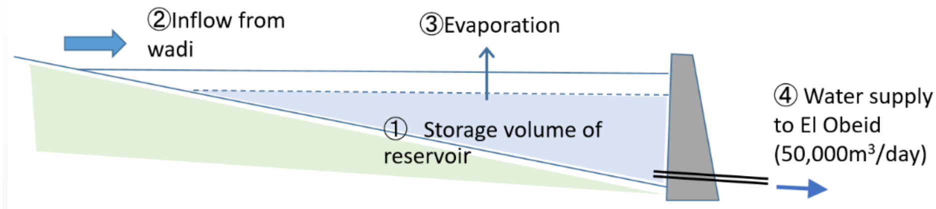


Figure 4.4-38 Image of Water Balance of the Bagara and El Ein Reservoirs

Storage of reservoir today (m^3) = ① water storage of reservoir yesterday (m^3) + ② inflow into reservoir today (m^3) - ③ evaporation from reservoir today (m^3) - ④ water consumption from reservoir today (m^3)

Evaporation from the Reservoir

Evaporation from the three reservoirs was estimated using the relationship between the volume (V) and surface area of the reservoir.

Daily evaporation (m^3/day) = surface area of reservoir (m^2) × 0.007 (m)

SW balance

The current water demand of El Obeid is 50,000m^3/day, 30,000m^3/day of which is supplied by the Al Sidir Wellfield. Consequently, the water supply necessary to fulfil this demand from the three reservoirs is 20,000m^3/day. The optimum water intake from the three reservoirs is analysed below:

Table 4.4-37 Current Water Supply to El Obeid

	Water source	Water supply (m^3/day)
①	Al Sidir Wellfield	30,000
□	Burubur, Bagara and El Ain	20,000
	Total	50,000

The optimum water intake from the three reservoirs is analysed using the equation below:

X+Y+Z = 20,000m^3/day

where,

- X is the water supply from the Burubur Dam
- Y is the water supply from Al Ain
- Z is water supply to and from Bagara

Note:

- The current water supply rate for El Obeid is 50,000m^3/day.
- The period for analysis is 32 years, i.e., 397 months

Generally, it is impossible to keep "X+Y+Z=50,000m^3/day" all through the year, as the three reservoirs will dry up by the end of dry season. Therefore, the best combination of X, Y, Z will satisfy the two conditions below:

a) "X+Y+Z=50,000 (m^3/month)" should be kept as long as possible.
b) The total amount of the water supply from the three reservoirs should be the maximum in the long-term.

<u>Results of Optimization</u>

After several trial analyses, the optimum water supply rate X, Y, Z was obtained for the combination of the Burubur (X), El Ain (Y) and Bagara (Z) Reservoirs, as shown in Table 4.4-38 and Figure 4.4-39.

Table 4.4-38 Results of Optimization

Reservoir Name	Daily Water Supply (m^3/day)	Average Number of Months to Supply Water (month) in 1 Year
Burubur (X)	10,700	11.5
El Ain (Y)	4,200	11.4
Bagara (Z)	5,100	11.6
Average	20,000	11.5

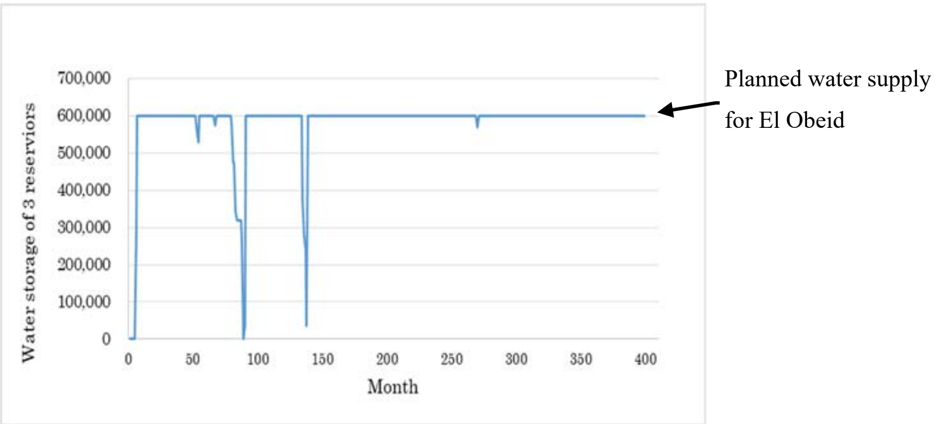


Figure 4.4-39 Water Supply to El Obeid from the Burubur, Al Ain and Bagara Reservoirs for 33 Years

<u>Results of Simulation</u>

As shown in the figure below, the effective operation of the three reservoirs would provide a stable water supply of 20,000m^3/day to El Obeid for 33 years.

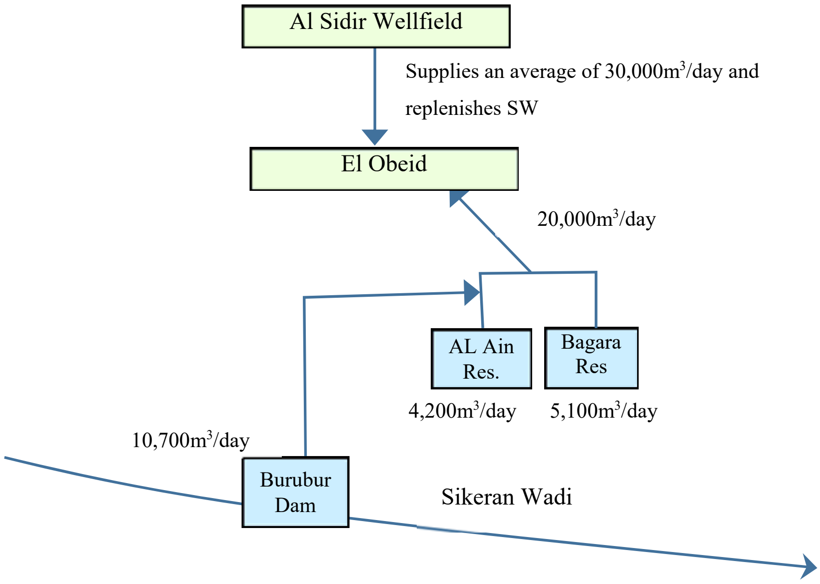


Figure 4.4-40 Water Supply to El Obeid Through Conjunctive use of SW and GW

(3) Current Water Problems in the Target Area

Based on the results of the water balance analysed in Section 4.4.5 (2), the current water problems in the target area can be pointed out as follows.

① **Excessive GW pumping in Bara town and the Al Bashiri area>**

Excessive irrigation water in the Bara town and Al Bashiri areas is causing the GW levels in shallow aquifers to decline rapidly, threatening to dry up wells. GW pumping for irrigation needs to be regulated to prevent this.

② **Excessive GW pumping from the Al Sidir Wellfield>**

GW levels in the Al Sidir Wellfield have been declining for a long period of time, making the sustainability of the water supply to El Obeid problematic. Future population growth in El Obeid is expected to cause a further decline in GW levels in the Al Sidir Wellfield. As a countermeasure, the amount of water withdrawn from the Sikeran Wadi should be increased, and the amount of water withdrawn from the Al Sidir Wellfield should be reduced. The optimal ratio of GW to SW withdrawal will be determined.

<Analysis to Solve Excess GW Pumping in Bara Town and Al Bashiri>

The calculation of safe pumping from the shallow aquifers in Bara town and the Al Bashiri areas for irrigation water is used to control the lowering of the GW level in the wells. Two methods are used to calculate the safe pumping rate.

(i) Simple method

(ii) Detailed method

(i) Simple Method

The distribution of wells in Bara town was modelled as shown in Figure 4.4-41, in order to estimate the safe yield of wells in the Bara town area. The drawdown of the GW level was calculated using this model.

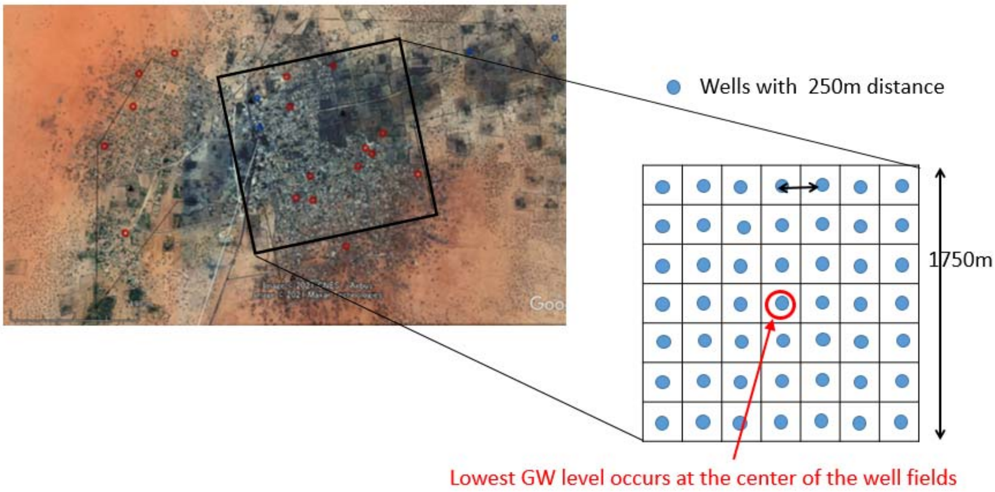


Figure 4.4-41 Drawdown of GW Level of Wells in Bara Town

The maximum drawdown of the GW level will occur in the centre of Bara town. The current water depth of the wells in Bara town ranges from 2.4m to 13.0m with an average of 7.8m, according to the participatory monitoring (see Figure 4.4-42 and Figure 4.4-43). Therefore, the long-term drawdown of the wells should be less than 7.8m. The allowable maximum drawdown, however, was set at 10m in this analysis, considering uncertainty in terms of data. Finally, the safe yield was estimated under the conditions shown in Table 4.4-39.

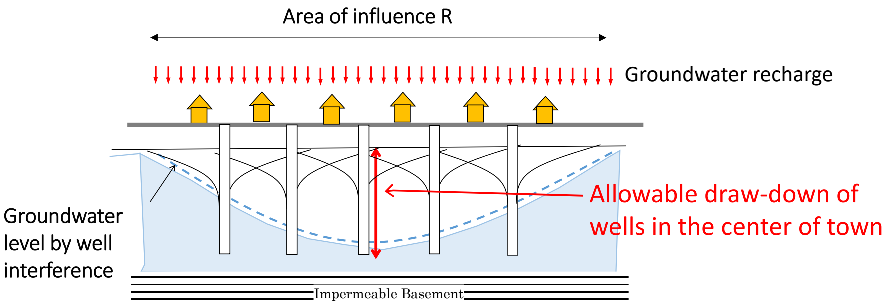


Figure 4.4-42 Model of Well Distribution in Bara Town

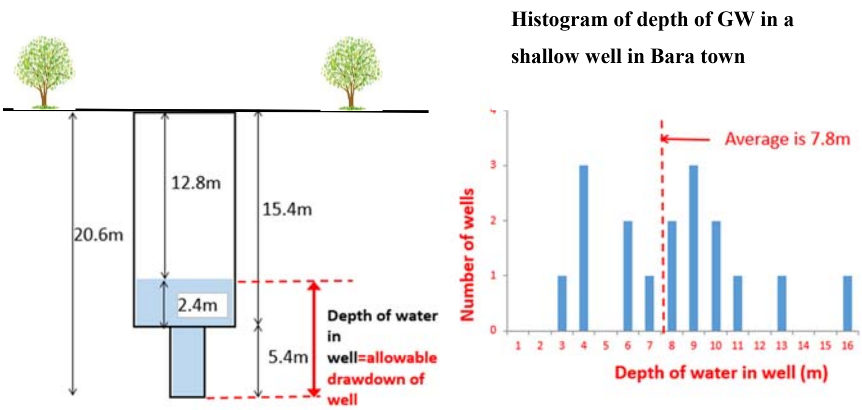


Figure 4.4-43 The Current Common Structure of Shallow Wells in Bara Town

Table 4.4-39 Conditions of Safe Yield Analysis

Condition	Assumed Value
Allowable drawdown of GW level in the centre of Bara town	10m
Coefficient of permeability of shallow aquifer	2×10^{-3}cm/sec (sand)
GW recharge as result of monitoring by automatic recorders	14mm/year

Results of Analysis

As a result of the analysis based on monitoring by the automatic recorders, the safe yield of one well was estimated at 37m^3/day on average in Bara town. The participatory monitoring results showed the real current pumping rate of 84.4m^3/day in one well in Bara town. This means that the real current pumping rate of wells is almost twice as great as the safe yield. Therefore, the GW level will gradually decrease in the long-term. According to the latest participatory monitoring results, the GW drawdown of Bara town is 0.37m on average for the year from May 2020 to May 2021, which is clear evidence of over-pumping of GW in Bara town.

(ii) Detailed Method

The simplified method concluded that the current pumping rate is twice as great as the safe yield. This is verified here using a GW simulation model. The simulation model used is the same as the model described in Section 4.4.5 (2) Water Balance Analysis. The following two cases were calculated:

(i) Case 1

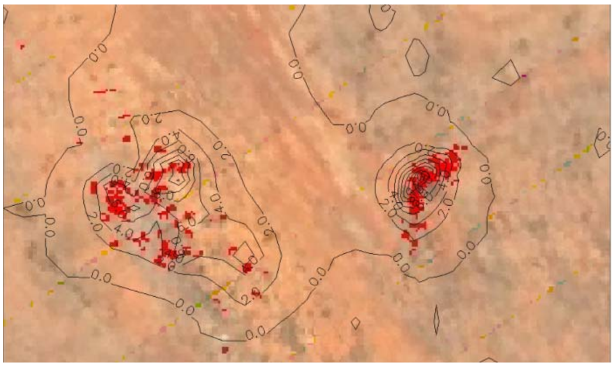
Calculate the decline in the GW level after 20 years if the current irrigation wells in Bara town and in the Al Bashiri areas continue to pump water at the current pumping rate.

(ii) Case 2.

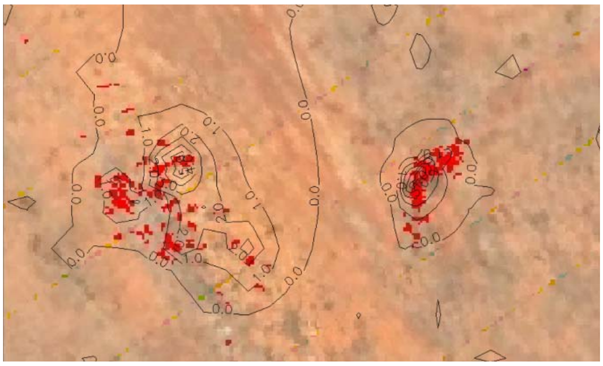
Calculate the decline in the GW level after 20 years if the current irrigation wells in Bara town and in the Al Bashiri areas continue to pump water at half the current pumping rate.

Calculation Results

The calculation results are shown in Figure 4.4-44.



(i) Decline in GW when pumping at current (2022) pumping rate



(ii) Decline in GW level when pumping at half the current pumping rate

Figure 4.4-44 Decline of GW Level of Shallow Aquifer by Irrigation Pumping

- In case (i), the GW decline in the Bara and Al Bashiri areas is up to 22m, and many depleted wells may result.
- In case (ii), the GW decline in the Bara town and Al Bashiri areas is within 8m and current pumping

can continue.

From the above results, it can be concluded that reducing irrigation GW pumping by 50% of the current pumping rate is necessary for sustainable GW use. In the WUC meeting in December 2022, the JPT requested that irrigation farmers should reduce their pumping by half, and the simulation results above also support this request.

The results of the above analysis are based on an analysis of the GW levels in shallow aquifers in Bara town and the Al Bashiri area. The above analysis only deals with shallow aquifers, as only shallow well monitoring results were available. On the other hand, the Al Sidir Wellfield is located in the southern area of Bara town, and a large amount of GW was pumped up from the deep aquifer. It has been pointed out that pumping from the deep aquifers may cause the GW in the shallow aquifers to move towards the deep aquifers. Researchers and engineers in Sudan have different opinions on the relationship between shallow and deep aquifers. However, this relationship cannot be ignored. The behaviour of the GW level in the shallow wells in the Bara and Al Bashiri areas, should the shallow and deep aquifers be interconnected, is discussed at the end of this section.

<Analysis to Solve Excessive GW Pumping from the Al Sidir Wellfield>

To address the issue of excessive GW pumping from the Al Sidir Wellfield, the amount of water withdrawn from the Sikeran Wadi will be increased, and the amount of water withdrawn from the Al Sidir Wellfield will be decreased. This measure will contribute to the preservation and sustainable use of the Bara Aquifer, maximizing withdrawals from the three SW sources of the Sikeran Wadi (Burubur Dam, Al Ain and Bagara Reservoirs) and minimizing pumping from the Al Sidir Wellfield. Using the long-term (1981-2013) river discharge date, the following two conditions are used to determine the plan for optimum water withdrawal from the Sikeran Wadi:

(i) The current water demand of El Obeid is 50,000m^3/day (2022), so the total water withdrawal from the three reservoirs will be increased from the current 20,000m^3/day to 50,000m^3/day.

(ii) It is assumed that 50,000m^3/day cannot be achieved at the end of the dry season. Even so, the total water transferred from the three reservoirs over a long period of time (33 years) should be maximized.

Conditions (i) and (ii) above minimize the GW supply from the Al Sidir Wellfield.

<u>Analysis Results</u>

The results of the analysis are shown in Figure 4.4-45. It is possible to send 50,000 (m^3/day) of water to El Obeid from the three reservoirs in the Sikeran Wadi during the rainy season, but this is not possible at the end of the dry season. Therefore, GW from the Al Sidir wells will be used during that period.

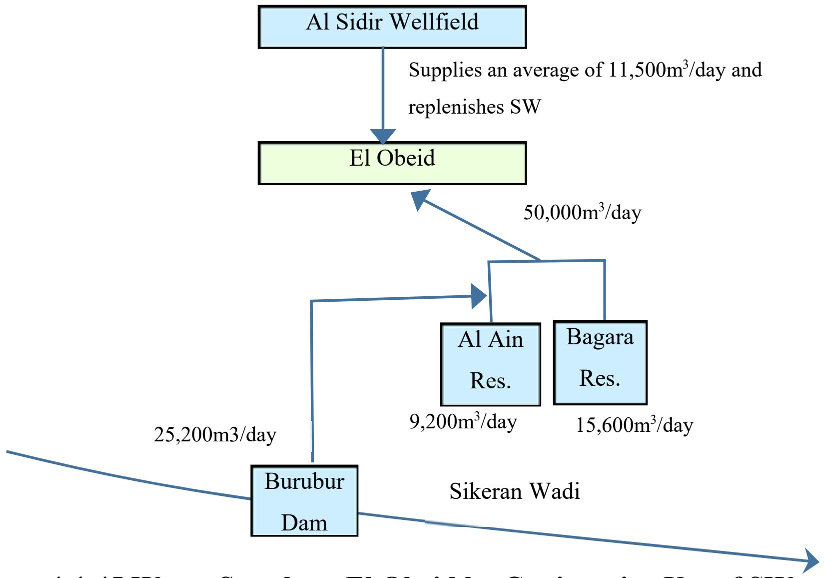


Figure 4.4-45 Water Supply to El Obeid by Conjunctive Use of SW and GW

Conservation Effect on the Bara Aquifer When Water Pumping from the Al Sidir Wellfield Is Reduced

The JPT and C/Ps calculated the recovery of the GW level in the Al Sidir Wellfield when the water supply from the Al Sidir Wellfield is reduced from 30,000 (m^3/day) to 11,500 (m^3/day) as shown in Figure 4.4-45. The simulation model used in the analysis is the same model used in “4.4.5 (2) Water Balance analysis”. Figure 4.4-46 shows the change in the water level of the Al Sidir Wellfield when the current pumping rate of 30,000m^3/day is reduced to 11,500m^3/day (40% of the current pumping rate). Figure 4.4-46 also shows the long-term change in the GW level when the pumping rate of the Al Sidir wells is changed in 10% increments, assuming that the current pumping rate (30,000m^3/day) is 100%.

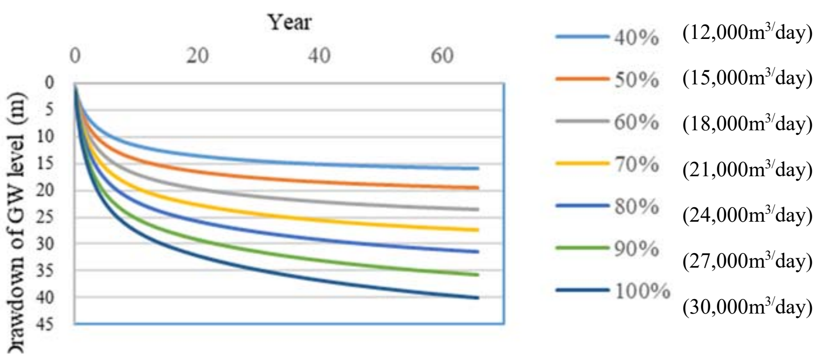


Figure 4.4-46 Long-term Change in the GW Level of the Al Sidir Wellfield Due to the Pumping Rate

When water is pumped from a well, the GW level stops the drawdown when the pumping rate and the GW recharge reach an equilibrium. The less the GW pumping rate, the shorter the time to reach an equilibrium and the less the drawdown in the GW level. Conversely, the greater the GW pumping rate, the longer it takes to reach an equilibrium and the greater the drawdown in the GW level, which may cause some wells to dry up. As shown in Figure 4.4-46, GW levels in the Al Sidir Wellfield continue to decline even 60 years after pumping at the current pumping rate (100%). When pumping at 40% to 50% of the current rate, the drawdown in the GW level will reach an equilibrium in around 30 years. Based on the above results, the JPT proposes that GW from the Al

Sidir wells can be used sustainably at 40% to 50% of the current pumping rate, as shown in Table 4.4-40.

Table 4.4-40 Conjunctive Use of GW and SW

Deep GW Consumption	Water Consumption m^3/day
Al Sidir pumping rate in current conditions	30,000
40% of current level by conjunctive use	12,000
10% of current pumping rate for water supply to other areas	3,000

(4) Water Problems of the Target Area in 2035 Clarified by the Technical Analysis

The current (2022) water problems in the target area were discussed in the previous section. Next, the following points can be examined regarding water issues in 2035.

① **Excessive GW Pumping in Bara and Al Bashiri**

If irrigation water in the Bara town and Al Bashiri areas is being pumped continuously at 2022 levels, wells will run dry at many locations. It is therefore essential to reduce pumping from irrigation wells to half the 2022 levels. On the other hand, the amount of water used for domestic purposes in the Bara town and Al Bashiri areas will also increase by 2035, but this is minimal compared to the amount of water used for irrigation. The increase in the amount of water used for domestic purposes will have only a 1m drawdown in the GW level, and thus will have little impact.

□ **Excessive GW pumping From the Al Sidir Wellfield**

In 2035, the population of El Obeid will increase, and water demand will increase from 50,000m^3/day to 65,500m^3/day. As a result, the optimal water withdrawal from the three reservoirs in the Sikeran Wadi was calculated by assuming that the pumping rate from the Al Sidir wells is the same as that in 2022, and the water withdrawal from the Sikeran Wadi will be increased. The optimization method is the same as in the previous section and the optimization results are shown in Figure 4.4-47.

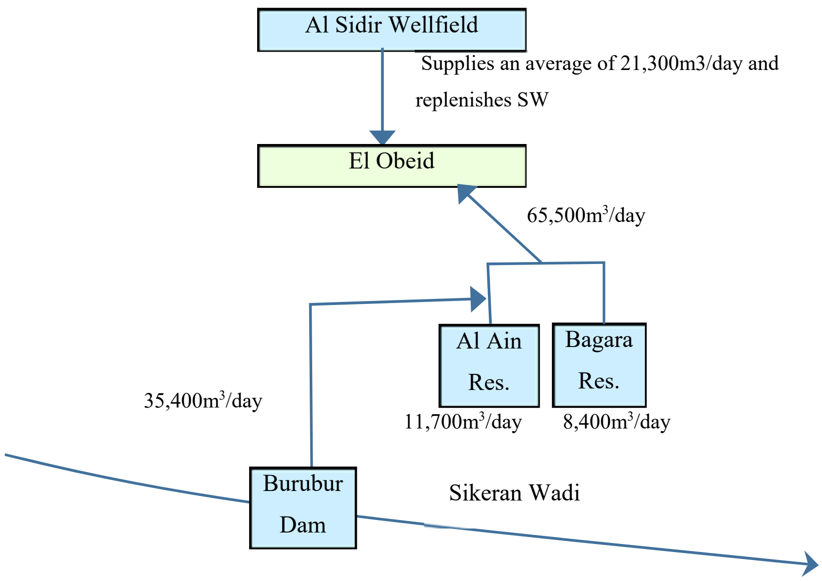


Figure 4.4-47 Water Supply to El Obeid Through Conjunctive Use of SW and GW

As shown in Figure 4.4-47, it is not possible to supply 65,500m^3/day from the Sikeran Wadi to El Obeid all year round, and the shortage must be replenished with GW from the Al Sidir Wellfield. In this case, the amount of water to be replenished is 21,300m^3/day, which corresponds to 70% of the current 30,000m^3/day (see Figure 4.4-46 and Figure 4.4-47). Of the three reservoirs in the Sikeran Wadi, the Burubur Dam is constructed on the main stream of the Sikeran Wadi and has a large volume of river water, which allows for an increase in the storage volume of the Burubur Dam. The Burubur Dam consists of 13 consecutive hafirs, and an increase in the supply capacity is possible by increasing the number of hafirs by one, namely from 13 to 14 hafirs. In this case, the storage capacity of the Burubur Dam would increase from 10,000,000m^3 to 11,538,450m^3. The calculation results are shown in Figure 4.4-48.

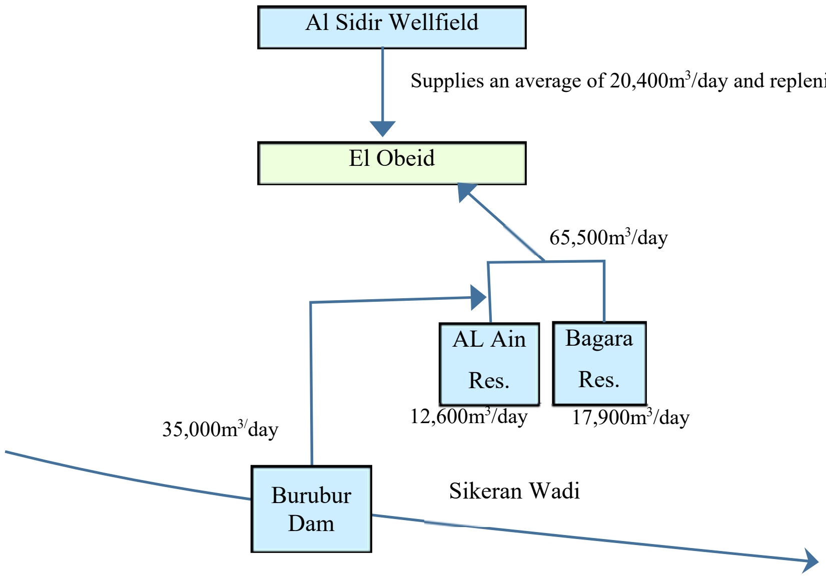


Figure 4.4-48 Water Supply to El Obeid Through Conjunctive Use of SW and GW

As shown in Figure 4.4-48, increasing the number of hafirs in the Burubur Dam from 13 to 14 does not increase the water supply, but rather decreases it. Due to the quantity of the river discharge volume at the location of the Burubur Dam, increasing the storage capacity of the hafirs will not increase the water supply capacity. Rather, this means that the effect of losses due to increased evaporation by increasing the surface area of the reservoir is more significant. In order to ensure a sufficient water supply to El Obeid and equally to prevent an increase in the amount of water pumped from the Al Sidir wells, the following measures should be taken:

- Reduction of water consumption by saving El Obeid's urban water supply and reducing leakage.
- Conveying of water from El Rahad, located downstream of the Sikeran Wadi, to El Obeid.

Continuous monitoring of the amount of GW that can be pumped from the Al Sidir Wellfield will provide a new potential evaluation with high accuracy. As a result, it may be possible to increase the amount of GW pumped from the Al Sidir wells within a sustainable range. With limited time remaining until 2035, there is an urgent need to assess water resources’ potential and formulate a water resources development plan to address this issue through activities led by the SWRC.

(5) Impact on the GW Level of Shallow Aquifers by Deep Aquifers

GW levels in the shallow aquifer in Bara town and the Al Bashiri area were analysed in the previous section. In this section, the decline of the GW level was analysed when dealing only with the shallow aquifer. However, since the shallow and deep aquifers are continuous across the clay layer, it is possible that the impact of pumping in the Al Sidir Wellfield could lower the GW level in the irrigation wells in Bara town. Al Bashiri, which is pumping GW for irrigation in the same way as Bara town, is located at a distance from the Al Sidir Wellfield and is therefore considered to be less affected by the Al Sidir Wellfield. Table 4.4-41 summarizes the current status of GW development in the shallow and deep aquifers and makes suggestions for future GW development.

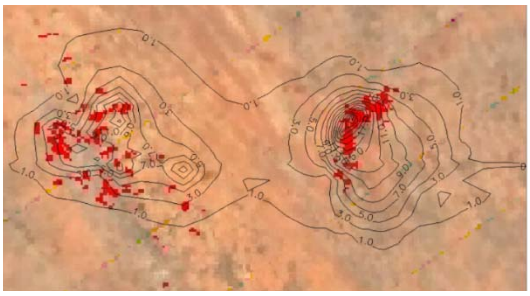
Table 4.4-41 Current Status and Proposed GW Development of Aquifers in the Target Area

Aquifer	Wells	Pumping Rate	
		Current (2022)	Proposed
Shallow aquifer	Shallow wells in Bara town and Al Bashir	30,000m^3/day(S1)	15,000m^3/day(S2)
Deep aquifer	Deep wells in the Al Sidir Wellfield	30,000m^3/day(D1)[1)]	12,000m^3/day (D2)

1) Current pumping rate from the Al Sidir Wellfield

As shown in Table 4.4-41, four combinations can be made from the current and proposed pumping rates. Using the four symbols (S1), (S2), (D1) and (D2), four (4) combinations are possible: (S1) and (D1), (S1) and (D2), (S2) and (D1), and (S2) and (D2). The pumping condition with the greatest pumping rate is (S1) and (D1), and the pumping condition with the lowest pumping rate is (S2) and (D2). In each case, Figure 4.4-49 shows the decline in the GW level, as calculated by the simulation model. Based on the results, the combination of (S2) and (D2) was adopted for the sustainability of GW use for irrigation in Bara town and Al Bashiri, as well as for the urban water supply from the Al Sidir Wellfield, taking into account the following two conditions:

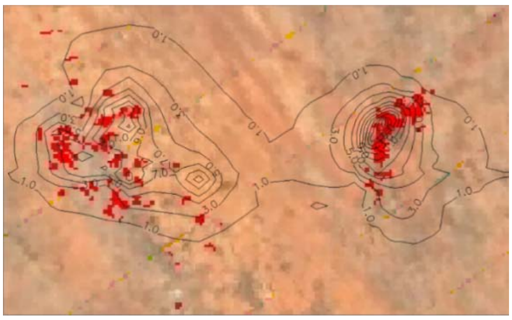
- The irrigation pumping rate in Bara town and the Al Bashiri area should be half (12,000m^3/day) of the current rate.
- Water withdrawal from the Sikeran Wadi should be increased and pumping reduced in the Al Sidir Wellfield from 30,000m^3/day to 12,000m^3/day.



(S1) and (D1): Max. drawdown is 30m

(S1) and (D2) : Max. drawdown is 25m

(S1) and (D2) Max. drawdown is 13m



(S2) and (D2) Max. drawdown is 9m

Figure 4.4-49 Predicted GW Level Drawdown Using a Combination of Irrigation Pumping and Al Sidir Wellfield Pumping

Future Measures

Once the GW reduction of the Bara targets has been established, the following policy measures should be discussed among the state C/Ps in order to implement measures to prevent the depletion of the GW level of the Bara Aquifer.

i. Deep GW is used as a source of water for El Obeid, and if this GW is reduced, a plan needs to be developed to replace the reduction with runoff from the southern wadi. Planning is necessary to build new facilities to increase water withdrawals from the Sikeran Wadi. This will require significant funding and will be funded with the agreement of the federal and state governments. At the same time, the MIUD plans to reduce water waste through a fixed rate system for water supply, and to reduce demand by limiting leakage from water supply pipelines.
ii. Shallow GW is used for irrigation in the Bara region, and water-saving irrigation will be promoted to reduce GW use. There is a need to provide irrigation farmers with GW reduction targets and to ask for their cooperation in saving water.

The above measures will be discussed in the SWRC meetings and the IWRM unit members will take the lead in initiating activities towards the realization of the measures.

Technical Transfer to State C/Ps

A water balance analysis was conducted for the entire country of Sudan in the 1st Phase of the JICA IWRM Project. In the water balance analysis, water resource potential and water demand were analysed, and the method of planning for water use facilities was transferred to the federal C/P. However, the C/Ps of North Kordofan State were not included in the technical transfer. Planning based on technical findings is an important aspect of IWRM practice. It is important for the state C/Ps to formulate water balance analysis under the guidance of the federal C/Ps. Through this analysis, it is intended that the C/Ps will recognize the importance of the water balance analysis, which will serve as a model for other states to formulate their own analysis.

The water balance analysis for Bara introduced methods such as the “Conjunctive use of GW and SW”, the “Coordination of urban water and irrigation water”, and “Cross-basin water transfers” to solve Bara's water problems. This analysis by the C/Ps supported by the JPT, was an important learning experience for the state C/Ps.

(6) Findings, Lessons and Challenges

The findings, lessons and challenges regarding the strengthening of monitoring and its application are described below.

6-1) Findings

The findings relating to the strengthening of monitoring and its application through the implementation of the pilot activities are as follows:

a) Risk to Water Resources Management Without Monitoring

A huge amount of GW is being pumped up without the GW level in the Al Sidir Wellfield being monitored. In addition, SW is being developed without wadi discharge monitoring in the Sikeran Wadi of North Kordofan State, which has led to water resources development without sustainability. The problem of the current practice in terms of water resources management, without regular monitoring of the project area, was clarified through the implementation of the pilot activity. Therefore, the monitoring of GW and SW is necessary to solve the problems, and monitoring system was fully established in the pilot activities.

b) Conjunctive Use of GW and SW

The monitoring result made it clear that the conjunctive use of GW in the dry season and SW in the rainy season is indispensable for a sustainable water supply throughout the year in the pilot project area, where there is no perennial river like the Nile River. The conjunctive use of GW and SW in El Obeid is a typical example. The methodology of conjunctive use, proposed by this pilot activity in North Kordofan State, will be applied at national level. The pattern and efficiency of the conjunctive use of GW depends upon the availability of SW and GW potential in each region. In the case of the pilot project area, the efficiency of conjunctive use is very high.

c) GW Use for Irrigation

In recent years, horticulture has been thriving around the local cities, in particular in Bara town in North Kordofan State. However, there are many wells used for irrigation without any controls in Bara town, leading to over-pumping and a significant drawdown in the GW level. GW monitoring revealed the critical situation of the depletion of the GW level in the pilot activity area. Lessons learnt from the pilot activity in Bara town and how to solve these problems are a good example for the other states.

d) GW Recharge to the Deep Aquifers

The Nubian sandstone formation and the Bara Aquifer in North Kordofan State are deep aquifers, which do not receive direct GW recharge from rainfall but receive a certain amount of GW recharge through the shallow aquifers. In particular, large-scale GW development in the deep aquifers will result in forced GW recharge from the shallow aquifers to the deep aquifers. The Al Sidir Wellfield in North Kordofan State, which pumps up GW from the deep aquifer of the Bara Aquifer, maintains a water balance by GW flow from the shallow aquifer to the deep aquifer. This means that the GW recharge to the shallow aquifer by rainfall ultimately serves as GW recharge to the deep aquifer. This indicates the appropriateness of treating the shallow and deep aquifers as a single body. The proposed measures in the pilot activity, based on the continuity of the Al Sidir wells and the Bara irrigation wells, are reasonable.

e) Use of GW Recharge

GW development potential is estimated from the amount of GW recharge by rainfall. The amount of GW recharge can be calculated from the daily changes in the GW level. In addition, Sudan has distinct dry and rainy seasons, and the GW recharge can also be roughly estimated from the difference between the highest GW level in the rainy season and the lowest GW level in the dry season. The GW recharge rate is a fundamental factor in planning for sustainable GW development. Sustainable GW development is possible as long as the GW is developed within the GW recharge. Based on this theory, the sustainability of the Al Sidir Wellfield and the sustainability of GW development for irrigation in Bara town and Al Bashiri were analysed, and a policy for future GW was proposed.

f) Use of Wadi Water Flow

The sustainability of the water supply of the Burubur Dam in North Kordofan State was analysed during the water balance analysis of the pilot activity, using the results of long-term rainfall and the runoff analysis of Phase-1 of the Project. The entire river basin of Sudan was delineated into 177 sub-basins, and the long-term runoff of the sub-basins was analysed using rainfall data over a 32-year period, utilizing software for long-term rainfall and runoff analysis in order to perform a water balance analysis in Phase-1 (see 4.4.5 (2) Water Balance Analysis). Therefore, it was effective to analyse the river runoff of the Sikeran Sub-Basin of North Kordofan State by applying the results of the water balance analysis of Phase-1 of the Project, with a simple adjustment. This methodology should be introduced into other Sudanese states, as this method is applicable to all river basins in Sudan.

6-2) Lessons Learned

a) Importance of Bottom-Up Approach in Water Resources Management

During Phase-1 of the Project, the C/Ps, supported by the JPT, analysed the water balance for the entire region of Sudan. They started the pilot activity in North Kordofan State during Phase-2 of the Project, and the water issues were gradually identified by implementing the monitoring of the pilot activity. The water issues are linked to the natural and social background of the region. Therefore, the actual situation regarding water issues must be investigated at local level, and a bottom-up approach is essential when dealing with local water issues. Moreover, it is true that there are similarities in water issues between different regions, and an understanding of the real situation relating to water issues in certain regions through the monitoring work will lead to an understanding of water issues in other areas. This indicates the importance of monitoring and sharing information between stakeholders to achieve a better understanding of water issues, in order to solve them.

b) Importance of Awareness of Future Risk

An awareness of the risk to sustainable water use caused people to take measures to resolve the issues. It was learned that awareness of risk drives people to act. Three examples of this lesson were obtained as shown below:

Awareness of Risk to GW Depletion in the Al Sidir Wellfield and Bara Irrigation Farm, and Motivation for Monitoring

The MIUD of North Kordofan State acknowledged the risk of over-pumping in the Al Sidir Wellfield without hesitation, when the JPT pointed out the risk of over-pumping at the beginning of the pilot activity in 2018. The MIUD subsequently drilled four monitoring wells in the Al Sidir Wellfield using its own budget, and decided on a policy to reduce water production in the Al Sidir Wellfield, even though the Al Sidir Wellfield had been expanded just three years previously, in 2015, with significant investment to increase the production rate. Hence, it was considered that the MIUD had concerns regarding over-pumping in the Al Sidir Wellfield, where no monitoring was being carried out. As a result, the MIUD accepted the analysis presented by the JPT that the GW level of the Al Sidir Wellfield would decline rapidly in the future. It has been suggested that awareness of the risk of over-pumping motivated the MIUD to start GW monitoring in the Al Sidir Wellfield. It is an important lesson that raising awareness on future risk, based on scientific research, can prompt decision makers to undertake the necessary action to solve the problems.

Awareness of Risk for the Sustainability of Southern Wadi Water Resources and Motivation for Monitoring

The JPT proposed the conjunctive use of GW and SW for the sustainable water supply of El Obeid. The proposal is that wadi water should be used for 6.5 months/year including during the rainy season, and that GW should be used for 5.5 months/year including during the dry season. This proposal was based on the long-term, rainfall-runoff analysis. Responding to this proposal, the MIUD, however, claimed that wadi water should be used for the whole year, by completely replacing the GW in the Al Sidir wells. Then the JPT requested that the MIUD present their claim on a theoretical basis. After the discussion, the JPT and the MIUD agreed that monitoring of the Sikeran Wadi should be implemented to obtain more reliable data for the long-term, rainfall-runoff analysis. The MIUD was motivated to start wadi monitoring after being made aware of the future risk. It can be stated that monitoring would not have been implemented without an awareness of future risks.

Awareness of Risk Regarding the Depletion of Shallow Wells and Motivation to Participate in Monitoring and Well Registration

Shallow well monitoring commenced with 60 private wells using the participatory monitoring approach in the Bara and Al Bashiri area. However, certain well owners gradually lost their motivation to continue with the monitoring work. In recent years, the AfDB has planned large-scale GW development in the Al Bashiri area, which is located near Bara town. There is a possibility that the AfDB project will have a negative impact on the GW level in Al Bashiri and Bara town. Due to such an critical situation, a meeting of the WUC was held in August 2021, with an invite for the irrigation farmers of Al Bashiri. The farmers of Al Bashiri and Bara expressed their clear intention to continue the monitoring process more thoroughly than previously. They wanted to clarify the impact of the AfDB project by conducting the monitoring themselves to ascertain whether the GW level in their wells would go down or dry up completely. The well owners of Al Bashiri and Bara wanted to protect their own wells by participating in the monitoring process. Therefore, it is more effective to motivate well owners to participate in monitoring by raising an awareness of the future risk of their well.

c) Importance of GW Resources Management at Basin Level

GW can be used in all seasons, but wadi water can only be used during the rainy season. Therefore, it is basic policy in terms of the water resources management of North Kordofan State that wadi water should be used as much as possible in the rainy season and GW should be used to compensate for the lack of wadi water in the dry season. Wadi water, however, fluctuates considerably every year. Establishing how much wadi water should be used is the most important decision in terms of conjunctive use. Although the Sikeran Wadi and the Al Sidir Wellfield belong to different river basins, the idea of the flexible utilization of two different water sources in different sub-basins for the water supply of El Obeid is a typical example of transboundary water resource management and is considered consistent with the IWRM approach.

d) Characteristics of the Water Issues in North Kordofan State

One notable lesson was that upstream/downstream river problems were less common in North Kordofan State than initially expected. Upstream/downstream problems will occur when water use upstream affects water use downstream, but this situation has not occurred in North Kordofan State. The wadi is a seasonal river, and the water flow of wadis occurs in response to short and concentrated rainfall during the rainy season; its flow is flood-like, with the peaks of the flow dissipating in a short period of time.

Even if there are small dams and hafirs upstream of the wadi, these can only store a small proportion of the short-lived floods, and most of the water flows downstream without being withdrawn. In the end, most of the floodwater of the wadi flows away unutilized, and eventually reaches the inland delta at the end of the wadi. Due to such characteristics of the wadi, it is difficult to imagine a situation in which people upstream and downstream of the wadi in North Kordofan State compete for wadi water, and the situation is similar in the most of Non-Nile regions of Sudan. The same logic applies to issues of water quality. It is less common to imagine a situation in which water pollution occurring upstream of the wadi flows downstream and causes water quality problems.

e) How to Solve the Water Issue in the Bara Aquifer

As explained in the previous description, the problem of the upstream and downstream flow of the wadi has not occurred in North Kordofan State. Instead, the problem of aquifer management has become apparent. GW from the Bara Aquifer can be pumped to convey water to the surrounding basement rock areas to solve the issue of water shortages, such as those in El Mazroub. However, the residents of Bara are concerned that by transporting their water to other areas, this will affect their own water use. There will be a conflict of interest regarding water use between the residents of the Bara Aquifer area and the residents of the basement rock area. In order to resolve this problem, the following steps are considered appropriate for resolution:

- A comprehensive framework will be proposed for the development and management of the Bara Aquifer, such as the conjunctive use of GW and SW, as well as water conservation and well regulations, based on technical analysis in conjunction with the monitoring.
- Information will be shared among the concerned parties to raise awareness of the water problems, such as a shortage of water quantity and a deterioration of water quality and its causes, based on the monitoring results.
- The state government should propose measures for the joint use of water resources that take into account the interests of the entire community, including the residents of the Bara Aquifer and the surrounding basement rock areas, until a consensus is reached among the stakeholders.
- Activities to solve issues, such as monitoring and its analysis, should be initiated to realize the relevant countermeasures. It is necessary that the activities are monitored, and the results of the activities are shared among other stakeholders.

The key to solving the water problems for all stakeholders is to share technical information, based on monitoring, in order that all stakeholders can agree on the proposed measures.

6-3) Challenge

a) Water Issues and Capacity Building to Be Solved

Regarding capacity strengthening in relation to monitoring and its use, the water issues requiring resolution were classified into four types in North Kordofan State, as shown in Table-4.4-42 below:

Table-4.4-42 Type of Water Issues in North Kordofan State

Classification	Issues to Be Solved Note)
a) GW	Declining GW level due to over-pumping
	Scarcity of GW
	GW contamination (due to geological reasons)
	GW contamination (due to human activities)
b) SW	Scarcity of SW
	SW contamination（due to human activities）
	Poor planning and design of small dams and hafirs
c) Irrigation Water Supply	Over watering of irrigated land

To address issues a) through to d) above, the following knowledge status of the C/Ps was identified in relation to knowledge building among the federal and state C/Ps through the implementation of the pilot activities.

a-1) Issues Relating to GW

<u>Federal C/Ps</u>

The issue regarding GW can be divided into i) the drawdown of the GW level due to over-pumping, ii) GW development and iii) the contamination of GW quality (as a result of geological causes and human activities). The federal C/Ps of the JPT originated from the GWWD of the MIWR, and have the necessary knowledge and experience to deal with the issues, especially GW development; they carry out the geological surveys of aquifers, field reconnaissance, geophysical surveys and pumping tests. On the contrary, they have less knowledge and experience of the analysis of the GW balance in the regional aquifer. To compensate for their weakness, the technical transfer was conducted during the water balance analysis in Phase-1 of the Project. Thus, the federal C/Ps fully understood the basic method of the water balance analysis, and they learned how to apply the method to the Bara Aquifer during the pilot activity in North Kordofan State. They can apply the method themselves in other areas at the next stage.

State C/Ps

As well as the federal C/Ps, the state C/Ps have sufficient knowledge and experience of the hydrogeological surveys of aquifers, the estimation of well capacity and the management of well drilling. However, they have limited knowledge of the water balance and the potential evaluation of the regional aquifers. In the past, GW was developed on a small-scale in North Kordofan State. In recent years, however, GW development has been implemented on a large-scale, thanks to the development of drilling techniques/machines for deep wells and the rapid spread of high-capacity pumping equipment. The state C/Ps do not have sufficient experience of extensive regional GW development, which is causing the regional drawdown of GW levels, currently taking place in the Al Sidir Wellfield. The technical transfer of the water balance analysis of the Bara Aquifer was conducted as a capacity building exercise for the state C/Ps. They can now perform a water balance analysis themselves at the next stage to improve their skills and to aim for the sustainable management of the SWRC.

a-2) Issues Relating to SW

Among the water issues related to SW resources and the development of wadis, two issues, i) the planning and management of SW supply facilities and ii) SW contamination, are listed.

Federal C/Ps

Hafirs and water-harvesting dams are the main facilities for SW development and supply. The GWWD of the MIUD has enough knowledge and experience of the planning and design of hafirs and water-harvesting dams. Hafirs are constructed along wadis, whereas water-harvesting dams are constructed across the wadi. For this reason, a more detailed hydrological survey and analysis are needed for the planning and design of dams, and long-term wadi runoff data are indispensable. Opportunities for wadi monitoring, however, were suspended after 1995, due to decentralization. It is for this reason that the engineers of the younger generation of the GWWD do not have sufficient experience of wadi monitoring and the runoff analysis of wadis. Such a situation has resulted in the poor planning and design of dams. Therefore, considering this issue, a technical transfer of knowledge on the rainfall-runoff analysis and the planning of water-harvesting dams/hafirs were provided for the federal C/Ps in Phase-1 of the Project. The results of this analysis can be utilized for the planning of new dams and hafirs in cases where there are limited existing monitoring data. The federal C/Ps have sufficient knowledge of this analysis, which was used for the analysis of sustainability of the Burubur, El Ain and Bagara Dams in North Kordofan State. The federal C/Ps analysed the SW potential of the Sikeran Wadi that flows into the aforementioned dams. Moreover, the federal C/Ps conducted a topographic survey of the El Ain and Bagara Reservoirs to investigate the condition of sedimentation on the bottom of both reservoirs. This is an excellent achievement indicating their technical expertise for dam management.

State C/Ps

The GWWD headquarters of the MIWR is primarily taking responsibility for the planning and design of dams, and the state branch of the GWWD is overseeing the site survey to support the activities of the GWWD headquarters of the MIWR. The engineers of the GWWD branch office of North Kordofan State have sufficient knowledge and experience of wadi monitoring in the field. The Japanese experts of the Project performed the technical transfer of knowledge to the state C/Ps, explaining how to calculate wadi discharge from the results of wadi monitoring. The state C/Ps, however, were not provided with technical knowledge on the long-term, rainfall-runoff analysis in Phase-1 of the Project. Therefore the federal C/Ps have a mandate to undertake this task instead of the Japanese experts. The federal C/Ps trained the state C/Ps as teachers on high level technical matters, such as the water balance analysis in Phase-2 of the Project.

a-3) Issues Regarding Irrigation Water

There are water issues regarding irrigation water even in the Non-Nile area. In North Kordofan State, horticulture is common and active in the Bara area using the GW of the Bara Aquifer. Over-pumping of GW has been identified in the Bara Aquifer and the GW level is rapidly declining, affecting GW use in the wider area. Water saving for irrigation purposes is the most effective measure to stop the rapid drawdown of the GW level, however, the state C/Ps did not have sufficient experience of dealing with these types of water problems until the pilot activity of the JICA Project raised these issues. The state C/Ps have acquired detailed knowledge of crop water requirements and water saving techniques to tackle these issues through the pilot activity of the Project, with the support of the federal C/Ps and the JPT. They continue to make efforts to solve these issues, working closely with the irrigation farmers in the Bara and Al Bashiri areas of North Kordofan State, by sharing information with the farmers. In order to extend the activities to the entire Bara Aquifer area, the first step is to continue the activities in the Al Bashiri/Bara town area and review the findings and lessons learned. The next step is to identify similarities and differences in the water issues between Al Bashiri/Bara town and other Bara Aquifer areas. New studies will be conducted to assess the differences as required. Based on the results of these studies, countermeasures to solve the water issues will be examined and implemented.

b) Importance of Dealing with Both Short- and Long-Term Water Issues

As well as dealing with long-term water issues, such as the GW potential of the Bara area, dealing with short-term water issues should not be ignored. In North Kordofan State, sandstone forms the main aquifer in many areas, such as the Bara area. Therefore, the pumped GW contains a considerable amount of sand particles from the aquifer, which can cause the submersible pumps to fail. Over-pumping beyond the capacity of the well also accelerates the outflow of sand particles from the aquifer. Techniques to control the inflow of sand particles into the wells are necessary in the design and construction of pumping wells. Improper design and construction, as well as incorrect judgement of the safe pumping yield from pumping tests, can cause the failure of the submersible pumps. The GW production of the Al Sidir Wellfield was drastically reduced for a long period of time between 2020 and 2021. It was the failure of the submersible pumps, caused by sand particles flowing out of the aquifer, which affected the pumping of the wells. In other words, not only the prediction of the long-term potential of the GW of the Al Sidir Wellfield but also the correct design and operation of the wells of Al Sidir Wellfield is important for sustainable GW use. Knowledge building regarding this matter should be carried out for the engineers of the MIUD.

c) Low Motivation of the Officials of the GWWD in North Kordofan State

The state offices of the federal GWWD are in charge of monitoring and water resources management in North Kordofan State. The current performance and issues relating to the GWWD in North Kordofan State were clarified through the pilot activity. The obstacles that interrupt the activity of the GWWD were highlighted and the demarcation of mandates between the GWWD and the state government (MIUD) was also established. One example of this is the low salary of the officials of GWWD, which requires them to conduct geological surveys and other work outside official work hours to compensate for the low salary. This leads to excessive work for the staff and negatively affects the efficiency of the monitoring work.

4.4.6 Water-Saving Irrigation

(1) Objectives and Activities

There are two irrigated farmland clusters in the Bara Aquifer, Bara town and its surrounding area, and the Al Kheiran area. Irrigation farming is an important livelihood; fruit and vegetables are cultivated through irrigation using GW. Farmers use the traditional irrigation method of surface irrigation by irrigating through earth water channels in the fields with movable pipes from the well. However, a considerable amount of irrigation water is wasted as a result of this method, which causes an increase in use of irrigation water according to the problem analysis (Figure 4.3-12). Of the irrigation farmers, 93% stated that they would expand the irrigation farms and 70% of rain-fed farmers claimed that they would start irrigation agriculture in the baseline survey. For this reason, the promotion of water-saving irrigation was selected as one of the pilot activities. Irrigation farmers usually use a well at their farm and use a generator to pump up water. The increasing cost of fuel, due to decreasing subsidies from the government, is also a problem for irrigation farmers. Saving water can also help solve this problem.

The former Ministry of Agriculture, currently the General Directorate of Agriculture under the Ministry of Production and Economic Resources has tried to expand irrigation lands in order that farmers may have more income, and has encouraged the state to improve the economy. However, this organization is not aware of how much water is used by irrigation and there was no coordination with the MIUD as regards the control of irrigation water. The General Directorate of Agriculture should work with the MIUD to decrease and control irrigation water. Although the General Directorate of Agriculture recognizes the importance of drip irrigation, it does not have data relating to the costs of installation or the feasibility of installation for ordinary farmers. The General Directorate of Agriculture should have access to this kind of information before promoting the installation of drip irrigation.

Based on interviews with farmers, the farmers in Bara and Al Kheiran generally use more than $50L/m^2$ of water during one irrigation session for crop production in the dry season. This is equivalent to one month's rainfall in June, the wet season in North Kordofan State, and is clearly excessive irrigation. Therefore, two methods were studied to improve irrigation methods and increase water use efficiency in the agricultural sector. The first is to shift from the conventional irrigation method to modern irrigation methods, and the second is to improve the conventional irrigation method to increase efficiency. It was also planned to improve the communication of officers between the water and the agriculture sectors through the pilot activity.

(2) Activities Implemented

1) Shifting from Conventional Irrigation Methods to Modern Irrigation Methods

The number of irrigated farms in the Bara area has increased from 435 in 2016 to around 900 in 2021, and the number of farmers using drip irrigation has increased to 45 as of 2021 (according to an official of the Bara Agricultural Directorate). In fact, during the field visit (2021, 10 September – 10 October), we saw the development of relatively large plots totalling several hectares along the main road, where new drip irrigation systems are being introduced. Since these new drip irrigation technologies are self-financed by the farmers, the profitability of drip irrigation is considered to be high.

According to an article published in Science (Grafton et al., 2018), the water use efficiency of drip irrigation compared to surface irrigation (conventional irrigation) is as follows. It can be seen that the water use efficiency of drip irrigation on crops is extremely high and the water saving effect is also high. Therefore, drip irrigation is an important technology in terms of the conservation of GW resources in the project area.

Table 4.4-43 Differences in Water Use Efficiency Among Irrigation Methods

	Surface Irrigation	Drip Irrigation
Crop transpiration	40-70%	85-95%
Evaporation	10-25%	5-15%
Surface runoff and subsurface recharge	15-50%	0-10%

However, drip irrigation is not suitable for crops with high planting density, such as leafy greens and root crops, although it is suitable for crops planted with space between them, such as fruit trees and fruit vegetables, since drip irrigation has the effect of dripping water gradually through small holes on the drip tube and the irrigated area is limited (Figure 4.4-50).

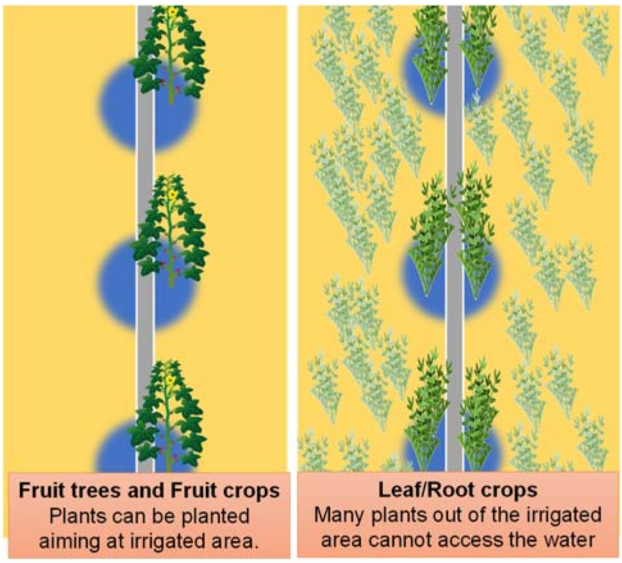


Figure 4.4-50 Crops Which Are Suitable for Drip Irrigation

Additionally, it is difficult for ordinary irrigation farmers to adopt drip irrigation technology because of the high initial investment. The Project investigated the cost and difficulty of financing the introduction of drip irrigation in the target area.

The cost of implementing drip irrigation was calculated from interviews with farmers who have actually implemented the system (Table 4.4-44). The irrigation plots included the drilling of new wells, the installation of solar panels and the construction of a fence around the entire field, which are typical conditions for the development of drip irrigation plots in a field. The total initial investment was USD 10,375/4.5 Feddan (1.89 ha).

Table 4.4-44 Installation Cost of Drip Irrigation

Item	Price (SDG/ 4.5 Feddan)	Year	Price (USD/ 4.5 Feddan)
Main line pipe (2 inch)	75,000	2021	180
Irrigation Tube (1/2 inch)	210,000	2021	504
Vulbe	40,000	2021	96
Joint parts between irrigation tube	30,000	2021	72
Joint parts between main pipe and irrigation tube	45,000	2021	108
T joint	15,000	2021	36
Solar panel (100 watt x 28 panels)	219,000	2019	4,765
Well digging	112,000	2019	2,437
Fence	100,000	2019	2,176
Total			**10,375**

Currency rate: 45.9577 SDG/USD (2019), 416.2808 SDG/USD (2021)

Based on the results of interviews with irrigation farmers in and around Bara town, this amount is equivalent to one to two years of the gross income of a typical irrigation farmer. This means that it would be difficult to invest solely using an individual farmer's own funds and that external borrowing would be necessary. Therefore, we interviewed representatives from the Agricultural Bank of Sudan to examine the feasibility of ordinary farmers obtaining loans to finance the capital investment necessary for the introduction of drip irrigation.

The interviews were conducted in Bara town and the results are summarized in Figure 4.4-51. It was clear that it is not practical for an ordinary irrigated farmer to obtain all the necessary funds for the introduction of drip irrigation through bank loans.

First of all, a bank account is required to borrow funds, but some farmers may not have the necessary ID to open a bank account. Therefore, it is necessary to obtain an ID first. If the investment plan is approved, the farmer can borrow up to 60% of the appraised value of the assets held as collateral. In the case of unsecured loans, the maximum amount is 400,000 SDG (around USD 1,000). In the case of farmers, the main collateral is agricultural land, which is priced at USD 2,200/Feddan in Bara and USD 224/Feddan in rural areas. Since the loan amount is capped at 60% of this amount, a farmer who owns a certain amount of land in Bara and in rural areas can only borrow 57% and 6%, respectively, of the USD 10,375/4.5 Feddan required. Therefore, unless farmers have a large amount of farmland or other surplus assets, it would be difficult for them to raise funds from agricultural banks to start drip irrigation on their own. In fact, when we asked about the bank's experience in providing loans for the introduction of drip irrigation, we found that loans were provided to those with a certain level of assets, such as retired officials from the Ministry of Agriculture.

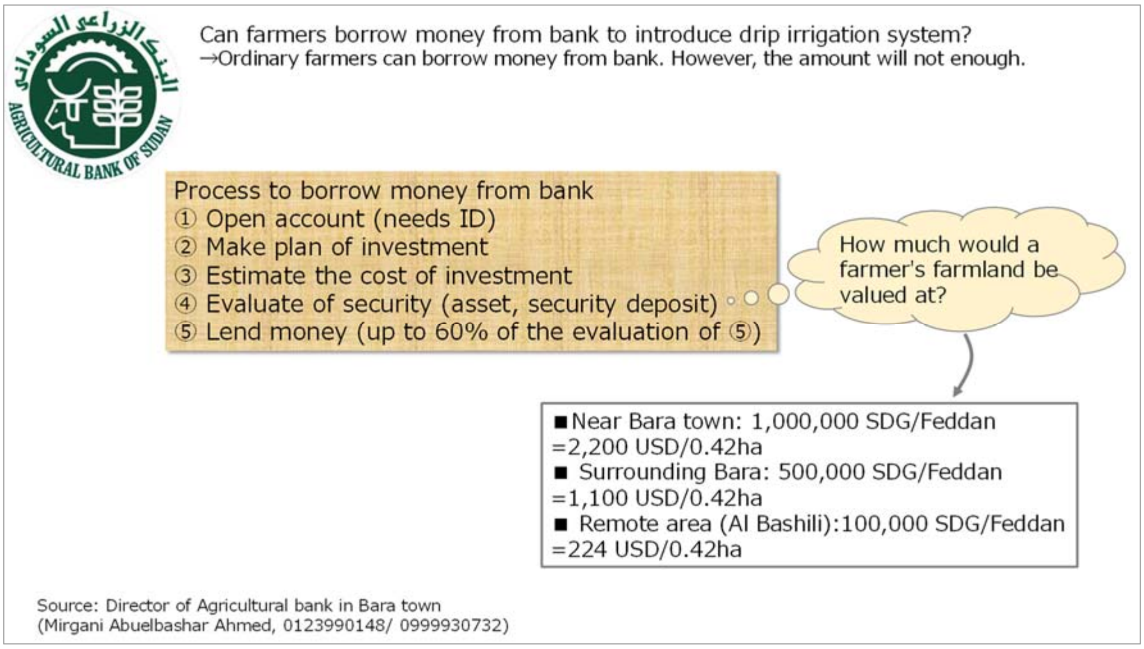


Figure 4.4-51 Criteria for Borrowing from the Agricultural Bank of Sudan

We also asked about the possibility of providing loans to farmer groups, but it was confirmed that it would be difficult to raise the necessary funds for the introduction of drip irrigation because the maximum loan amount would be 400,000 SDG (about USD 1,000), which is the same as an unsecured loan, since only microcredit is available for groups.

Furthermore, even if the initial cost required for installation is secured, maintenance costs must also be considered. Generally, the life span of drip tubing is three to five years, and maintenance costs would be incurred to continue using the drip irrigation system. Therefore, the introduction of drip irrigation systems for crops is limited, as these are not profitable after taking maintenance costs into account.

As described above, the spread of drip irrigation is certainly desirable for agricultural areas where GW resources are scarce, but the effect of reducing the amount of irrigation water in the entire area is currently very limited, as this is restricted to farmers who can afford the initial installation costs and crops that are profitable enough to cover the maintenance costs. The effect of irrigation reduction on a region-wide basis will be very limited at present.

2) Improving the Efficiency of Conventional Irrigation Methods

As described above, the effect of reducing the volume of irrigation water through the introduction of drip irrigation is limited; the Project tried to reduce the volume of irrigation water by improving the irrigation method practiced traditionally by farmers in the target area.

The results of the interview survey suggested that many farmers may be irrigating more than $50L/m^2$ of water, which may constitute excessive irrigation.

Based on a soil survey conducted in September 2019, the water-holding capacity of the soil at a depth of 30cm was estimated to be approximately $50L/m^2$, which means that a single irrigation session can provide water to the soil with the full capacity of water-holding. The proportion of the irrigated water that exceeds the soil water-holding capacity moves immediately to the deeper layers by gravity, while the water that does not exceed the soil water-holding capacity is retained in the soil through surface tension between the soil particles. From the second day after irrigation, the movement of water to the deeper layers by gravity becomes slow, and water in the soil is lost mainly through water absorption by the plants and evaporation.

Therefore, irrigation should ideally compensate for this loss. Local farmers usually irrigate daily or every few days, but if the irrigation interval is only a few days, it is unlikely that all of the 50L/m^2 of water retained in the soil is lost through transpiration and water absorption by the plants. Therefore, the remaining water is wasted each time the soil is irrigated.

(a) Reduced Irrigation Frequency Experiment

In order to study the possibility of reducing irrigation water, a reduced irrigation frequency experiment was conducted from November 2022 to February 2023, targeting two farmers in Bara and two farmers in Al Kheiran, who are also WUC members.

Initially, the C/Ps supported by the JPT designed a test in which the one-time irrigation amount was reduced, but the farmers explained the difficulty in accurately varying the one-time irrigation amount, so we decided to conduct a test in which the frequency of irrigation was reduced.

Firstly, the project members tried to collect information relating to harvested vegetables, crop calendars and the way in which farmers irrigate in the target area from the General Directorate of Agriculture. However, the project members discovered that the directorate does not have such data. The main focus of the directorate is rain-fed agriculture and the members do not have the experience or the resources to support irrigation agriculture.

Therefore, prior to the start of the experiment, cooperating farmers were interviewed about the crops they grew in the dry season and their irrigation frequency. Based on this, they were asked to grow one or two crops (arugula, radish, carrot, and okra) both with ordinary irrigation frequency and two thirds to a half of reduced irrigation frequency (Table 4.4-45).

Table 4.4-45 Target Crops and Irrigation Frequency of the Farmers

Area			Bara		AlKheiran	
Farmer			Omer Mursid	Ibrahim Dani	Bakari Alnagar	Ismaiel Siddig
Target crop			Okra	Arugula	Arugula, Radish	Carrot
Irrigation frequency	Ordinary	Zone 1	Once in 2~3 days	Once in 3 days	Once in 3 days	Once in 2~5 days
	Reduced	Zone 2	Once in 3~5 days	Once in 6 days	Once in 5 days	Once in 4~8 days
		Zone 3	Once in 4~7 days		Once in 7 days	
Timinig of changing irrigation frequency			4 days after sowing	5 days after sowing	7 days after sowing	6 days after sowing

The results of the experiment are as follows:

a) Arugula

The target farms were those of Ibrahim Dani and Bakari Alnagar.

A decrease in yield was observed in both farms as a result of reduced irrigation frequency (Figure 4.4-52). Therefore, reducing the irrigation frequency appeared to have a negative impact on production. Looking at these results only, it would appear that reducing irrigation frequency has a negative effect on production.

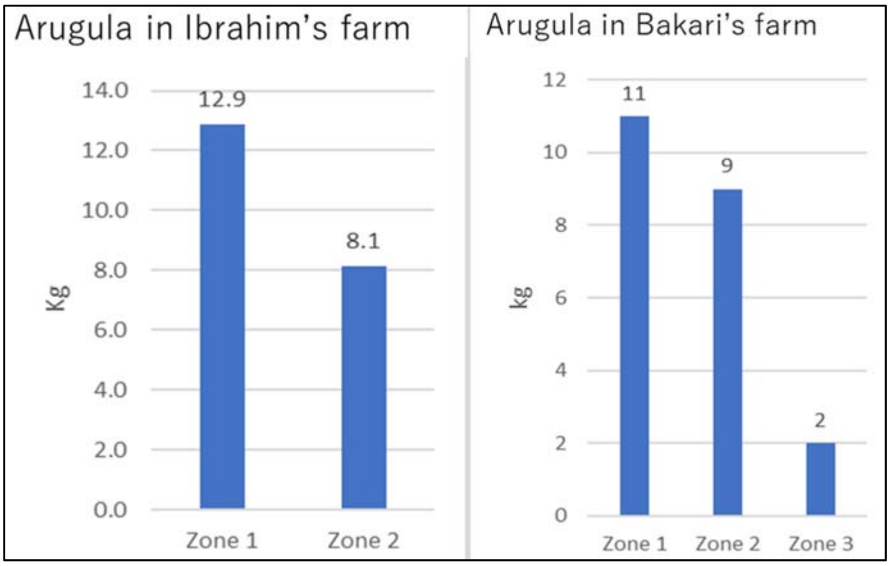


Figure 4.4-52 Yield of Arugula

However, in the case of arugula, long, thin leaves or so-called excessive elongation were observed in Ibrahim Dani's ordinary irrigated area. These characteristics of long, thin leaves are caused by dense plantings, limited sunlight and over-fertilization, but can also be caused by over-irrigation. Since the fertilizer, planting density and climatic conditions were not changed in the test section, it is possible that over-irrigation contributed to this phenomenon. Plants with such leaves are affected by sudden weather changes, such as drought, as well as pests. There is also a negative impact on quality too, with plants staying fresh only for a short period after harvest.

Reducing irrigation frequency could be detrimental to production but reducing the amount of irrigation water each time could have a positive effect on production.

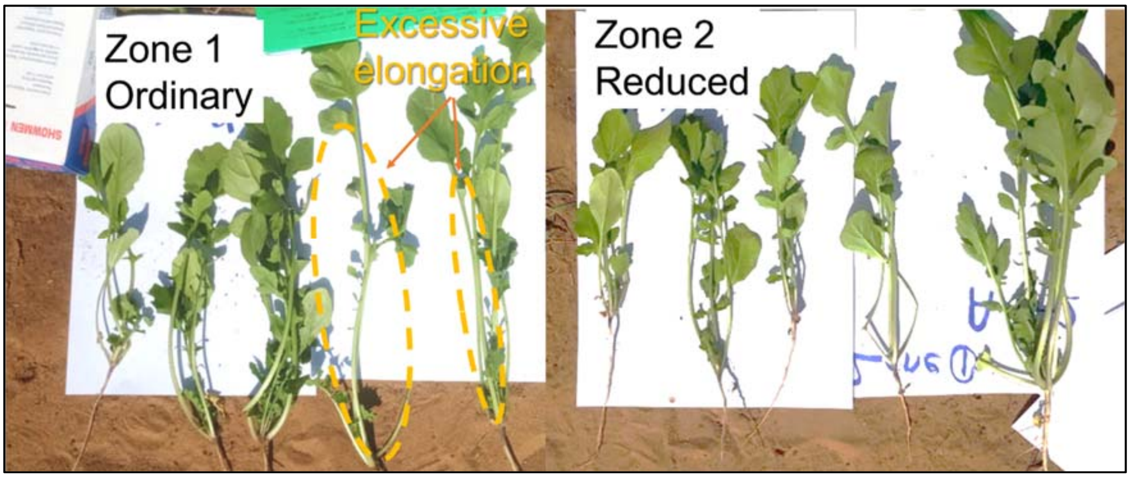


Figure 4.4-53 Growth of Arugula in Ibrahim Dani's Farm

b) Radish

The target farm was that of Bakari Alnagar. A decrease in yield was also observed in the case of the radish crop, due to the decrease in irrigation frequency.

In Zone 3, where the irrigation frequency was once every seven days, dull green leaves which are a sign of water shortage were observed. In addition, negative effects were noted in relation to plant height, root length and root thickness, suggesting that a high degree of dryness has a significant negative impact on plant production.

On the other hand, in Zone 2, which was irrigated once every five days, there were no signs of water shortage, and both root length and root thickness tended to be greater than in the ordinary irrigated area.

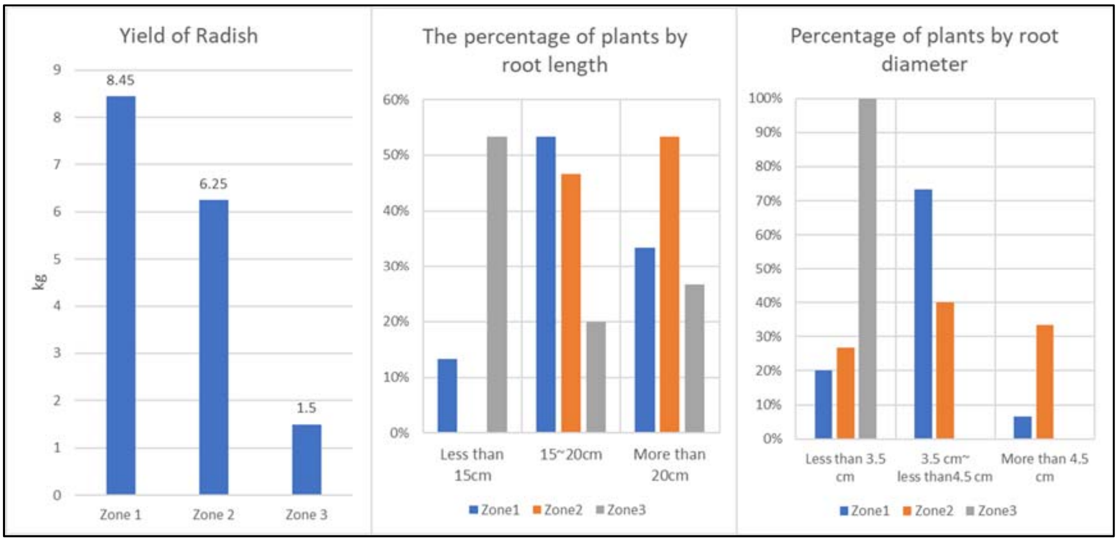


Figure 4.4-54 Yield of Radishes (Left), Percentage of Plants Measured by Root Length (Middle) and Percentage of Plants Measured by Root Diameter (Right)

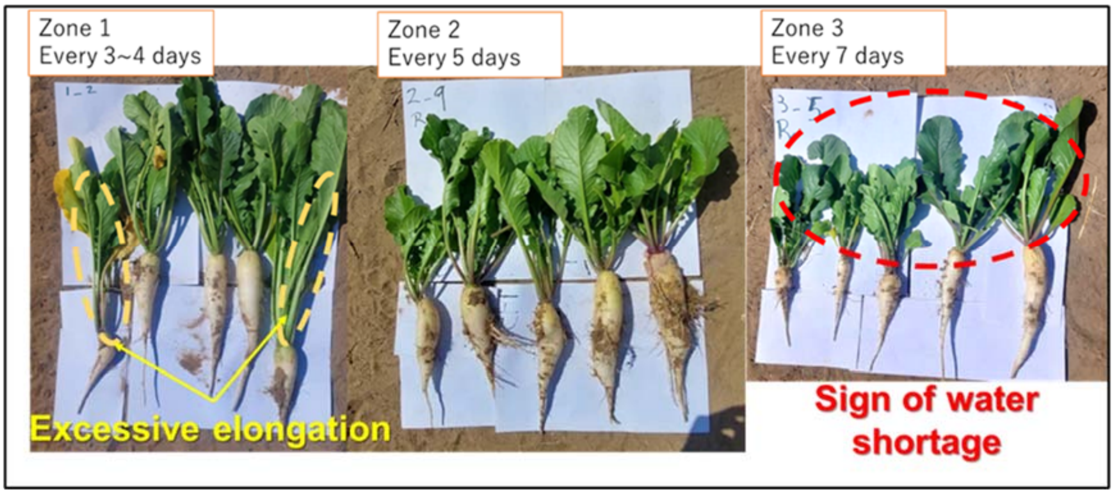


Figure 4.4-55 Growth of Radishes

This may be due to the plant's own adaptive strategy when faced with light drought, whereby the radish tried to adapt to the shortage of water by extending its roots to search for water and stored more water in the root areas.

In addition, in the normally irrigated area, excessive elongation was observed as in the case of the arugula. This suggests that there is room to reduce the amount and frequency of irrigation for radishes.

c) Okra

The target farm was that of Omer Mursid.

Unfortunately, yield data could not be obtained because the harvest was delayed from the estimated harvest date previously obtained from the farmer in the ordinary and reduced irrigation areas. An ordinary irrigated zone and two reduced irrigated zones (Zone 2 and Zone 3) were set up in the farm. Even though Zone 2 was irrigated more frequently than Zone 3, growth was significantly inferior (Figure 4.4-56). Although a clear cause could not be found, Zone 2 was located in a slightly more sloping location than Zone 3, and it is possible that the slight difference in slope affected the runoff of irrigated water out of the plots.

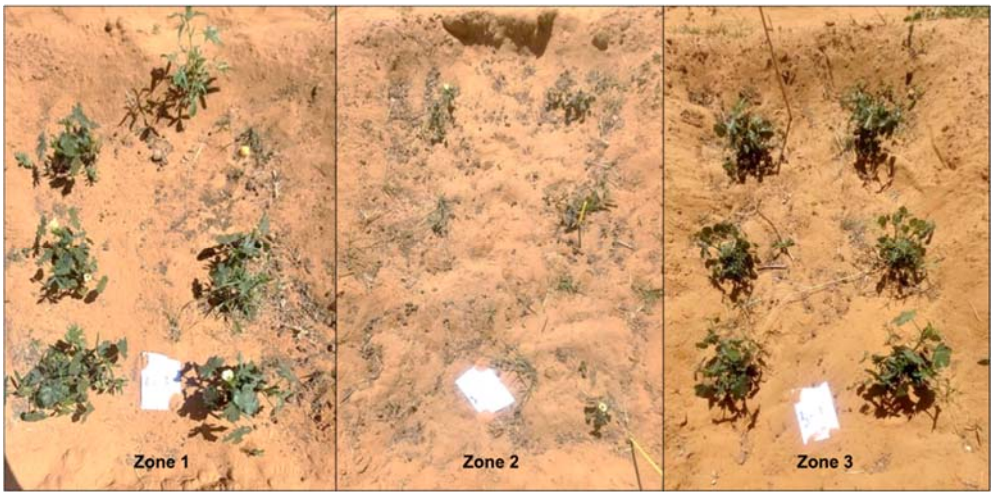


Figure 4.4-56 Growth of Okra

Comparing the growth of plants in Zone 1 and Zone 3, a high mortality rate was observed in Zone 3. On the other hand, the growth of the plants that survived did not differ significantly in terms of plant height, indicating that the reduced irrigation frequency did not result in inferior growth. This suggests that the reduction in irrigation frequency increased the mortality rate of the plants due to drought in the early growth stage, before the roots had fully extended to the subsoil and that the plants that were successfully saved were able to grow by extending their roots to the deeper soil layers. However, the number of fruits at the beginning of the harvest was less in Zone 3 than in Zone 1, and it is possible that the reduced irrigation caused a delay in growth at the early stage, resulting in a delay in the start of harvest.

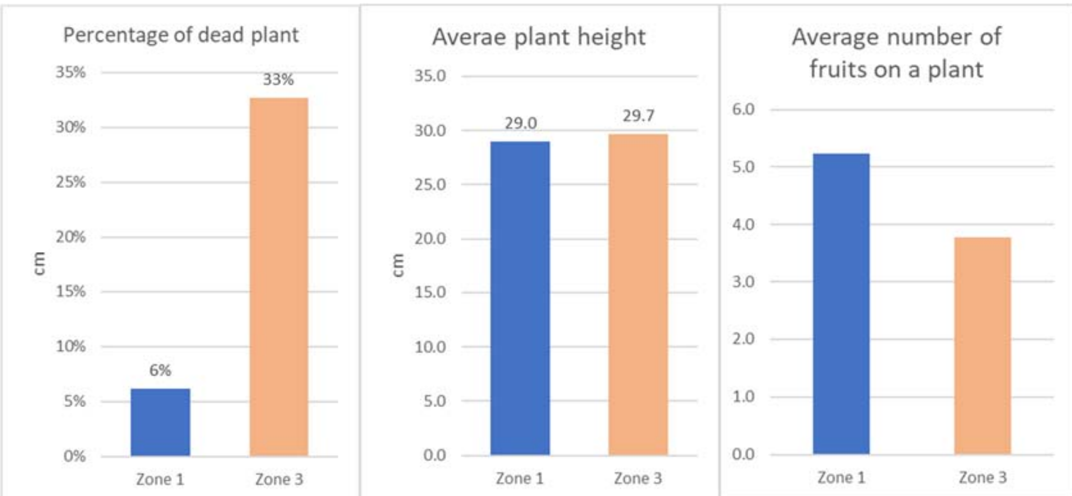


Figure 4.4-57 Mortality (Left), Average Plant Height (Centre) and Average Number of Fruits (Right)

d) Carrots

The target farm was that of Ismaiel Siddig.

Results were not available for comparison of the ordinary and reduced irrigation zones, as the plants in the reduced irrigation zone were eaten by grasshoppers before they had grown.

However, the farmer himself conducted a similar test with onions. He and the project team found that onions irrigated at a reduced irrigation rate (once every five to six days) had larger ball parts than those irrigated at the ordinary irrigation rate (once every three days). This can be attributed to the fact that, as in the case of the radishes, the plants adapted to the light drought and stored water in the ball part of the onion.

(b) Root Length Survey

From the above experiment involving varying irrigation frequency, it was inferred that the roots of the plants in the early growth stage were short and could only absorb water from the shallow layers of the soil, which were easily dried by evaporation, causing the plants to die. Therefore, to confirm the root zone of the arugula and radishes in the early growth stage, we conducted a pulling survey of the arugula at 12 days after sowing and the radishes at 13 days after sowing, grown under ordinary irrigation conditions at Ibrahim Dani's farm in order to measure root length.

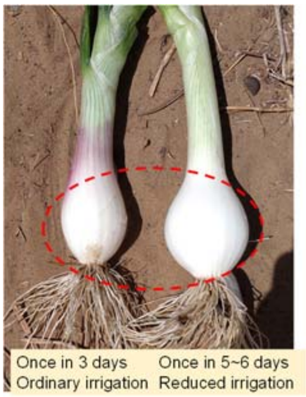


Figure 4.4-58 Comparison of Onion Ball Size

The results showed that root length was around 6cm for the arugula and 9cm for the radishes. This suggests that both the arugula and radishes mainly absorbed water from the shallow soil area at a soil depth of 0 to 10cm in the early stage of growth.

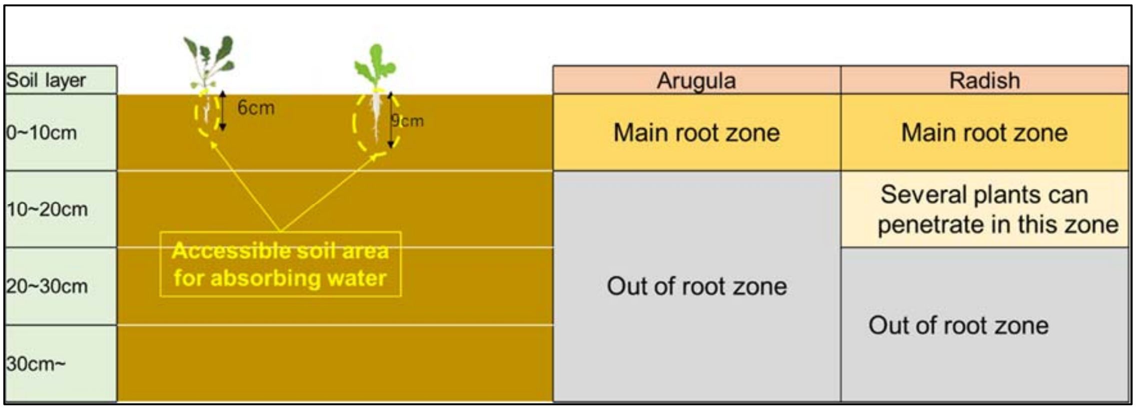


Figure 4.4-59 Root Zone of the Arugula and Radishes in the Early Growth Stage

In the ordinary irrigated zone of the water saving experiment, the root length at the time of harvest was around 9 to 17cm for arugula. In the later stages of growth, the roots were able to extend deeper, but the roots mainly spread in the 0 to 10cm soil area, which easily becomes dried out. On the other hand, in the case of the radishes, the root length was around 15-25cm, suggesting that water absorption was possible from a soil depth of 10-20cm, where the effects of desiccation due to transpiration are less significant.

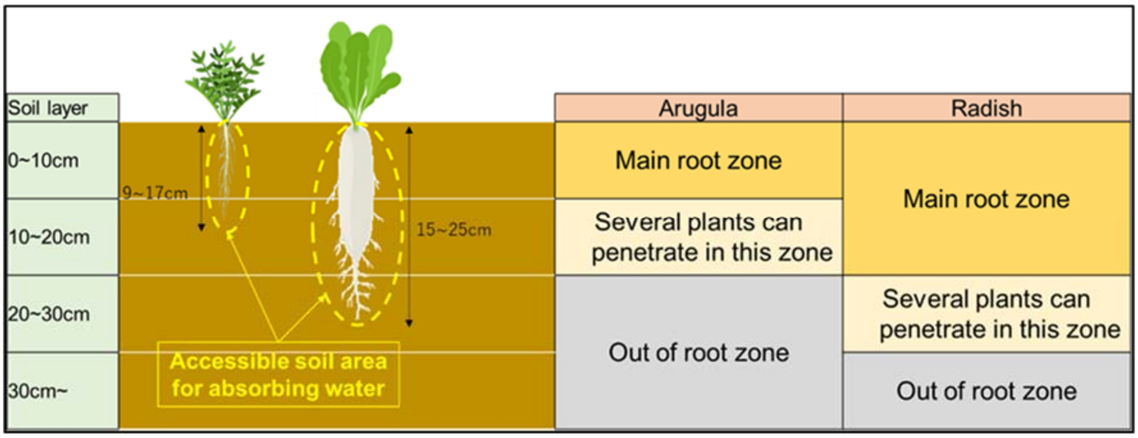


Figure 4.4-60 Root Zone of Arugula and Radishes at Harvest

(c) Soil Water-Holding Capacity Test

Since the soil depths accessible to the crop for water absorption were identified based on root lengths at the beginning of growth and at harvest, an analysis of the amount of water held by each soil depth was conducted to determine whether the water quantity for one-time irrigation was appropriate for the range of water absorption available to the crop.

The test was conducted using an area of Omer Mursid's farm, preparing three 1m2 square plots and pouring 54L (three jerry cans), 36L (two jerry cans) and 18L (one jerry can) of water evenly over the plots. Three days later, soil samples from the depths of 5cm, 15cm, 30cm and 50cm were collected. The soil samples were weighed while wet, then air-dried, and after sufficient moisture had evaporated, the dried soil was weighed and the moisture content was calculated from the difference.

The results of the root length study suggest that leafy vegetables such as arugula and other crops in the early stages of growth absorb water mainly from a depth of 10cm in the soil, and non-leafy crops absorb water in the later stages of growth, mainly from 20cm deep in the soil. Therefore, it is thought that irrigation should be conducted to maintain water in the soil from a depth of 0 to 20cm. However, in all the plots where the 54L (three jerry cans), 36L (two jerry cans) and 18L (one jerry can) of water were applied, there was no significant difference in the amount of water retained in the soil between the depths of 0 to 20cm.

In the plots where 54L and 36L of water were poured, more water was retained in the deeper areas over 25cm than in the plot with 18L. However, plant roots in the soil at this depth may not grow sufficiently because the soil is very hard, as confirmed in a simple test of soil hardness in all the farms.

Consequently, water deeper than this depth is likely to be wasted in crop production. Therefore, if a farmer is irrigating using more than 20L/m² of water per irrigation, much of it is likely to be wasted because it flows outside the range accessible to the plant roots.

Table 4.4-46 Held Water Amount by Soil Depth and Root Area of Crops

Soil depth	Applied water			Root area		
	18L	36L	54L	Leaf crop	Root/Fruit crop	
					Early growth stage	Late growth stage
To be used for plants						
0~10cm	5.5 L/m2	5 L/m2	5 L/m2	**Main root area in all growth stage**	**Main root area**	**Main root area**
10~20cm	6 L/m2	7 L/m2	7 L/m2	Possible root area at late growth stage	Possible root area	
Seldom to be used for plants						
25~35cm	2.5 L/m2	7 L/m2	7.5 L/m2	Outside of root zone		Possible root area
45~55cm	2.5 L/m2	6 L/m2	6 L/m2	Outside of root zone		

(d) Soil Type Test

Since the water-holding capacity of soil varies with soil type, a soil sampling test was conducted at all four target farms to determine whether the results of the aforementioned soil water-holding capacity test could be applied to other farms. A common method of evaluating soil type is to divide soil particles by size, with the ratio of sand, silt and clay particles. The water-holding capacity of the particles increases in the order of sand particles, silt particles and clay particles; the more sand, the lower the water-holding capacity of the soil. To measure the proportion of soil particles, a simple soil test was performed using a bottle. Soil and water are mixed in a plastic bottle, stirred and left to settle, and the height of the settled soil particle phase is measured after five minutes, two hours and 48 hours.

The results of the simple evaluation (Table 4.4-47) show that sand particles predominate in all the soils collected from the four farms; although the silt content varies slightly, the soils belong to the sandy soil category according to the International Soil Association method, and it is unlikely that the water-holding capacity of the soils would differ significantly. The results of the soil water-holding capacity obtained in the above test are likely to be similar to those obtained in the other farmers' fields.

Table 4.4-47 Soil Type in Each Farm

Area	Farm	Composition of soil particles			Soil type
		Sand	Silt	Cray	
Bara	Omer	99.3%	0.7%	0.0%	Sandy
	Ibrahim	87.5%	12.5%	0.0%	Sandy
Al Kheiran	Bakari	96.6%	3.4%	0.0%	Sandy
	Ismaiel	92.1%	7.9%	0.0%	Sandy

(3) Suggestions and Revisions Required to Continue the Experiment

The experiment was conducted only once and was also limited in terms of the number of target farms and crops as well as the agriculture season. It is necessary for farmers and the General Directorate of Agriculture to continue this kind of experiment to save irrigation water further. Therefore, the Project has made a simple plan based on the results of the experiment enabling them to continue.

There are two approaches as follows to save water using the traditional/conventional irrigation method. Depending on the crop type and growing stages, it is important to:

a) Decrease the amount of water per irrigation

b) Change the irrigation frequency

As for approach a), reducing the amount of one-time irrigation water is a relatively safe approach, and considering the water-holding capacity of the soil, it is possible to reduce the amount of irrigation water by up to 20L/m2 (2cm irrigation depth in a plot). Although the water-holding capacity of a field changes depending on the soil type, in fields with sandy soils, which are common in this region, irrigation of more than 20L/m2 is considered to be wasteful because the water runs off outside the root zone. In addition, some farmers use chemical fertilizers such as urea to grow okra, tomatoes, etc. These chemical fertilizers are easily soluble in water and are likely to run outside the root zone following excessive irrigation. This runoff of chemical fertilizers leads to economic loss in terms of fertilizer wastage, as well as GW pollution, therefore, it is important to reduce the amount of water per irrigation session.

Approach b), which changes the irrigation frequency, is likely to increase the risk of plants dying due to drought because the root zone of leafy vegetables, such as arugula, as well as root and fruit vegetables at the early growth stage is limited to the shallow soil area that is easily dried out by evaporation. On the other hand, root and fruit crops during the late growing stage are less likely to be severely affected by drought, as their roots extend into deeper soil layers, which are less affected by soil moisture loss due to evaporation, and they can absorb water from these deeper soil layers.

In the case of root crops, growth of the edible root parts of the radishes and onions improved when irrigation frequency was reduced, probably because the plants themselves grew roots and stored water in the roots in preparation for drought. Therefore, reducing the irrigation frequency and providing light drought stress in the late growth stage may contribute to yield increase. In addition, one target farmer reported that when he irrigated his tomato plants less frequently than usual, the plants were more vigorous than with the ordinary irrigation frequency, which may also be related to the plants expanding their root zone in order to adapt to drought conditions. Not only does the expanded root zone increase access to water, but it also allows the plant to absorb nutrients from a larger area of the soil, which may have resulted in a more vigorous plant. Thus, the potential for a longer harvest period is promising in fruit vegetable crops that have a long harvest season.

Table 4.4-48 Root Length, Water Absorption Area and Risk in Relation to the Approaches by Crop Categories

	• Leaf crops at all the growth stages	Root crops and Fruit crops	
		Early growth stage (From sowing to 2 weeks after sowing)	Late growth stage (From 2 weeks after sowing to harvesting)
Root length	Short	Short	Long
Water absorption area	Shallow soil area which can be easily dried by evaporation.	Shallow soil area which can be easily dried by evaporation.	Shallow soil area and deeper soil area which keep water longer time
1. To reduce one-time irrigation amount	Less risk	Less risk	Less risk
2. To reduce irrigation frequency	**High risk**	**High risk**	Less risk

Although the results of the experiment with the four target farmers demonstrated the aforementioned water-saving potential, further experiments are needed to verify whether the approach of reducing the amount of water per irrigation session and changing the frequency of irrigation for root and fruit crops at the late stages of growth is effective.

a) **Experiment to Reduce the One-Time Irrigation Water Quantity**

Target farmers	Farmers who irrigate at a depth of 3cm (irrigation volume of 30L/m2 or more)

Target crops	All crops

Two test plots, one with ordinary irrigation and the other with reduced irrigation, should be prepared. In each plot, bars are placed, as shown in the figure, to indicate the amount of water per irrigation.

After sowing, the ordinary irrigated zone is irrigated to the usual depth and the reduced irrigated zone is irrigated to between two thirds and a half of the ordinary irrigation depth until harvest. Then the yields should be compared. The irrigation depth should not be less than 2cm.

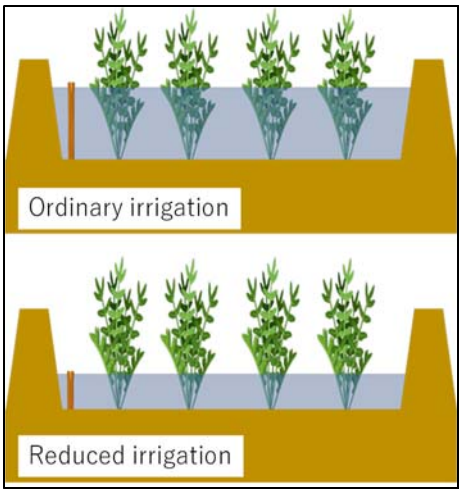


Figure 4.4-61 Image of Irrigation Plots

b) **Experiment to Reduce Irrigation Frequency**

Target farmers	Farmers who grow root and fruit crops with an irrigation depth of 2cm (20L/m2 irrigation volume) or less
Target crops	Root and fruit crops

The irrigation frequency should be reduced to two thirds of the ordinary irrigation frequency. The timing required to change the irrigation frequency is around 10 days to two weeks after the farmer has confirmed that most of the seeds in the test zones have sprouted. At the time of harvest, the yield should be monitored. The root length and root thickness of root crops should be compared in the ordinary zone and the reduced zone. For fruit crops, it is also advisable to check the growth conditions, such as plant height and the period from the start of harvesting to the completion of harvesting. The test plan here, such as the recommended irrigation amount and frequency, namely 20L/m^2, is proposed based on the results obtained from a sandy soil with a low soil water-holding capacity. The figures depend on the soil type so that the irrigation amount and frequency can be set at a lower level. In addition, the ideal amount of irrigation water should be given in a method that compensates for water lost through evaporation and water absorption by the plants between irrigations. Furthermore, since some of the crops in the experiment showed a sign of over-irrigation, it is likely that the crops will grow in a more healthy way if the soil moisture content is less than the full water retention capacity. However, the amount of water lost from the soil varies according to soil type, weather conditions, the types of crops grown and their growth stages, so it is important to find the appropriate amount through continuous trials. Since root length in the soil area accessible to plants varies depending on the stage of growth, irrigation frequency can be further reduced by setting the irrigation frequency more precisely, according to the stage of crop growth.

(4) Presentation of the Results of the Experiment and Plan to Continue to the General Directorate of Agriculture

The project team presented the results of the experiment and the plan how to continue the experiment explained above at the Directorate of Agricore in February 2023. Eight officers from the directorate attended, which included the acting DG, the Director of the Horticulture Directorate, the Director of the Planning and Policies Directorate and the director of the Technology Transfer Directorate. The acting DG said that he would like to continue this experiment under the supervision of the directorate.

The reason the project members held this meeting was to share information on the irrigation experiment and the possibility of saving water among the directorate, as well as to secure the commitment of the directorate. Two state C/Ps participated in the experiment, but it was difficult for them to continue on an individual basis. There is a need for the directorate to continue to support this kind of experiment. The role of the directorate is important in terms of finding solutions as to how much irrigation water can be saved under different conditions.

After the meeting, the project team prepared and shared the guiding document setting out how the experiment should continue with the directorate.

(5) Presentation of the Results of the Experiment and the Plan to Continue the Work in the WUC

The results and plan were presented in the 6th WUC meeting, as written in the section of the WUC above. The WUC members have been encouraged to save irrigation water in all the WUC meetings and were willing to share this information on how to save irrigation water with others.

(6) Findings, Lessons and Challenges

1) Findings

Feasibility of Drip Irrigation

The installation costs and possibility of accessing a loan from a bank were studied. It was identified that it is difficult for ordinary farmers to install a drip irrigation system. The WUC with the NRMC are currently holding discussions with governmental banks to borrow money, as written in the section of the WUC, and the conditions of loans may be relaxed. Drip irrigation is a good way to save water, but farmers should have sufficient profits to cover the initial investment cost and the maintenance cost. The government and the WUC should work together with farmers to ensure that they are not in financial difficulty after installing the drip irrigation system.

Saving Irrigation Water Using the Traditional Method

The possibility of saving irrigation water using the traditional method was highlighted by the experiment. The experimental results show that mild drought improves the growth of crops, and that traditional irrigation methods can lead to the conservation of irrigation water. Although some donors installed drip irrigation systems previously, no trials were carried out to identify how to save water using traditional irrigation. The General Directorate of Agriculture and farmers were interested only in drip irrigation before the project members started the experiment. However, the experiment changed their way of thinking and one farmer even started his own trial.

Awareness Raising of the General Directorate of Agriculture

The pilot activity raised the awareness of officers of the General Directorate of Agriculture in terms of water use in irrigation and irrigation agriculture through the TC, the SC, the SWRC and the presentation meeting of the experiment, although this level of awareness is still not sufficient. The two state C/Ps learned from the pilot activity. For one of the state C/Ps based in El Obeid, this was the first time for him to work with irrigation farmers. They are expected to share their experience and knowledge with other officers.

2) Lessons

Simple Plan

It was not easy for the C/Ps and farmers to understand how to conduct the experiment. Consequently, experiment zones were not prepared as planned, monitoring by the C/Ps was not conducted properly and records were not kept by farmers. When continuing this kind of experiment, the plan must be very simple and a basic level of data should be collected.

3) Challenges

Lack of Knowledge and Extension Activities on Irrigated Agriculture by the General Directorate of Agriculture

As a result of the interviews and the implementation of the experiment, it became clear that the General Directorate of Agriculture in North Kordofan State has neither conducted any research or extension activities regarding irrigated agriculture, nor has any knowledge or experience in providing guidance to farmers as regards irrigated agriculture. Moreover, the branch office of the Federal Agricultural Research Centre in North Kordofan, does not conduct research on irrigated agriculture. Therefore, it is not easy to support irrigation agriculture in North Kordofan.

Lack of Statistics on Irrigation

The General Directorate of Agriculture does not have statistics on irrigation lands, harvested crops and water use by irrigation, although some data are available, as certain farmers have registered their lands with the directorate. This incomplete data makes it difficult to estimate water use by irrigation and to control irrigation water. The project team had to collect such information directly from farmers before the experiment was conducted. The way in which statistics should be developed needs to be discussed for the future.

4.4.7 Pilot Introduction of GW License System

(1) Background and Objectives

There is a lack of a control system regulating shallow and deep well drilling and pumping, as shown in the analysis of the water problems in Bara Aquifer. Certain government officers are very worried that GW is currently over-pumped, and the situation will worsen if new wells are drilled and water is extracted further without any control. Therefore, "well registration system creation" was selected as one of the pilot activities. This aims to control well digging and pumping by making well registration obligatory. Applicants should apply for their well and register it with the government before they use the well.

The Regulation for Groundwater 2016 (hereafter the Groundwater Regulation) was signed by the Minister of the Ministry of Water Resources, Irrigation and Electricity (MWRIE) in 2016 at federal level to improve water resource management. This regulation has three aspects, the first is to issue licenses for the digging of wells, the second is to issue licenses for the extraction of GW and the third is to register well drilling companies. However, the regulation has not been implemented, due to a lack of budget and the insufficient intuitional framework of the ministry. To enforce the regulation, the MIWR established the Basin Department, consisting of a license unit, a modelling unit and an information centre under the GWWD. The license unit has run training courses on the new regulation for MIWR officers, but the unit has not done any practical work in terms of issuing licenses.

There are no approved laws or regulations obligating users to obtain approval to register wells and extract GW in North Kordofan State. Although the Water Environment and Sanitation (WES), the rural water supply unit and the GWWD sometimes approve the drilling of new wells after checking an applicant's specifications, the process or format is not standardized and data relating to wells are not kept or shared among the relevant bodies. Therefore, there is no accurate data with regard to wells, such as the number, location and purpose, and frequency of use.

The MIWR requested that the project members use the short-term actions of the Project in North Kordofan State as a pilot scheme, with the aim of enforcing the Groundwater Regulation. The project team met the undersecretary and representative of the GWWD in January 2020 to discuss how to coordinate the work of the GWWD and the Project. The feedback from the GWWD to the project team was as follows:

- The GWWD wishes to create a mechanism to implement the Groundwater Regulation at state level.
- The GWWD would like to select members from the directorate to create a team and to send this team to North Kordofan State.

One officer from the GWWD was assigned as a coordinator for the Project in February 2020, but no team was formed during the project period.

The project members planned to pilot this GW regulation in North Kordofan State to establish the flow of procedures since the regulation does not clarify specific responsibilities or the way in which to issue a license. The project team also aimed to identify the best way in which to implement the regulation and to create a capable organizational structure at federal and state levels.

(2) Activities

1) Groundwater Regulation

The items listed below are abstractions of the important parts of the Groundwater Regulation.

Table 4.4-49 Outline of the Groundwater Regulation 2016

Chapter 1 Preliminary Provisions	
Article 1	Name of regulation and commencement date
Article 2	Application and exception This law will apply to all existing wells and those constructed subsequently once the regulation has been signed, except the wells owned by the military and exploratory wells.
Article 3	Definition of words “Groundwater use” means drilling a well and extracting GW
Chapter 2 License for GW Use	
Article 4	Requirements for a license for GW use The following requirements must be met before a license may be issued: (a) Specify the drilling site with specific coordinates by identifying the GW basin, where the well is located. (b) Specify the purposes of drilling. (c) Specify the diameter and depth of the GW well to be drilled with the requirement to link the purpose of use with the engineering design of the GW well. (d) Specify the required quantities by specifying the type and size of the pump to be installed. (e) Select the contractor who will drill the GW well (f) Submit any partnership contracts between the license applicant and another party to the ministry for review and approval, and keep copies of these.
Article 5	Conditions for granting a license Applicants should submit the following documents:

	(a) A technical, environmental and economic feasibility study, according to the indicators determined by the ministry. (b) A company or partnership registration certificate or work name in accordance with current legislation. (c) Documents proving ownership of land or a valid lease contract for the required license period. (d) Approval from the ministry to drill wells.
Article 6	Purpose of granting a license The license shall also be given to traditional and modern agricultural irrigation.
Article 7	Granting of license for GW use: (1) The license to use GW can be given to anyone at the discretion of the ministry after the payment of the prescribed fees. (2) The ministry may provide a license to permit the usage of GW according to its appropriate consideration. (3) If the ministry rejects a license, the applicant should be notified within 15 days of the date of rejection.
Article 8	Terms and renewal of license The license is valid for two years and is renewed at the end of each financial year.
Article 9	Obligations of licensee The licensee should: (a) Submit an annual report to the ministry, including the technical aspects of the well and the quantity of water to be withdrawn. (b) Take all necessary precautions to minimize any negative environmental impacts resulting from the use of GW and comply fully with environmental standards and in accordance with the laws. (c) Comply with specifications, technical studies and digital maps prepared by the ministry in the field of GW research regarding the determination of the layers of the earth, the existence, quantity and quality of the water and capacity of the aquifer, and respect any studies received from approved houses, accredited by the ministry. (d) Use the well for the purpose for which it is intended.
Article 10	Registration and inventory of GW wells: (1) The ministry shall make an inventory of and register existing wells and wells under construction. (2) The ministry shall register the well after confirming that the contractor and owner of the well are committed to the requirements of the license. (3) The ministry shall keep a record of the number of wells in each GW basin, with an indication of the quantity of available water. (4) The ministry may delegate its own authority to register and create an inventory of the competent authorities within the state.
Article 11	Ownership certificate of GW well Each registered ground well under Article 10 shall be granted a certificate of ownership/
Chapter 3 Contractors	
Article 12	Basis of registration and classification of contractors The ministry shall determine the required basis for the registration and classification of contractors, such as professional and financial ability, practical and scientific experiences, and types and size of machines and equipment.
Article 13	Registration and classification of contractors The ministry shall register and classify contractors with specific fees for each category. Only those registered can drill, develop and maintain the well and install a pump.
Article 14	Obligations of contractor: (1) Ensure that a valid license has been issued to use the GW of the site before drilling the GW well. (2) Keep the registration certificate in the workplace. (3) Take precautions and procedures to protect the ground basin. (4) Fulfil all specifications and conditions set by the ministry when licensing the use of GW. (5) Employ qualified workers to ensure the optimum use of the GW well. (6) Inform the ministry should the GW well need to be closed for any reason.
Chapter 4 General Provisions	
Article 15	Historical monuments and mineral wealth
Article 16	Validity of GW use

	The ministry may determine the period of validity for using the GW, according to the purpose for which the GW well was drilled or the quantities of GW available in the GW basin in which the GW well is located.
Article 17	<u>Access to licensed sites</u> A representative of the ministry shall be entitled to enter the licensee's sites to verify that he has fully implemented the license requirements, including sampling and conducting the necessary tests.
Article 18	<u>Monitoring well</u>
Article 19	<u>Penalties</u>
Article 20	<u>Revocation of license</u> The ministry may cancel the license in any of the following cases: (a) pollution of a well (b) over-extraction of water beyond the quantity permitted (c) unavoidable damage caused by extraction
Article 21	<u>Appeal</u>

Source: MIWR

2) Explaining the Regulation to State Officers

The MIWR did not have a chance to explain the regulation to the water officers at state level before the start of the JICA IWRM Project and officers at state level did not know about the regulation. Consequently, the federal C/Ps, led by the project director, along with officials from the GWWD, visited North Kordofan State and explained the Groundwater Regulation to the relevant officers in October 2019. More than 40 participants such as officers of the water and agriculture sectors, representatives of two private well drilling companies and the Humanitarian Aid Commission attended the meeting. The meeting covered the Groundwater Regulation and the Water Resources Acts of the NWRC, and other laws. Although the regulation was explained, the functions of the state ministry in this regard and the responsibilities of the federal ministry in guiding the states were not discussed.

3) Discussions on How to Apply the Groundwater Regulation

The project members, both from the federal and state governments, continued the discussion from June 2020 (mainly online) to decide how to apply the regulation in practice, which is not written in the regulation. This was important in terms of developing an organizational framework for law enforcement at different levels.

(a) Process of Application

The application process for licenses was decided as shown in the figure below. An application is first submitted to the locality, then sent to the state and federal government (GWWD).

The water manager, who is an officer seconded from the MIUD (note that the representative for the other states comes from the SWC) to supervise water supply at the locality, receives the application documents, categorizes the application in terms of local/trans-basins and carries out a preliminary evaluation of the application. Next, the water manager passes the application to the executive officer. The executive officer acknowledges receipt of the application and feedback and checks the preliminary evaluation, then the application is sent to the state GWWD for the secondary evaluation before approval. If the application includes more than three wells or a well that consumes a significant amount of water, the application is sent from the state to the federal government.

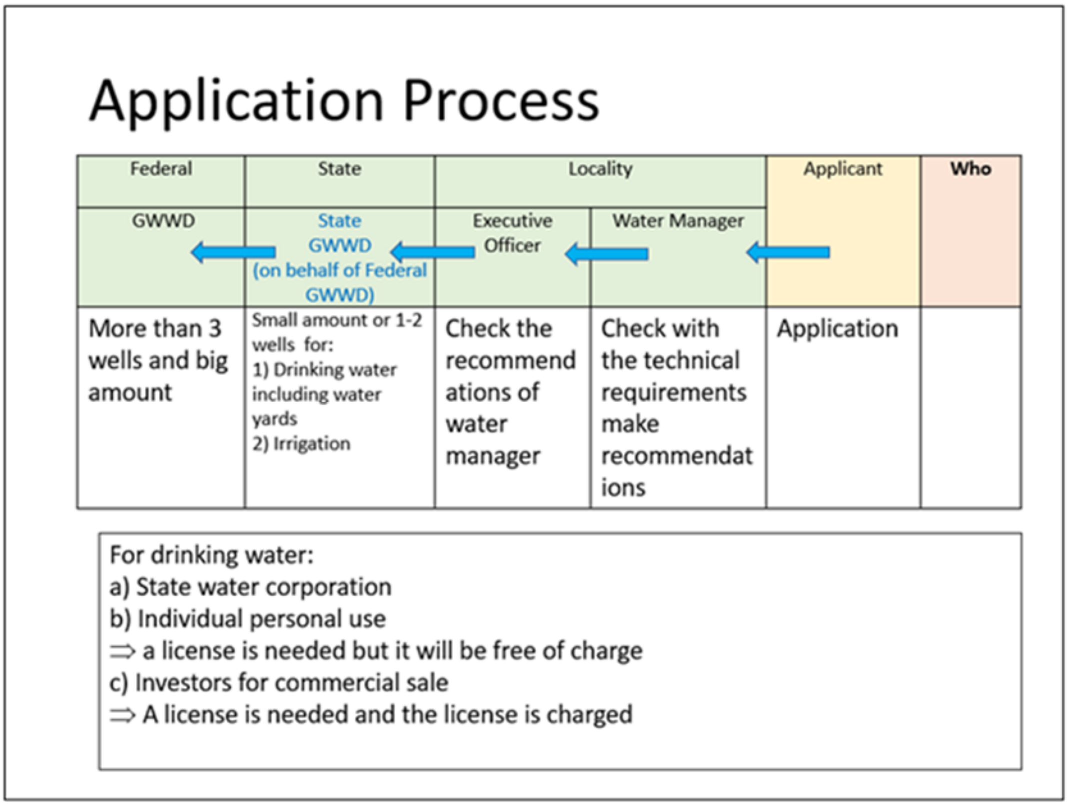


Figure 4.4-62 Application Process for GW License

The GWWD is the main player as regards the Groundwater Regulation but it does not allocate officers at locality level, therefore, cooperation between the water manager and other officers seconded from the MIUD to the locality is necessary.

(b) Demarcation Between the Federal and State Governments

The demarcation regarding the type of aquifers for which the federal and state government should be responsible in North Kordofan was decided as follows, as this was not set out in the regulation.

Table 4.4-50 Aquifer Classification for GW License

Aquifer Classification		Responsible Organization for License
Transboundary aquifer	• Bara Aquifer • Nubian sandstone	Federal government
Local aquifer	Basement rock	State government

The classification of aquifers in Table 4.4-50 is based on the fact that the transboundary aquifer has a large-scale distribution, showing large GW development potential, and the local aquifer has a small-scale distribution, showing limited GW development potential. From a strict geological viewpoint, both the shallow aquifer and the deep aquifer are located in the area of the transboundary aquifer. However, only the shallow aquifer is distributed in the basement rock area.

The shallow aquifer is on a small-scale and the deep aquifer is on a large-scale. Therefore, there is a proposal that even in the area of the transboundary aquifer, the shallow aquifer should be classed as a local aquifer. Table 4.4-51 shows the classification of the aquifers and the proposed organization responsible for the management of the transboundary aquifers.

Table 4.4-51 Classification of Transboundary Aquifer and Proposed Organizations Responsible for GW Management

<table>
<tr><th colspan="2">Aquifer</th><th>Proposal-1</th><th>Proposal-2</th></tr>
<tr><td rowspan="2">Transboundary aquifer</td><td>Shallow aquifer</td><td>The shallow aquifer and the deep aquifer are connected. Both aquifers should be considered from a hydrogeological viewpoint. Therefore, the federal government should manage the shallow aquifer</td><td>The GW of the shallow aquifer is pumped up through numerous hand-dug wells for the rural water supply and irrigation. Therefore, the state government should manage the shallow aquifer.</td></tr>
<tr><td>Deep aquifer</td><td colspan="2">The GW of the deep aquifer is pumped up through deep wells for the urban water supply and large-scale projects, such as commercial irrigation. Therefore, the federal government should manage the deep aquifer.</td></tr>
</table>

Following the discussions, it was concluded that the federal government should, at present, manage two aquifers (shallow and deep) through the state office of the federal GWWD. However, if the number of GW licenses increases in the future, the state office of the GWWD may not be able to handle the situation alone. Therefore, further discussion is necessary to decide which proposal in Table 4.4-51 is suitable for the effective enforcement of the GW license system and GW management.

(c) Revision of the Application Format

The MIWR had established an application format. However, this format was not user-friendly with many difficult technical words, and the two types of applications for new wells and existing wells were included on one form, leading to confusion. However, the federal GWWD was reluctant to revise the format, as the format had been approved by the MIWR and the project team could not revise all the points. The following decisions were made and proposals were given to the GWWD.

- The project members prepared two types of formats for 1) existing wells and 2) new wells. Regarding the existing wells, applicants apply for a license to use GW. In the case of new wells, applicants must first obtain permission to drill a well and then apply for a license to use GW. The table below shows the outline of the format:

Table 4.4-52 Outline of Application Format

1st Part	Information of applicant
2nd Part	Location of well
3rd Part	Purpose of drilling
4th Part	Agreement of Ministry's visit
5th Part	Conditions for license
6th Part and 7th Part	Required information and documents for license

- The project members proposed that certain documents required to be submitted for the existing wells should be abandoned, as applicants may no longer have access to documents relating to a well constructed a long time ago.
- The format needs further revision after pilot licensing. The application form requires that the applicant fills out technical information regarding the well. This technical information is collected only in the case of boreholes being drilled by drilling rigs and can only be filled out by the driller. The reason why the current format requires this information is because there is a duty to control illegal drilling companies to avoid poor well drilling or to maintain the quality of the wells to be drilled. Therefore, this information is not relevant for hand-dug shallow wells, making it difficult for the well owners to fill out the form. To improve the format, the application should be divided into two parts. The first part should contain basic information relating to the well applicant, the

intended use of the well and the expected pumping rate, and the second part should comprise information on borehole specifications. Only the first part should be submitted in the case of hand-dug shallow wells, while both the first and second part should be submitted for boreholes.

- Pilot licensing was implemented using the revised application format with the modifications mentioned above. However, the format needs further revision so that the applicants can complete the forms themselves easily. Otherwise, the GWWD staff should help the applicants fill out the technical information for all wells requiring an application.

4) Pilot Licensing

The project team decided to carry out pilot licensing in the Bara Aquifer, where many wells are concentrated, by targeting the wells the project members chose for participatory monitoring as they already have connections with the owners or operators of wells and can request their cooperation when applying for the license. The wells of the WUC members are also included. It is important to promote the wealth of administrative experience of government officers and the understanding of well users, by encouraging the registration of existing wells in this area.

The purposes of the pilot licensing are:

① To verify the potential division of roles and coordination among the federal, state and locality governments, based on the application process decided upon by the project members.

② To learn lessons from practical actions and to improve the formats and the application process in order to expand the licensing system in the future.

③ To have a database in which to collect accurate data of well and water use, so as to manage the GW resources in the future.

The federal C/P, who is a coordinator of the Groundwater Regulation, came to North Kordofan for the first time in December 2022 after he had been assigned to the Project to meet the relevant officers in the state government to discuss how to implement the Groundwater Regulation. This visit became possible after the project manager negotiated with the undersecretary and the DG of the GWWD. The coordinator explained the Groundwater Regulation and the plan for pilot licensing to water users at the 5th WUC. The WUC members were keen to know details of the plan, as they were worried about the uncontrolled drilling of new wells in Bara. They also had concerns as to whether they could trust the government with this kind of regulation, which could make them reduce water use. Then, the WUC members and owners/operators of the monitoring wells had another meeting with the state C/Ps and the federal coordinator of the regulation. The C/Ps explained to the WUC members and others how to fill out the revised application form and which necessary documents should be attached. The C/Ps gave the application format to around 20 well owners/operators including the WUC members. They are now preparing the application format and the land ownership document.

It is expected that the GWWD will issue a license soon for the existing wells, after receiving the application formats with the necessary documents; the GWWD will collate the comments on the format and the application process from the WUC members to revise them in the future if necessary.

The license will be given free of charge during this trial to motivate water users to get a license. Under normal circumstances, it will be necessary to evaluate whether or not a license should be granted, but since no standards have yet been set by the federal and state GWWD, the state GWWD will currently grant licenses for all wells that have been applied for. The first priority is to get the well registered in order to collect well data to analyze the balance between GW use and the GW level. The second step is to use the data to make decisions to manage and control GW.

License Based on the Evaluation and Validity of Safe Yield in the Future

a) Confirmation of Compliance with the GW Law Through Monitoring

The Groundwater Regulation Act (2016) aims to discourage the over-pumping of wells and to achieve sustainable GW use. The monitoring of the GW level and the pumping rate (m^3/day) of wells is sufficiently effective for the implementation of the Well Regulation Act. As shown in Figure 4.4-63, the issuance of a well permit needs to be judged in relation to the safe yield of wells in the area. If the total pumping rate from the wells is less than the regional safe yield, well permits should be issued without any restriction. However, if the total pumping rate exceeds the regional safe yield, the issuance of well permits should be suspended and existing well permits reviewed; well permits should only be re-issued according to water use priorities.

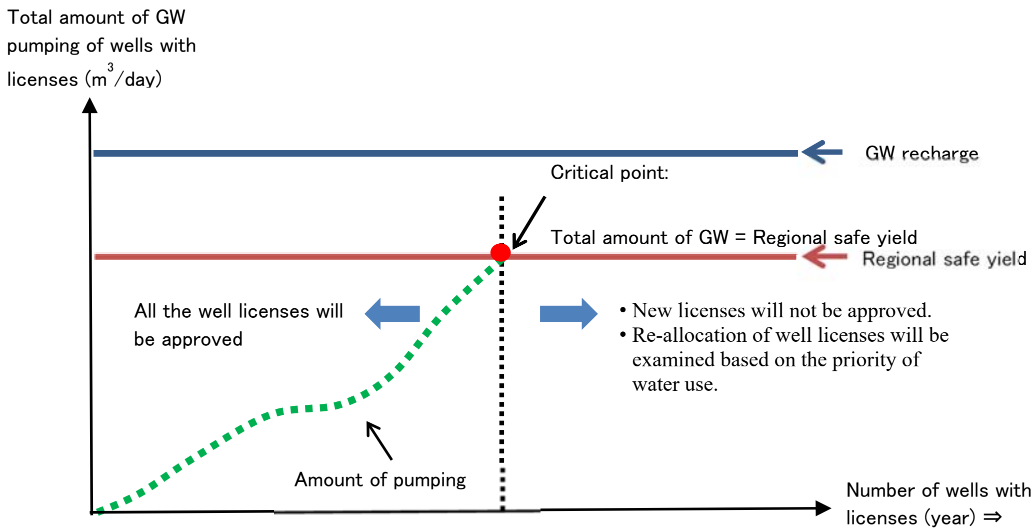


Figure 4.4-63 Relationship Between Well licenses and Regional Safe Yield

b) Determining the Regional Safe Yield of Wells

The regional safe yield of wells is an important determinant in the issuance of a well permit. In order to calculate the regional safe yield, it is common to calculate the GW recharge rate and estimate the regional safe yield of wells from this, however, this estimation of the regional safe yield involves many assumptions. Therefore, it is more reliable to estimate the safe yield of wells from the results of GW level and pumping rate monitoring. When the pumping rate of the region exceeds the regional safe yield, the GW level will continuously decrease, as shown in Figure 4.4-64.

The total pumping capacity of the region in this situation can be defined as the regional safe yield of wells.

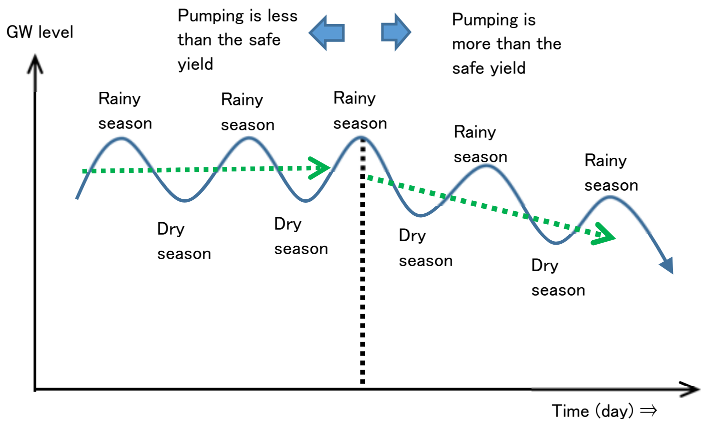


Figure 4.4-64 Determining the Safe Yield of Wells by Monitoring

c) Phased Operation of GW Management

Considering the relationship between the well permits, the total pumping rate and the regional safe yield of wells in the area, GW management should be implemented in three stages, as shown in Figure 4.4-65.

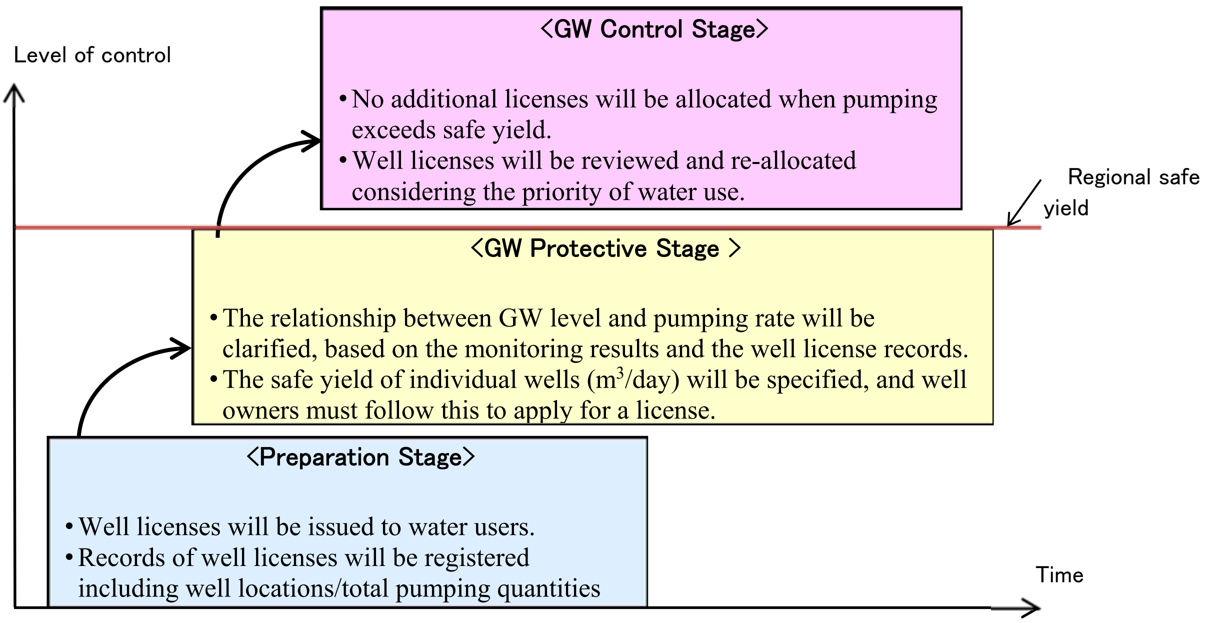


Figure 4.4-65 Enforcement of Well License System Stage by Stage

After issuing the well permits, the total pumping amount of the registered wells will be recorded. At the same time, the monitoring of the GW level and the pumping rate will continue, so as to establish the relationship between the GW level and the pumping rate. The issuance of well registrations should be controlled, so that the total pumping rate does not exceed the safe yield of wells of the region. If the total registered pumping rate does exceed the regional safe yield of wells, new well permissions shall be suspended. The registered wells will be re-allocated according to the priority of GW use, so that the total pumping quantity of the registered wells is less than the regional safe yield of the wells. The priorities will need to be discussed and agreed upon among the stakeholders.

5) Database

The database for well licenses was created to manage information on the registered wells. Registered wells will be managed using this database. The format for input to and output from the database has been completed. The content of the database is explained in Section 4.4.8 Database Creation.

(3) Findings, Lessons and Challenges

1) Findings

Enforcement of the Groundwater Regulation

The Groundwater Regulation was not enforced for over five years although it was approved in 2016. The C/Ps discussed the importance of this regulation with the undersecretary and the GWWD, and finally the MIWR started taking action. This is an important step for the MIWR, in particular the GWWD, as it was unsure how to implement the regulation, but this process has now been initiated.

Preparation of the Application Formats and the Application Process

The application format has been revised by the project team and the application process has been agreed as the first step, although both should be improved further based on the experience of pilot licensing before the full implementation of the Groundwater Regulation.

Prioritization of Areas

As a result of the pilot activities, it was found that the MIWR is attempting to apply the GW licensing system uniformly throughout the country. The situation differs from region to region in terms of GW use, availability and risk of GW depletion. Therefore, it is desirable to prepare and apply a licensing system that matches the GW situation in each region. In addition, rather than applying the system uniformly to all regions, it is necessary to apply them by focusing on the regions most at risk of depletion of GW resources. The federal C/P in charge of this subject first tended to adhere to the concept of introducing the license system uniformly throughout Sudan, however, he came to understand the need for prioritization of the areas with a higher risk of GW depletion, as a result of continuous guidance by the JPT.

2) Lessons

Difficulty of Enforcing the Groundwater Regulation

If the state governments prepare and implement GW regulations independently, as in Japan, they can be operated according to local conditions. However, the MIWR had the intention to roll out the regulation nationwide. Therefore, the GW licensing in the Pilot Project proceeded in line with the federal Groundwater Regulation and in consultation with the federal GWWD. It took time to coordinate the federal and state levels. This system of the federal MIWR taking a lead and becoming involved in decision-making makes it difficult for the state governments to determine the application format and evaluation criteria for licensing at state level according to local situation. The MIWR needs to reconsider future developments, including allowing the states to have some authority.

3) Challenges

Involvement of the Locality Officers

Although the application procedure established the roles of water manager and executive officer in the localities, the federal and state GWWD C/Ps communicated directly with the water users, therefore, there was no locality involvement in the pilot activity. If a large number of wells are to be targeted in the future, it will be impractical for the state GWWD to respond to each well user individually. Therefore, there is a need to increase the involvement of personnel within the localities.

Insufficient Organizational Structure at State and Federal Level

The GWWD Kordofan office does not have a sufficiently large workforce or sufficient equipment, such as computers, to enforce the regulation after the pilot stage. Only one office was involved in pilot licensing. The licensing unit under the federal GWWD is also limited in terms of human and financial resources as regards taking the initiative to expand the licensing system to all states. The federal government should be responsible for supporting the states in relation to licensing operations, including organizing briefings for state officials to enforce the Groundwater Regulation, giving advice on the procedure of awarding licenses in each state, providing guidance on monitoring and database aggregation. However, the federal GWWD has not prepared adequately for these tasks. It appears that the implementation of the Groundwater Regulation is still considered a low priority within the MIWR.

Insufficient Data and Knowledge to Evaluate Applications

The state government has insufficient data on GW to evaluate applications for licenses and the federal government does not have the necessary knowledge and data to guide the state governments in this regard. There is no option other than to award licenses to all the applicants over the coming years. To collect data and set standards aquifer by aquifer when evaluating applications is a considerable challenge.

Registration of Well Drilling Companies

The Groundwater Regulations require the registration of drilling companies. However, this could not be covered by the Project. There are many cases of well construction failure, due to the limited capabilities of well drilling companies, therefore, the registration of companies with the appropriate technical knowledge and skills is very important.

Licensing for New Wells

When submitting an application for a new well, applicants must first gain permission to drill a well and secondly must obtain a license for GW use. The pilot activities targeted only the existing wells. The application process for a new well is more complicated than that for an existing well. Therefore, the federal and state GWWD should conduct further trial licensing for new wells.

Coordination with Other Directorates at State Level

Coordination among the GWWD, the WES and the rural water supply unit was poor in terms of granting permission to drill a new well, and this is a problem. As the financial and human resources of the GWWD are limited, the GWWD should coordinate with the WES and the rural water supply unit to capitalize on the support available to the GWWD. The method of coordination has not yet been discussed, although the project team proposed that they should hold a coordination meeting.

4.4.8 Database Creation

(1) Background and Objectives

a) Issues to be Solved

The purpose of the database creation is to establish a GW and SW water monitoring database and a well database, which will be accessed by the state government for water resource management. The database will be used for discussions and policy-making relating to the sustainable use of the Bara Aquifer as part of a consensus-building/policy-making system within the SWRC and the WUC. There is a considerable amount of data on existing wells in North Kordofan State, however, information on existing wells is stored in different formats, and it is not collected and managed in a unified way. Due to this situation, the C/Ps including the stakeholders cannot not use the data effectively. In order to improve this situation, the JPT promoted information sharing by creating a water resource database, which is expected to be accessible to stakeholders in a unified data format.

As a medium to long-term goal, the JPT provided support to the C/Ps to establish a database update cycle and to build a system capable of managing continuous data input and information utilization. Initially, the JPT planned to develop a database on existing wells, however, the baseline survey showed that this required the more basic skill of GIS and database development. In order to develop such a skill, the JPT revised an implementation plan for database development. The C/Ps started from a more basic skill development, utilizing the existing database and implementing the iteration of progressive development. Each C/P was assigned several subjects (themes) of database development. Through database development, the C/Ps learned the basic procedures of utilizing GIS and document preparation through database development.

b) Purpose of the Database

The database covers information relating to GW and SW monitoring data and well specifications. It will provide information and access to the database for government organizations as needed and will be used for water resource management. At the same time, the database will be used for consultation and policy-making as regards the sustainable use of the Bara Aquifer in a consensus-building/policy-making system, centred on the SWRC and the WUC. More specifically, the database will provide stakeholders with the opportunity to effectively use existing hydrogeological/hydrological and water supply information by collecting, compiling and sharing hydrogeological/hydrological information among stakeholders. The database will also provide basic information for implementing water resource development and management projects in the Bara Aquifer. The database will record and accumulate information on water resources in the Bara Aquifer and surrounding areas, and will enable database users to retrieve the information they need for a specified time or area. In addition, the database will be used to input the results of water resource monitoring conducted during the short-term actions, to evaluate the water resources potential. Based on the information in the database described above, this will be used to formulate policies to implement water resource management in the Bara Aquifer.

Specifically, the following three databases were created in the pilot activity:

a) Registration for well licenses was planned in accordance with the Groundwater Regulation (2016), and a database was created to manage information on the registered wells.
b) The existing well data were collected as indicated below:
   - Data on wells in the Bara Aquifer owned by the GWWD of the federal government
   - Data on wells in the Bara Aquifer owned by the federal WASH project
   - Well data of water yards for the rural water supply in the Bara Aquifer, managed by the MIUD
c) Water resource monitoring was conducted to analyze GW and SW development potential, and GW levels and wadi flow rates were continuously observed.

An outline of the database is summarized in Table-4.4-53.

Table-4.4-53 Progress of Database Creation

Type of Database	Progress
2. Database of registered wells	Well registration was conducted on a trial basis in the Bara area. Registered wells are managed using a database. The format detailing input to and output from the database was completed. The input of information on registered wells is scheduled to start from April 2023.
2. Database for existing well inventory	Information from the existing well inventory (1,000 wells under the GWWD, approximately 2,000 wells under the WES and approximately 300 wells under the MIUD) was recorded in the database. The information is shared among the stakeholders for the purposes of water resource management and development by the North Kordofan State government.

3. Database for the results of water resource monitoring	The format for data input was completed. The monitoring data are easily input, saved and retrieved from the database. Monitoring information is stored in a database in an Excel format.

(2) Content of Database

The development of the database constitutes a critical role in the context of an integrated water resources management project. It provide stakeholders with access to relevant information regarding water resources and serves as a central repository of information. In addition, it provides important insights gleaned from SW and GW monitoring activities. It also stores the existing well inventory collated throughout the Project life span, as well as a license management system.

The different components are detailed in the following paragraphs.

a) Monitoring Database

<u>Surface Water</u>

The database relating to SW monitoring consists of a time series of water heads within defined measurement points in the wadis and hafirs. Flow velocities are then computed from the measured water head to establish water head-velocity graphs.

Measurements were carried out manually, adopting an hourly step during the rainy season for three consecutive years, in 2020, 2021 and 2022 in four different locations namely:

- Bagara and Elain Hafirs
- Kazgail and El Sikeran Wadis

This dataset will serve to track the change in the water head and flow velocities in the wadis and hafirs. By monitoring the SW in these areas, we can better understand the patterns of water flow and plan appropriate measures to manage water resources.

<u>GW</u>

GW monitoring consists of time series data relating to the water level in carefully defined candidate wells. Measurements were carried out manually for the first two years between the months of February and August on a daily basis. The total number of manually monitored wells is 60, distributed equally between Bara town and the irrigation and water yards. After installing nine automatic recorders in nine wells in July 2021, measurements of the water level and temperature were taken automatically at a higher frequency, which can be adjusted based on the user requirement until September 2022.

Data are stored in Excel sheets and linked to GIS software. This connection allows easier access to monitoring data which are displayed on the software, whereby basic information is shown for each well in addition to the corresponding graph, illustrating its water level time series. This database has been established to track the fluctuations in the GW level and aquifer drawdown patterns.

	W-1	W-2	W-4	W-5	W-6	W-7	W-8	W-9	W-12
21-Feb									
22-Feb									
23-Feb									
24-Feb									
25-Feb									
26-Feb						12.6			
27-Feb						12.6			
28-Feb						12.5		14.6	
29-Feb						12.5		14.6	
1-Mar					30.8	12.5		14.6	
2-Mar			26.1	25	30.8	12.5		14.6	
3-Mar	20.20		26	25	30.8	11.9		14.6	
4-Mar	20.72		26	25	30.8	12.5	24.7	14.6	
5-Mar	20.72	25.4	26	25	30.8	12.5	24.7		
6-Mar	20.72	24.4	26	25	30.8	12.5	24.7		
7-Mar	20.11	24.5	26	25	30.8		24.7		
8-Mar	20.11	24.2	26.5	25	30.8		24.7		
9-Mar		23.6	26.5	25	30.8		24.7		
10-Mar		23.2	26.5	25	30.8		24.7		
11-Mar		23.4	26.5	25	30.8		24.7		
12-Mar		24.6	26.5	25	30.8		24.7		
13-Mar		24.2	26.7	25	30.8		24.7		
14-Mar		25.4	26	25	30.8		24.7		
15-Mar		24.6		25	30.8		24.7		
16-Mar		25.2		25	30.8		24.7		

(a) Participatory Monitoring

Serial_number:				
4852669				
Project ID:				
B-5				
Location:				
Abud Rahman mosque				
LEVEL				
UNIT: m				
Offset: -23.000000 m				
Altitude: 490.000000 m				
TEMPERATURE				
UNIT: -C				
Date	Time	ms	LEVEL	TEMPERATURE
2021/7/25	19:36:49	0	-22.281	30
2021/7/25	19:46:49	0	-22.286	30.1
2021/7/25	19:56:49	0	-22.287	30.1
2021/7/25	20:06:49	0	-22.29	30.1
2021/7/25	20:16:49	0	-22.289	30.2
2021/7/25	20:26:49	0	-22.295	31.4
2021/7/25	20:36:49	0	-22.295	31.1
2021/7/25	20:46:49	0	-22.295	30.7
2021/7/25	20:56:49	0	-22.296	30.5
2021/7/25	21:06:49	0	-22.296	30.5
2021/7/25	21:16:49	0	-22.298	30.5
2021/7/25	21:26:49	0	-22.296	30.5
2021/7/25	21:36:49	0	-22.298	30.4

(b) Automatic Recorder

Figure 4.4-66 Well Monitoring Database

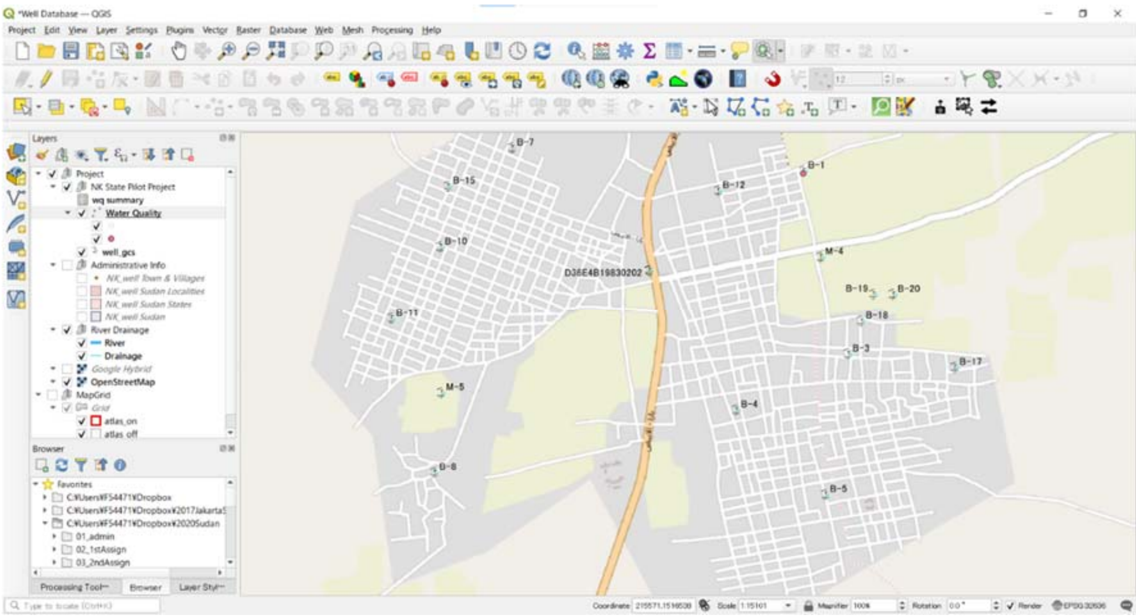


Figure 4.4-67 Typical Output of Monitoring Data in GIS Software

b) Database for Well Inventories and Registered Wells

Database for Well Inventories

This component would be used as a reference to identify the existing water resources and their characteristics. The main objective would be to estimate the water usage which is essential for planning various future projects, managing irrigation activities, etc.

The existing well inventory is composed of the different data already acquired from the relevant authorities. It consists of the following:

- Bara shallow wells
- Hafirs and Dams Construction Report
- Water Yards Construction Report
- WASH data

Drilling permits and licenses would be issued based on constraints, such as the distance from existing wells. Additionally, the possibility of updating existing licenses would be evaluated using the same data. In conclusion, this system would allow the sustainable management of water resources.

The database may be used in the following way, for example, when planning to dig a new well, the water and geological information of the existing wells near the well digging site can be searched in the database and this information can be used as a reference to plan well digging and improve the success rate of well digging.

Additionally, with the implementation of the future well registration system, well registration information will be managed by the database. As a consideration for database management, the GWWD North Kordofan office will manage the collection, accumulation, input, correction, update and publication of the data centrally to enhance the reliability and public nature of the database.

Table-4.4-54 Example of Well Inventory Database

Basin Name	Int. Nr.	Location	LatN	LongE	Total Depth	SWL	DWL	Yield	TDS	Well Use
Basement Complex	D36I3A20140810	AL SHUTEEB (2)	14.01444	31.0558	148.4					Drinking
	D35H6B20160618	UMM NALA MAHMOUD	13.6443	29.8897	64.1	40.7	60.4	3	289	Drinking
	D35H3A20071215	ABU FARDA (EDDODIA)	13.05	29.5666	129	109.9	114	15.6	365	Drinking
	D35H3B20050624	AL RAKIB	13.01027	29.85	66	0	0	0	0	Drinking
	D35H3B20050601	UM DONDOUR	13.0125	29.9702	60	40.7	0	1.14	956	Drinking
	D36J2A20010401	UMM DAMIR	14	32.0166	247	62	0	3	1757	Drinking
	D36I1A19960616	WAD JABUR	14.20527	31.59	30	5.4	20.75			Drinking

<u>**Database for Registered Wells**</u>

Currently, there is no obligation to submit data on well drilling in North Kordofan State, consequently, well data are not centralized. In response, the Groundwater Regulation (2016) requires well owners to register their wells. Submitting basic information on existing and newly drilled wells to the federal government is a requirement of well registration. With this system, information on all existing and newly drilled wells would be entered into a database without exception.

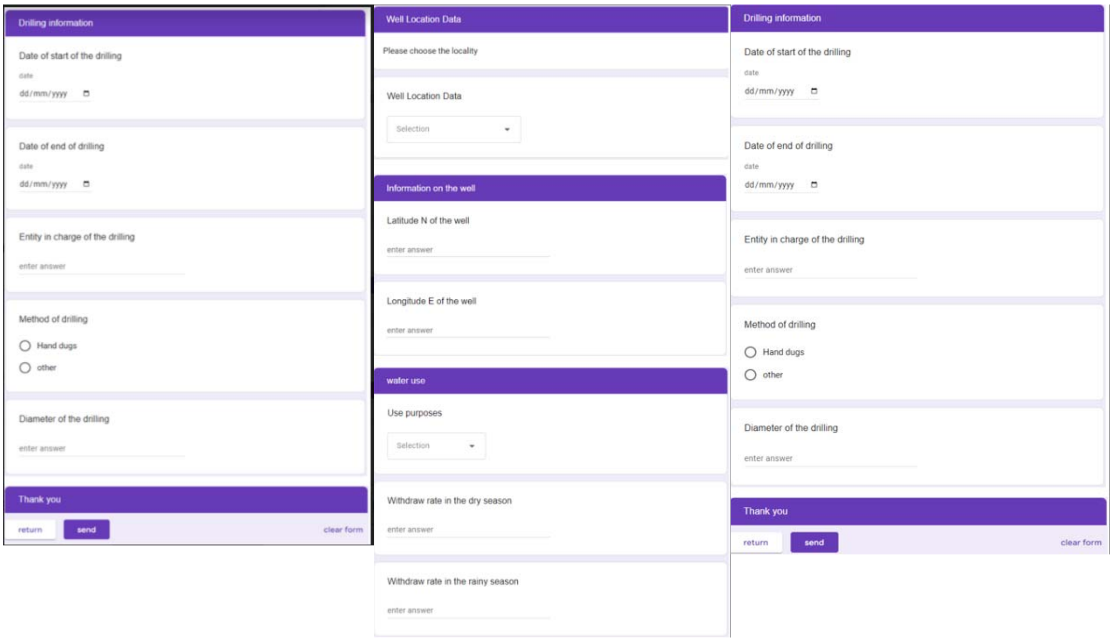


Figure 4.4-68 Input Form of Well License Registration

c) Database Management System

The operation of the database is as follows:

- The database will be operated and maintained by the IWRM unit of the SWRC in North Kordofan State and information on water resource management and development in the state will be shared with the stakeholders; since the members of the IWRM unit of the SWRC are composed of the GWWD and MIUD officials, the database will effectively be jointly operated and maintained by the GWWD and MIUD. These two organizations are permanent organizations and can ensure sustainability in the management of the database.
- The budget for the operation, management, maintenance and sharing of the database (data input, updating and modification) will be allocated annually in the SWRC budget. Personnel and financial support are expected from the GWWD and MIUD.
- Training materials for the database have already been developed and the technology transfer was completed by one of the Japanese experts on data-input, modification and management of data-history.

d) Data Sharing

- The database was initially planned to be accessible to the public via the Internet. However, well data are personal data and are not suitable for public access. Therefore, it was decided to share the data only within the departments of the state government responsible for the management of water resources. All three databases are under the management of the IWRM unit. The table below shows the operation and maintenance structure of the databases, as well as the relationship between the organization and the databases, indicating who updates them, how they are updated, etc.

Table-4.4-55 Organization and Personnel in Charge of the Database Under the SWRC

Type of Database	Organization and Personnel in Charge of the Database under the SWRC		How to Update the Database	Target of Data Sharing
Well license	GWWD	Hydrogeologist	Enter information into the database when individual	SWRC, MIUD, GWWD

				well registrations are made.	
Well inventory		GWWD	Hydrogeologist	Collect well data from the WES on a regular, annual basis and enter into the database.	SWRC, MIUD, GWWD
Monitoring	Shallow aquifer	GWWD	Hydrogeologist	Data will be collected once a month and entered into the database	SWRC, MIUD, GWWD
	Deep aquifer	GWWD			
	Water quality	MIUD	Water quality analyst	Water quality analysis will be conducted twice a year and the results entered into the database.	SWRC, MIUD, GWWD
	SW	MIUD	Hydrologist	Monitoring will be conducted from July to October and the results will be entered into the database.	SWRC, MIUD, GWWD

- The database is operated and managed by the state government C/P, who does not have advanced design and operation skills related to databases. The experts within the JPT confirmed the technical level of the C/Ps and adopted the method of recording data in an Excel format, a database that can be operated, maintained and managed without difficulty by the C/Ps.
- The purpose of the database in this pilot activity is to assist the state government C/Ps in managing GW in the Bara Aquifer. With this objective in mind, the database was created with the assumption that it would be used by the state engineers. The scope of the database was determined based on the overall consideration of the manpower, technology, available software and equipment of North Kordofan State, as well as the budget available from the SWRC, and it was agreed upon in conjunction with the federal and state C/Ps.

e) Effective Use of the Database

Effective Use of Well Inventory Data

The database for the well inventory can be used, for example, to search for hydrogeological information on existing wells in the vicinity of a planned drilling site, and to use this information as a reference for planned well drilling to improve the success rate of well drilling.

(3) Findings, Lessons and Challenges

1) Findings

In North Kordofan State, no database aimed at water resource management existed until the pilot activities were initiated. Only the WES and the MIUD well databases were available for the maintenance and management of rural water supplies. There was no regular monitoring of GW and SW, and there was no database to record monitoring results. Only an Excel sheet with the results of past individual monitoring was stored and well drilling data were not stored after the mid-1990s. It was under these circumstances that the pilot activities were initiated. The objective of the pilot activities was the conservation and sustainable use of the Bara Aquifer, and the basic data to achieve this objective did not exist. Therefore, the Pilot Project began by initiating new monitoring and collecting data. The existing database of well inventories was effective in determining the location of existing wells but did not record information on the hydraulic properties of the aquifer.

2) Lessons

It was identified that the existing WES and MIUD databases were inadequate in terms of sharing information and considering countermeasures in the SWRC and WUC for the purpose of conserving the Bara Aquifer. In addition, a database containing the results of GW/wadi monitoring was needed to evaluate the water resources available. In this Pilot Project, the necessary databases have been created, and a system was established to operate and maintain them. On the other hand, the people involved in the database in North Kordofan State lacked skills and experience, and a database that required advanced operational technology was not appropriate. Therefore, a database that does not require advanced technology was needed. The database would be used effectively in the discussions between the SWRC and the WUC to resolve water issues. In order to do so, the data from the database should be used to accurately indicate the nature of the water problem and its causes. The state government C/Ps already have the technology and are expected to make use of it.

Chapter 5 Achievement of the Project Activities

5.1 Methodology

The achievements of the JICA IWRM project were assessed in the following two ways.

- Assessment of the achievements of the JICA IWRM Project in contributing to solving the water resources management issue in the Al Bashiri Area and promoting IWRM in Sudan
- Assessment of the achievements of each pilot activity by applying the indicators established by JICA

The assessment for the Al Bashiri area was made by placing all five pilot activities in a larger conceptual context with the goal, objective and outputs as higher-level concepts above each pilot activity. The implementation of the pilot activities results in achieving the outputs, then lead to attaining the objective and goal. The achievements of the activity in Khartoum in supporting the revitalization of NWRC are assessed in the same way in terms of the achievements of the JICA IWRM Project in contributing to the promotion of IWRM in Sudan.

The achievements of each of the five pilot activities were assessed in detail by applying the indicators established by JICA for the respective pilot activity.

5.2 Overall Assessment of the JICA IWRM Project

(1) Assessment of the Pilot Activities in North Kordofan

Conceptual Framework

The achievement of the JICA IWRM Project is assessed from an overall perspective. For this purpose, the five pilot activities presented in the preceding sub-section are placed in a larger framework along with the goal, objective and outputs as the hierarchical concepts of the pilot activities, as shown in Figure 5.2-1. While the goal, objective and outputs were not explicitly identified and presented in the official project document, they were perceived by the C/P team and the JPT as the important underlying factors behind the pilot activities. This overall conceptual framework has been prepared for the North Kordofan government initiative to tackle the GW resources in Bara. The achievements of the JICA IWRM Project are assessed by analyzing to what extent they were successful in contributing to this overall conceptual framework.

The goal is defined as "*people's lives are improved socially and economically*". The lives of the Bara people will be improved with a stable supply of safe water; socially their lives will improve as a result of a greater sense of security, less risk of conflict and better quality GW and economic improvements will be made due to higher agricultural productivity and lower fertilizer costs. The objective is defined as "*depletion of groundwater is prevented and water use efficiency is improved in Bara*". The risk of the depletion of GW resources was regarded as the core problem behind the pilot activities, therefore its prevention was defined as the objective. The improvement of water use efficiency is also included as part of the project purpose because of its contribution to the achievement of the goal from an economic aspect.

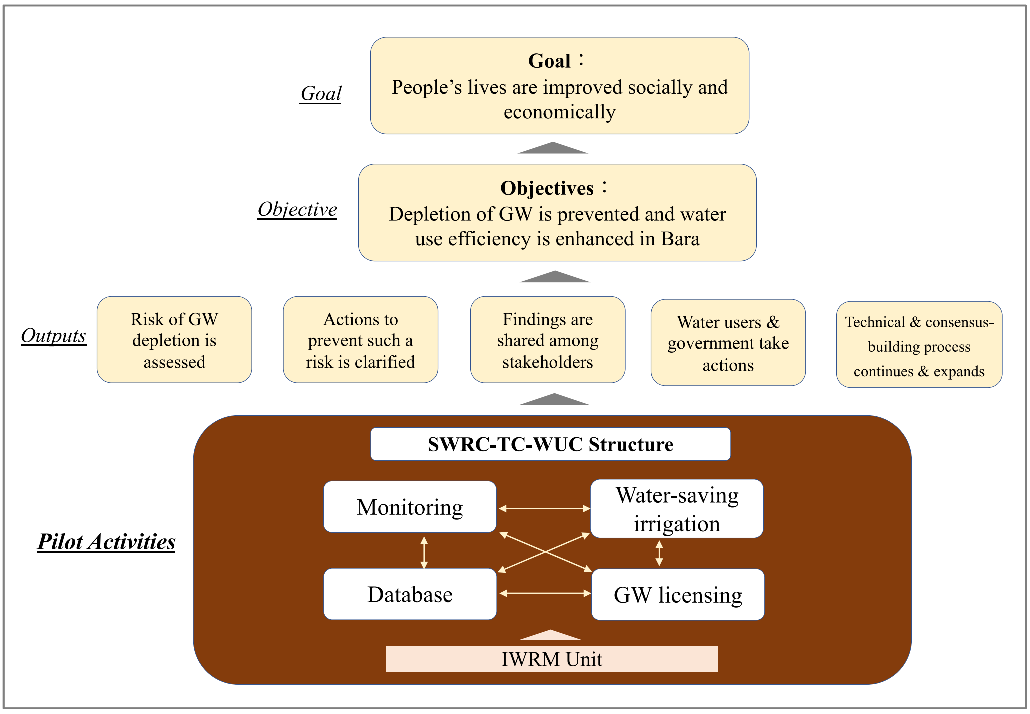


Figure 5.2-1 Pilot Activities in a Larger Conceptual Framework

Outputs fill the gaps between specific activities and the objective, by showing how each activity contributes to the achievement of the objective. Five outputs are required to achieve the objective: "*the risk of groundwater depletion is assessed*", "*actions to prevent such a risk are clarified*", "*findings are shared among stakeholders*", "*water users and the government take action*" and "*technical and consensus-building process continues and expands*". Five pilot activities shown at the bottom were implemented to achieve the objective. The progress and results of the pilot activities are shared and improvements and next actions are discussed at the SWRC, TC and WUC; the next actions are implemented on the ground with mutual links. This is a continuous and circulatory process like a spiral, as conditions surrounding water resources continue to change, therefore, achieving the objective requires a continuous effort. The IWRM unit supports this entire process.

Assessment of the JICA IWRM Project

The achievement of the JICA IWRM Project is assessed with reference to the five outputs. Table 5.2-1 presents a summary of its achievement.

Table 5.2-1 Achievement of the JICA IWRM Project with Reference to the Overall Conceptual Framework

Outputs	Activities under the JICA IWRM Project	Achievement of the JICA IWRM Project
Risk of groundwater depletion is assessed	• Groundwater and surface water monitoring was conducted. • A water balance analysis was conducted. • It clarified that Bara's groundwater will be depleted in the near future in the event that the current pumping rate continues.	Achieved
Actions to prevent such a risk is clarified	• The need for awareness raising of water users to halve the current pumping rate was clarified. • An experiment on water-saving irrigation for traditional irrigation methods was conducted with the cooperation of irrigation farmers as a short-term action and it clarified the possibility and need for reducing irrigation water use. • The groundwater licensing system began to be introduced on a pilot basis as a medium-term action. • Conjunctive use of groundwater and surface water was proposed as a long-term action.	Achieved
Findings are shared among stakeholders	• The result of the water balance analysis was reported to TC and SWRC. • It was explained to WUC. • WUC members transmitted the need for halving the current pumping rate to ordinary water users.	Achieved
Water users and government take actions	• Four irrigation farmers participated in the irrigation water-saving experiment for traditional irrigation methods • A community started to shorten the time for distributing groundwater to local residents. • An irrigation farmer voluntarily experimented to reduce the irrigation frequency for onions and found lower irrigation frequency resulted in larger onions.	Partially achieved
Technical and consensus-building process continues and expands	JICA IWRM Project did not reach this stage under the formal SWRC-TC-WUC structure.	Sudanese side to follow

The following must be noted:

- Efforts made to clarify the risk of GW depletion by water balance analysis were the first attempts of their kind in Sudan. A vague concern about the risk of groundwater depletion felt by water users before the Pilot Activities were implemented came to be identified as the clear and specific problem that should be tackled as a result of the technical analysis.
- As a result of awareness raising at WUC meetings, some action was taken on the ground, as shown in Table 5.2-1. This fact is a big finding. Water users responded to awareness raising following technical explanations by taking action to save water. This is because it is the water users who are affected most by GW depletion and are most keen to prevent it.
- The approach of the pilot activities to create a WUC involving water users in GW resource management, therefore, proved to be effective. Water users are ready to cooperate with the government in the event they are approached with technical explanations and a clear target.
- However, the objective of preventing GW depletion and enhancing GW use efficiency will take time. This approach, which has been found to be effective following the pilot activities should be continued and expanded on the Sudanese side until the total amount of GW extracted is reduced by half. It is possible to judge at that point that the IWRM approach takes root. This process, however, should be repeated and continued to cope with changing situations and maintain the effectiveness of the IWRM approach.
- Since water is an indispensable component of people's lives, especially in non-Nile areas with limited water resources, attaining the objective would greatly contribute to improving them. The continued effort by the Sudanese side to attain the objective and the goal is expected in this sense.

(2) Assessment of the JICA IWRM Project Regarding the Federal Initiative to Disseminate IWRM in Sudan

Conceptual Framework for the Federal Initiative to Promote IWRM in Sudan

The subject of the NWRC should be perceived in a larger context. Figure **5.2-2** presents the conceptual framework as regards the federal initiative to disseminate IWRM throughout Sudan.

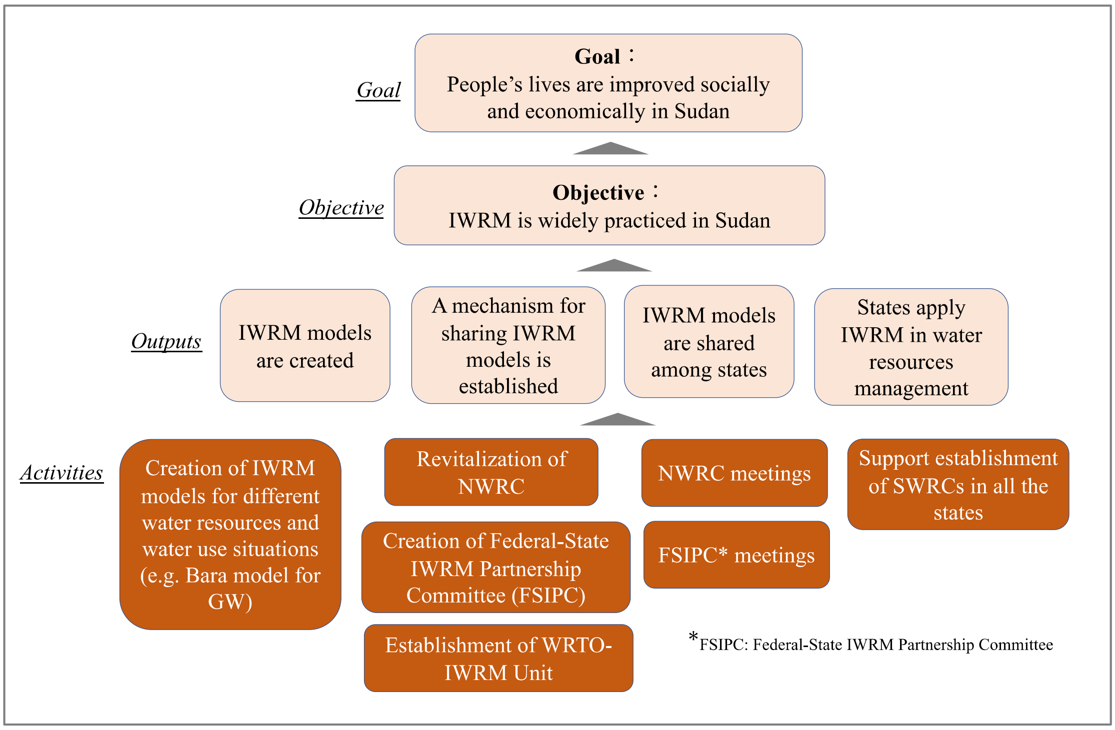


Figure 5.2-2 Conceptual Framework for the Federal Initiative to Disseminate IWRM throughout Sudan

As is the case for the pilot activities in North Kordofan, the conceptual framework above is formulated as a federal initiative to disseminate IWRM throughout Sudan, the initial part of which was supported by the JICA IWRM Project. The goal is defined as "*people's lives are improved socially and economically in Sudan*". An adequate supply of water of good quality will ensure stable lives for people, a greater sense of security and fewer conflicts, and will contribute to higher income through the rational use of water. This goal could be achieved once IWRM becomes commonplace in water resources management in Sudan. The objective is, thus, defined as "*IWRM is widely practiced in Sudan*". Four outputs are required to fulfil the objective: "*IWRM models are created*", "*a mechanism for sharing IWRM models is created*", "*IWRM models are shared among states*" and "*states apply IWRM in water resources management*". A set of activities must be undertaken to fulfil the outputs shown at the bottom of Figure **5.2-2**.

Assessment of the JICA IWRM Project

Table 5.2-2 shows the level of achievement of the JICA IWRM Project with reference to this conceptual framework.

Table 5.2-2 Achievement of the JICA Project with Reference to the Conceptual Framework for Disseminating IWRM in Sudan

Outputs	Activities under the JICA IWRM Project	Achievement of the JICA IWRM Project
IWRM Models are created	• Bara IWRM Model was created in North Kordofan State. • There was a report at the Federal-State IWRM Partnership Committee (FSIPC) held on March 15, 2023 funded by JPT that West Darfur State also has experience in implementing IWRM.	Achieved
A mechanism for sharing IWRM models is established	• MIWR counterparts and JPT discussed how National Water Resources Council (NCWC) should be revitalized following the 1995 Water Resources Act Amendment and proposed the formal establishment of FSIPC to strengthen links between the federal government and state governments. • They proposed the relocation of the IWRM Unit to WRTO to strengthen the organizational capacity of WRTO. • All these proposals were unofficially approved by the WRTO chairman and proposed to the MIWR minister.	Partially achieved
IWRM models are shared among states	• The Bara IWRM model was presented to the representatives of the 18 states at FSIPC held on March 15, 2023. • The case of West Dafrur in adopting IWRM was also reported at FSIPC.	Partially achieved
State apply IWRM in water resources management	• Replication of the Bara IWRM model is yet to happen in other states.	Sudanese side to follow

The following must be noted:

- The pilot activities in North Kordofan was an endeavour to create an IWRM model and the JICA IWRM Project was successful in creating such a model. The first Federal State IWRM Partnership Committee (FSIPC) meeting held on 15 March, 2023 provided all eighteen states to explain the water sector situation in their states–and the West Darfur representative highlighted the experiences of promoting IWRM. Different experiences of IWRM like these could be collected and accumulated, so that different IWRM models become available for states and areas in pursuit of better water resources management.
- The federal C/P group proposed the revitalization of NWRC, capitalizing on the 1995 Water Resources Amendment Act enacted in 2021. They also proposed the establishment of the FSIPC and the first meeting was convened on 15 March, 2023, financially supported by the JPT. The FSIPC is, however, yet to be formalized by MIWR. The IWRM unit is also being proposed as a measure to strengthen the organizational capacity of the WRTO to undertake the functions newly defined by the 1995 Water Amendment Resources Act. The second output with regard to creating a mechanism for sharing IWRM models is, therefore, still underway and can be perceived as "*partially achieved*" as the unofficial agreement of the MIWR decision-makers has been gained, although an official launch is yet to come.
- The third output, that of sharing IWRM experiences, has also been partially achieved since the experiences in North Kordofan and West Darfur were shared with the representatives of the other 16 states at the FSIPC meeting. The information sharing was, however, introductory, and repetitive and more detailed information sharing would be needed in preparation for replication in other states.
- The fourth output, namely, the application of IWRM in each state is expected to be achieved through continuous effort as the Sudanese initiative.

5.3 Assessment of the Pilot Activities Using the Indicators Proposed by JICA

Table-**5.3-1** presents the level of achievement of the pilot activities by applying the indicators proposed by JICA for each of the pilot activities. A brief summary follows.

(1) SWRC

The following are important points to be noted concerning the indicators for the SWRC:

- Since the legal base of the SWRC was established in February 2022 and considering the high motivation of the North Kordofan C/Ps in continuing the SWRC activities, the sustainability of the SWRC largely depends on budget availability. The North Kordofan government, as is the case in all the other states, has been suffering from a chronic shortage of funds, due to political, social and economic instability and a reduction in international cooperation. As is the case since the middle of the 2022 fiscal year, an amount of 1 million SDGs per month was promised by the MIUD Director General for the operation of the SWRC in 2023, by allocating part of the water sector budget of the MIUD.
- The capability of the North Kordofan C/Ps has been largely upgraded by their participation in the JICA IWRM Project. There are some areas, however, which require further capacity development such as the long-term runoff analysis for SW and the capability of managing SWRC and TC meetings. Continuous support by the MIWR C/Ps and the WRTO-IWRM unit, once established, is expected.

(2) WUC

The following are important points to be noted concerning the indicators for the WUC.

- More than two years have passed since the WUC was established, and the appointment of members to key positions, as well as the roles and activities of the WUC, were decided through discussion. It can be said that the foundation for the continuation of WUC was established.
- The scientific knowledge and data on GW obtained at the WUC changed the way of thinking that water is a finite resource and that careful use is necessary.
- The irrigation experiment was conducted just before the end of the Project. It is necessary for the C/Ps to support discussions on how the WUC will continue to work on this kind of water-saving irrigation and how to save domestic water. Then, the results of these actions should be fed back to the SWRC.
- The state government should allocate some of the budget to the IWRM unit to continue WUC activities.

(3) NWRC

The following are important points to be noted concerning the indicators for the NWRC:

- The sustainability of the NWRC is yet to be seen, as no official action has yet been taken to secure its revitalization. The first step that the MIWR and the WRTO should take is to request the NWRC member organizations to nominate official representatives.
- The 1995 Water Resources Amendment, Act, enacted in August 2021, forms the legal base for the NWRC. It defines the specific functions of the NWRC and the WRTO, which is mandated to be the technical working body supporting the NWRC. However, the WRTO's organizational capacity at present is not adequate to undertake the new functions defined by the 2021 Amendment, so the WRTO itself has been studying how to reinforce its capacity in terms of human resources and budget. The MIWR C/P team proposed the relocation of the IWRM unit, which has been in place in the Groundwater Department of the General Directorate of Groundwater and Wadi, to the WRTO to strengthen the organizational capacity of the WRTO. The MIWR C/Ps who participated in the JICA IWRM Project are expected to be the core members of the WRTO-IWRM unit once it is officially launched.
- Budget allocation will be an important subject in the process of formalizing the revitalization of the NWRC and strengthening the WRTO's organizational capacity.

- Recognition of the need to revitalize the NWRC is high within the WRTO as a result of repeated presentations by the MIWR C/Ps and the JPT. Recognition of the MIWR's decision-makers is also expected as a result of a number of presentations given by the MIWR C/Ps but this has yet to be confirmed.

(4) Monitoring

The following are important points to be noted concerning the indicators for monitoring.

A water resources monitoring system was established for the Bara Aquifer and Shekeran Wadi through the JICA IWRM Project. The water resources monitoring consists of three aspects: i) GW level (shallow and deep aquifers), ii) wadi flow rate and iii) GW quality. The monitoring results have been used in the SWRC and WUC to formulate policies to achieve sustainable GW use in the Bara Aquifer. Monitoring was carried out by the IWRM unit of the SWRC in North Kordofan State, which is composed of GWWD and MIUD engineers, who are currently conducting monitoring as part of their daily work. Through the implementation of monitoring between 2019 and 2023, the location, methodology, frequency and staffing for monitoring implementation have been established. IWRM unit members have also become proficient in the analysis of monitoring results through the implementation of monitoring. They have a clear sense of urgency regarding the declining GW level in the Bara Aquifer, especially the depletion of the GW level of irrigation wells. They are also keenly aware of the need for conjunctive use of GW in the Al Sidir Wellfield and SW in the Shekeran Wadi. This awareness is the driving force behind their continued monitoring.

(5) Water-Saving Irrigation

The following are important points to be noted concerning the indicators for water-saving irrigation:

- Farmers understood why the phenomenon of a low water level in their irrigation wells occurred, as a result of the knowledge gained in the WUC.
- Amid growing awareness of water conservation, farmers participated in the irrigation experiment of the JICA IWRM Project and learned from the experimental results that it is possible to save more water than currently. Four farmers were targeted, and the results were announced at the WUC meeting, so it is expected that information sharing will be promoted among WUC members and irrigation farmers. One WUC member stated that he wished to advise other farmers who overirrigate to reduce irrigation water based on the experiment.

(6) GW Licensing

The following are important points to be noted concerning the indicators for GW licensing.

- This was an attempt to implement the federal level Groundwater Regulation at state level, but there were many matters that had to be decided in relation to operation, and much time was spent engaging in preliminary discussions. However, the application process and format for implementation have been prepared.
- The government officers and water users understood the importance of this regulation to control the of use of GW through the WUC and SWRC and other meetings.
- The Project did not reach the point of granting GW licenses. However, many operational lessons were learned. It also became clear that both the federal and state governments need to develop an organizational structure for the implementation of the regulation.

(7) Database

The following are important points to be noted concerning the indicators for the database.

A water resources database has been created within the JICA IWRM Project. The water resources database has been used by stakeholders for the sustainable use of the Bara Aquifer. The database has also been used by the SWRC and WUC for consensus-building and policy-making. The database will consist of three types: i) a database of the registered wells, ii) a database of the wells inventory and iii) a database of the monitoring results. The IWRM unit of the SWRC is in charge of database operation and maintenance. The IWRM unit members consist of engineers from the GWWD and the MIUD. The database is being operated as part of their daily work. The budget for the operation of the database is allocated annually in the SWRC budget. The database was created using Excel and GIS as core software. Therefore, the database can be operated by IWRM unit members as it does not require advanced skills and knowledge. Using the information on the database, in addition to the well inventory and monitoring results, the safe pumping yield of the irrigation wells in Bara were proposed and presented at the SWRC and the WUC. As a result, a proposal and consensus was reached to halve the amount of water used for irrigation.

Table-5.3-1 Achievement of the Pilot Activities According to the Indicators Proposed by JICA

SWRC

Target	Indicator		Achievement as of March 2023	
SWRC and WUC are formally established, actions discussed and agreed are implemented, their contents and outputs are reported back to SWRC and WUC	SWRC	Formal establishment (approval of state governor)	Achieved	State Decree of February 2022, No 13 for SWRC and No16 for TC
		Establishment of entity responsible for management and implementation of agreed agenda	Partially achieved	Establishment of IWRM Unit is approved, but waiting for decree for official establishment
		・Membership and functions clearly determined for SWRC and TC ・Membership and functions clearly determined for IWRM Unit	Partially achieved	State Decree 13 and 16 determine the roles and membership of SWRC and TC.
		Budget allocation	Achieved	I million SDG per month was allocated for 2022 and 2023
		Convening meetings, twice a year for SWRC and four times a year for TC	Achieved	April 2022 for SWRC/TC joint meeting. December 2022 for SWRC meeting. March 7 for TC and March 9 for SWRC
		Change of recognition of SWRC, TC and IWRM Unit members toward consensus-building, satisfaction with consensus and discussion, situation of the Bara aquifer, trust on other members, trust on WUC	Achieved	Observations of the meetings
		Implementation of agreed activities and feedback to SWRC and WUC	Partially achieved	Achieved under the JICA project. Yet to be seen after the JICA Project ends.

Water Users Committee (WUC)

Objective	Indicator	Achievement as of March 2023	
To formally establish SWRC and WUC, implement actions based on discussions and agreements in SWRC and WUC, and feedback details and results of the actions to SWRC and WUC	Formal establishment	Achieved	The WUC was established in November 2020.
	Clarification of WUC members and roles (formal administrative document)	Achieved	A document explaining the roles, activities and core executive members of the WUC was prepared and shared with TC in March 2023, although it is not a governmental document.
	Securing the budget	Partially achieved	The budget for the WUC has been put as part of the activities of the IWRM unit, but it is unclear whether the budget will be allocated from the state government.
	Having regular meetings: 4 times a year	Achieved	Four meetings were held in the last year.
	Changes in awareness and behavior of WUC members such as attitude toward consensus building, satisfaction with agreements and discussions, understanding of the current situation of the Bara Aquifer, trust in other members, trust in state governments and SWRC, strengthening of relationship between SWRC and WUC, promotion of information sharing from WUC to water users	Achieved	The information provided at the WUC has led to actions such as limiting the hours of water supply to wells and the establishment of a Natural Resource Management Committee. Two representatives of the WUC have also joined the SWRC, which has strengthened the relationship with the government.
	Taking individual actions based on agreements and discussions, and feedback to WUC and SWRC	Not achieved	It will be monitored by the IWRM unit.
	Establish an entity responsible for the operation of the WUC and for managing the implementation of its decisions	Achieved	The core members of WUC were decided and they lead the other members.

NWRC

Target	Indicator		Achievement as of March 2023	
MIWR formally establishes NWRC, its management structure including linking the federal and state governments is established, formulation of IWRM-related policies, programs and actions are formulated based on discussions and consensus reached at NWRC and they are disseminated to states	NWRC	Formal approval for establishment of NWRC and establishment of entity responsible for NWRC management and implementation of agreed agenda	Partially achieved	NWRC has been already in place, but not revitalized yet. WRTO yet to be strengthened to function according to 1995 Water Resources Act Amendment
		Membership and functions clearly determined	Achieved	Determined by the 1995 Water Resources Act Amendment in 2021
		Establishment of management structure	Partially achieved	WRTO obligated to support NWRC is already in place, but its organizational structure needs strengthening
		Establishment of a mechanism to link federal government and state governments	Partially achieved	The Ministry of Federal Governance is a member of NWRC on behalf of all the states. Federal-State IWRM Partnership Committee was convened on March 14, 2023 as part of the JICA IWRM Project. It should become a part of the NWRC structure.
		Budget allocation	Sudanese side to follow	No budget has been allocated yet
		Regular convening of NWRC meetings; twice a year	Sudanese side to follow	No meeting has been convened yet
		Approval of IWRM Guideline by NWRC	Sudanese side to follow	No meeting has been convened yet, so no approval yet
		Sharing of the outputs of the JICA IWRM Project such as Nation-wide Water Resources Survey, water balance analysis, problem analysis and others	Sudanese side to follow	No meeting has been convened yet, so no sharing yet
		Formulation of nation-wide policies, programs and actions based on consensus and discussions at NWRC	Sudanese side to follow	No meeting has been convened yet, so no formulation of plans, programs and actions yet
		Dissemination of consensus and discussions at NWRC to the state level	Sudanese side to follow	No meeting has been convened yet, so no dissemination to the states yet
	Capacity of MIWR/WRTO	Capability to manage NWRC	Sudanese side to follow	WRTO's organizational capability yet to be strengthened

Monitoring

Objective	Indicators	Achievement as of march 2023	
Establish a groundwater and surface water monitoring system (with monitoring data managed sustainably in a database) to be used for consultation and policy making for sustainable use of the Bara Aquifer in a consensus building/policy making system led by SWRC and WUC	Establish monitoring regime (Bara Aquifer, surface water)		
	Establish an organization (government, residents, farmers)	Achieved	State/federal government and WUC worked together to establish a participatory monitoring implementation system. The CPs provided support by maintaining close contact with the well owners.
	Staffing	Achieved	GW, SW, and WQ monitoring was conducted by groundwater engineers, hydrologists, and water quality engineers from the IWRM UNIT of the SWRC.
	Type of Monitoring Engineer in Charge	Achieved	Monitoring plan including monitoring sites, monitoring frequency, monitoring method, CPs in charge, labor mobilaozatio car arrangement and cost preparation etc. were established
	Equipment Deployment	Achieved	JICA provided 10 automatic recorders (AR). Federal GWWD installed two ARs in Al Sidir well field.
	Budgeting	Achieved	The cost of monitoring GW, SW and WQ is to be budgeted annually by the SWRC of NKS.
	Staff capacity (monitoring and analysis)	Achieved	Through 4 years of monitoring, their capacities for conducting participatory monitoring, AR and SW monitoring were strengthened. C/Ps have sufficient experience and capacity in data acquisition, analysis, and evaluation.
	Utilization of monitoring data		
	Bara aquifer (shallow groundwater)	Achieved	Participatory monitoring was conducted from February 2020 to October 2021. And monitoring with a AR was initiated instead since then.
	Bara Aquifer (deep groundwater)	Achieved	Manual GW level monitoring began in February 2020 innAl Sidir well field. Monitoring continued until October 2021, and GW monitoring using two AR will begin in April 2023.
	Surface Water	Achieved	4 sites along the Shikeran wadi were established as monitoring stations and monitored for four years from 2019 to 2022.
	Calculation of groundwater availability in Bara and planning and consensus building of countermeasures in SWRC and WUC	Achieved	The GW recharge rate was calculated using the results of participatory monitoring and AR's monitoring. Based on the result, the safe pumping yield of the wells was calculated. And the result were reported to SWRC and WUC. Activities will be initiated to stop over-pumping.
	Conjunction use plan for GW and SW	Achieved	The amount of SW potential and GW potential was estimated from monitoring. The results of both were synthesized to develop a conjunction use of SW and GW for the sustainable water supply of El Obeid. Within this plan, an appropriate pumping plan of Al Sidir well field and an appropriate water intake plan for 3 reservoirs present in the Sikeran wadi were proposed
	Discussions, planning of measures, and consensus building at SWRC and WUC using monitoring data	Achieved	From the beginning of the pilot activities, SWRC and WUC have always presented the latest monitoring results and analysis results, and the awareness of SWRC and WUC on the water issues in the Barra has been improved.

Water Saving Irrigation

Objective	Indicator	Achievement as of March 2023	
To do water-saving irrigation by irrigation farmers through discussions, agreements, and decisions at SWRC and WUC with the support of the state government. To feed back the results and issues at the site to SWRC and WUC to promote sustainable use of irrigation water.	Share discussions at SWRC and WUC, promote understanding of groundwater conditions	Achieved	Discussion at WUC and SWRC were shared to water users through the representatives of WUC.
	Trial of water-saving irrigation	Partially achieved	The trial experiment was conducted though only once.
	Feedback to WUC on results and challenges from the water-saving irrigation trial	Partially achieved	The results of experiment and plan how to continue the experiment was shared in the 6th WUC.
	Awareness of sustainable groundwater use, expansion of awareness change to non-WUC members	Achieved	The WUC members have shared information about the groundwater situation and the AfDB project other water uses, and their understanding has improved. They have established the Natural Resource Management Committee, which has expressed their opposition to the AfDB project.

Groundwater License System

Objective	Indicator	Achievement as of march 2023	
To establish the well licensing system, promote understanding of the use of the Bara Aquifer by stakeholders. To promote sustainable water use in Bara by strengthening control of ground water and by promoting discussion and policy decisions under the consensus-building/policy-making system centered on the SWRC and WUC. /	Official approval as a system and establishment of an organizational structure for implementation	Achieved	The groundwater regulation was approved in 2016. The license unit was created under the federal GWWD.
	Establishment of organizational structure and staff allocation at state level	Partially achieved	Although it was decided that state office of GWWD is be responsible for practical work, both human resources and budget are insufficient.
	Securing budget to implement the new system in the state	Partially achieved	The budget for the introduction of the groundwater licensing system has been put as part of the activities of the IWRM unit, but it is unclear whether the budget will be allocated from the state government.
	Creating a license application format and determining the flow from application to granting a license	Partially achieved	The application format has been modified to make it easier for users to use. After trial licensing, it is planned to be revised further. The application flow has been decided and the division of roles of the locality, state and federal governments. The actual division of roles will be adjusted after the pilot activity.
	Creating the implementation guidelines (including classification maps and excavator lists) for supporting officials	Partially achieved	Although draft guidelines have been formulated, there are still many blank parts.
	Registration of existing wells and development of a well ledger as a new system	Partially achieved	The database has been created for wells to be registered. No input has been done yet.
	Start of operation: Receipt of application → Evaluation of validity (utilization of well ledger, technical evaluation using groundwater monitoring data and simulation) → Decision to whether grant a license	Not achieved	Under normal circumstances, it is necessary to evaluate whether or not a license should be granted, but since no standards have been set yet by the federal and state GWWD.
	Share information and exchange opinions on new license applications at SWRC	Not achieved	Generally speaking, opinion exchange at SWRC does not affect whether or not a license is issued. However, if there are concerns about new developments like the AfDB project, it is possible to exchange opinions at the SWRC.
	According to the agenda of SWRC and WUC, discuss using the well ledger, and plan and agree on countermeasures according to the characteristics of the agenda)	Not achieved	It will take time to collect enough date for discussion.

Database Creation

Objective	Indicators	Achievement	Remarks
Establish a groundwater and surface water monitoring database and a well database, and use the database for water resource management with access to it by government organizations as needed, as well as for consultation and policy making for sustainable use of the Bara Aquifer in the consensus building/policy making system led by the SWRC and WUC To be used for	Public database of wells		
	Data sharing with well registers	Achieved	The contents of the existing well registers and the contents of this database will be shared within the relevant departments of the state government.
	Collection of well data and establishment of a public database of wells	Achieved	Three thousand well data from WES, 900 well data from the federal GWWD, and 300 well data from MIUD were collected and compiled into a database.
	Establishment of a data sharing mechanism	Achieved	The well data will be operated, maintained, and updated by the IWRM Unit in the SWRC of North Kordofan province, so that the data can be shared by the relevant state government departments that are members of the SWRC through the IWRM UNIT.
	Procedures and capabilities for maintenance and data updates	Achieved	Well data will be operated, maintained, and updated primarily by the IWRM Unit in the SWRC in NKS; the IWRM Unit has received capacity building by the JPT.
	Budget Secured	Achieved	The budget for operating, maintaining, and updating the database is included in the SWRC budget for North Kordofan province and is allocated annually.
	Operationalize and use the database to consult and build consensus at the SWRC/WUC	Achieved	The database contains information on conservation management of the Bara aquifer. This was presented at the WUC and SWRC, and countermeasures are being discussed.
	Registered Well Database	To be followed up by Sudanese	This database was created through this project and is the first database of its kind in Sudan and does not exist in other states. This database will be used to manage information on registered wells in all states.
	Groundwater and surface water monitoring database		
	Data collection and data sharing mechanism established	Achieved	The database will be operated and managed by the IWRM Unit and can be shared among the relevant state government ministries and agencies that are members of the SWRC.
	Procedures and capacity for maintenance and updating of data	Achieved	Since the database is organized using Excell, the procedure for updating the data is easy and can be carried out by the Provincial Government CP without any problems.
	Budget for database maintenance	Achieved	The budget for the database is allocated annually as SWRC's budget
	Consultation and consensus building using the database at SWRC/WUC etc.	To be followed up by Sudanese	The results of the analysis were presented at SWRC and WUC, and discussions and consensus building were conducted.

Chapter 6 Recommendations on IWRM Promotion

6.1 IWRM Model Created by the JICA IWRM Project

A set of recommendations for promoting IWRM in North Kordofan and Sudan are presented in Chapter 5. The definition of IWRM is intended to place the recommendations presented later in the chapter at the same level of understanding for readers with various perspectives.

There are a number of common definitions of IWRM, which are widely shared, as shown below.

- *"A participatory planning and implementation process, based on sound science, that brings stakeholders together to determine how to meet society's long-term needs for water and coastal resources while maintaining essential ecological services and economic benefits" (USAID).*
- *"a process which promotes the coordinated development and management of water, land and related resources in order to maximize economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems and the environment"(GWP 2000).*
- *"IWRM is a systematic process for the sustainable development, allocation and monitoring of water resource use in the context of social, economic and environmental objectives" (CAPNET-2005).*

All three definitions capture the essence of IWRM that can be expressed by such keywords as *"participatory", "coordinated", "systematic", "sound science", "stakeholders", "ecological service", "eco-system and environment", "sustainable", "economic benefit", "social welfare" and "equitable".*

These views are widely shared by water resources planners and engineers all over the world. The activities in North Kordofan were initiated and undertaken with these common definitions in mind, and from there a new model of IWRM was developed, the "Bara IWRM Model", as shown in Figure 6.1-1, based on the experiences in the Bara area. The conceptual framework for the pilot activities, shown in Subsection 4.6, together with the SWRC-TC-WUC and the IWRM unit structure, is proposed as the Bara IWRM Model. A set of recommendations in this chapter are presented to encourage the Bara IWRM Model to take root and function sustainably.

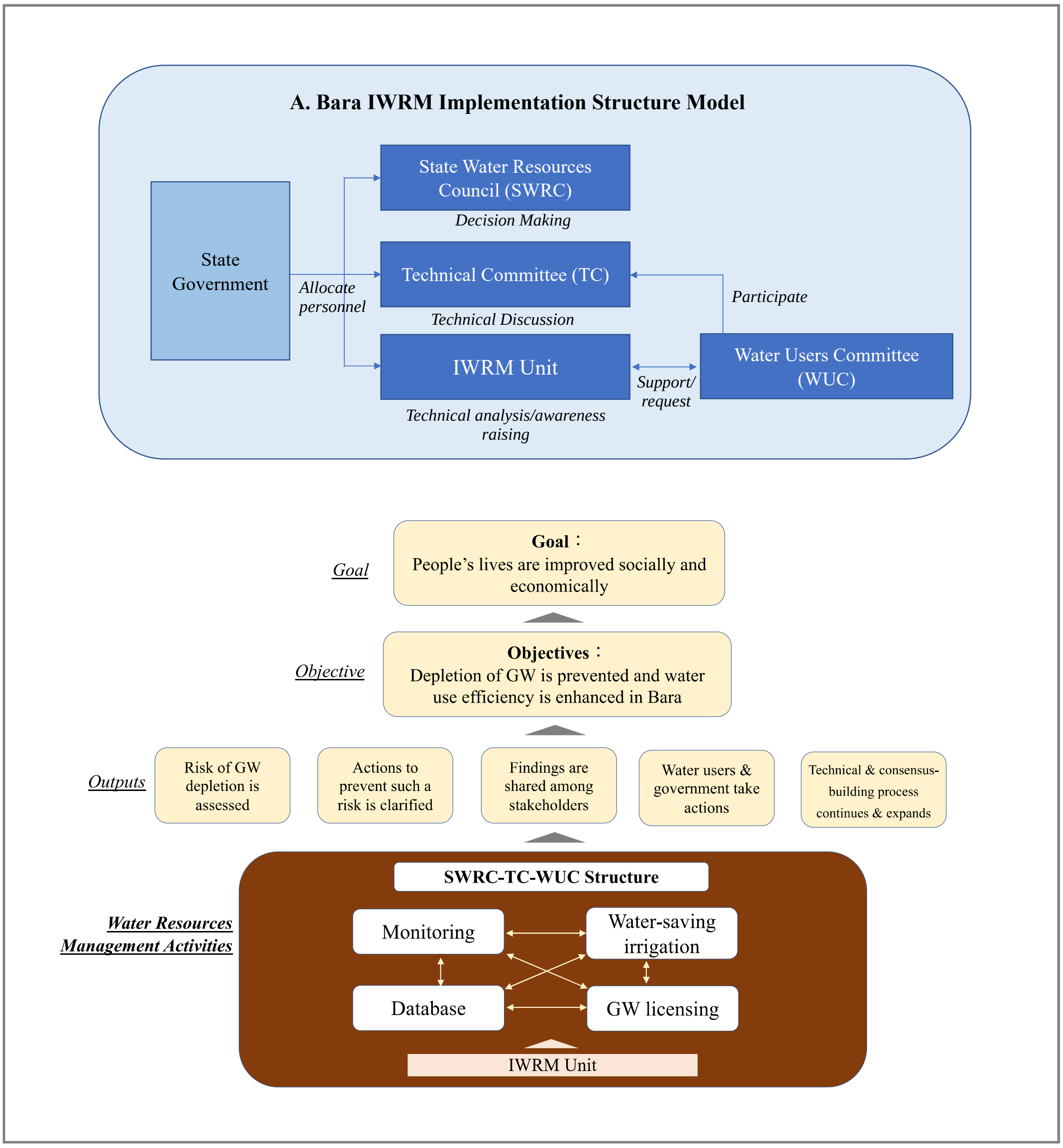


Figure 6.1-1 Bara IWRM Model

The following explains the considerations behind the Bara IWRM Model.

- The organizational structure shown at the top is proposed as the structure through which to promote IWRM. Various water resources management activities are to be undertaken under this organizational structure.
- The goal of water resources management activities is to ensure that "the people's lives are improved socially and economically". This goal will be achieved by ensuring that "the depletion of groundwater is prevented and water use efficiency is enhanced in Bara". People's livelihoods and society will be stabilized by a reliable supply of water through sustainable GW use. Reducing over-irrigation and promoting crop cultivation with the appropriate irrigation water amount will raise farmers' income levels by increasing agricultural productivity and reducing fertilizer costs. GW pollution will also be reduced.
- The principle of IWRM is water resources management based on the catchment area rather than the administrative boundaries. Such an IWRM process like the Bara IWRM Model, prepared for a sub-aquifer, could be replicated in other aquifer and river catchment areas, and integrated in locality level and state-

level initiatives. The state government and locality offices are, thus, able to manage the water resources in their jurisdictions based on natural boundaries according to the IWRM principle.

- One of the meanings of the term "integrated" with regard to IWRM is the integration of a technical/engineering approach and a social/institutional/legal approach. The rationale behind IWRM is that the conventional engineering and supply oriented approach alone does not work, and it is necessary to integrate various factors on the demand side, such as non-structural measures, participation and coordination into the planning and implementation process. The Bara IWRM Model proved that such a multi-sector and participatory approach is effective. It is a successful example of maintaining a good balance between technical inputs and social/institutional/legal inputs.
- While there is a tendency to emphasize the importance of participation and coordination when discussing IWRM, it should be kept in mind that an engineering and technical analysis forms the basis of IWRM, as water resources are a natural resource, the behaviour of which can only be captured accurately by technical analysis. Coordination and participation do not work when there is no technical basis. As technical capacity in Sudan is still limited, its strengthening would be an important factor in terms of establishing IWRM in Sudan successfully. The Bara IWRM Model was able to make an impact on the ground because of its technical base for coordination and participation.
- Data management plays a crucial role in IWRM. Data on natural conditions and water resources should be regularly monitored and assembled in a database. Accurate data on existing conditions provide a solid basis for various technical analyses and the preparation of an action plan, which can suggest appropriate solutions to water issues.
- There should be an appropriate consensus-building mechanism that ensures the vertical (e.g., federal-state-locality-community) and horizontal coordination of various stakeholders (e.g., water-agriculture-investment, etc.) and participation by water users. This kind of mechanism enables the state government and locality office to address water issues appropriately, as well as enhance the effectiveness of measures for solving water problems. An important characteristic of the Bara IWRM Model is the establishment of the WUC. This works as a channel for mutual communication between the government and the water users and has been successful in making an impact on the ground.
- An important element of IWRM is demand-side management. Changing the behaviour of water users to minimize water wastage is an efficient way of easing water supply-demand tensions without considerable investment. The promotion of water-saving irrigation, while using traditional irrigation methods, was a short-term measure proposed by the IWRM Bara Model to control water demand.
- The legal and regulatory framework is an important element of IWRM. Controlling the development and utilization of water resources by means of a licensing and registration system is also an efficient way of easing water supply-demand tensions without considerable investment. This is especially the case with regard to GW, since the development of GW is implemented through the drilling of wells by individuals, such as investors and farmers. These are not only water users, but are, at the same time, implementers of water resources development. Controlling their behaviours from an overall basin/aquifer perspective is an important approach of IWRM. The pilot introduction of the GW licensing system was undertaken with this concept under the Bara IWRM Model.
- This overall IWRM process continues over many years, in accordance with changes in conditions. It is a spiral process repeating the same activities and gradually solving water problems.

6.2 Recommendations on IWRM Promotion in North Kordofan State

6.2.1 Overall Recommendations for the Application of the Bara IWRM Model

Overall recommendations including the flexible and step-wise application of the Bara IWRM Model and the standard process for its application are proposed as follows:

(1) Flexible Application of the Bara IWRM Model

While the Bara IWRM Model is the basis for disseminating IWRM in North Kordofan, it could take different forms from area to area, depending on the water resources' situation and water use pattern. The Bara IWRM Model should be modified, if necessary, to suit local conditions and the best approach should be found.

An appropriate approach could be found somewhere between the two ends: the demand-side-oriented approach at one end and the supply-side-oriented approach at the other end. In any case, the technical analysis should provide a scientific basis and participation and coordination should always need to be integrated into the planning and implementation process in a way matched to the local condition. Figure 6.2-1 illustrates this concept.

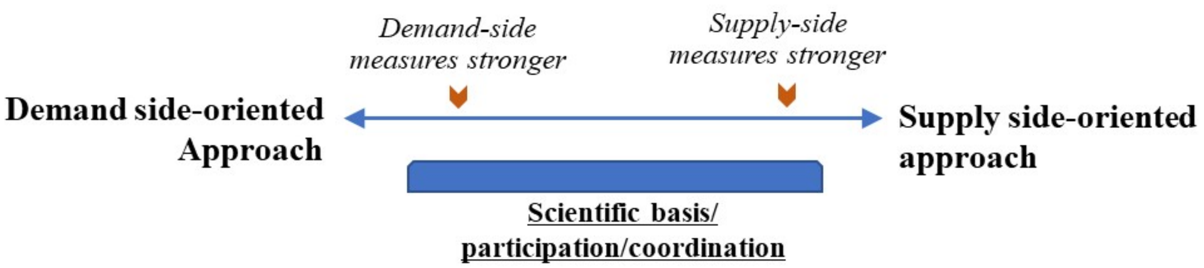


Figure 6.2-1 Demand Side-oriented Approach and Supply Side-oriented Approach

(2) Standard Process of Applying the Bara IWRM Model

While the IWRM approach should be promoted in consideration of local conditions and in three steps as shown later, the standard process of IWRM application as shown below in Figure 6.2-2 should always constitute the basis throughout the three steps. The pilot activities under the JICA IWRM Project were undertaken according to these steps. This standard process constitutes part of the Bara IWRM Model.

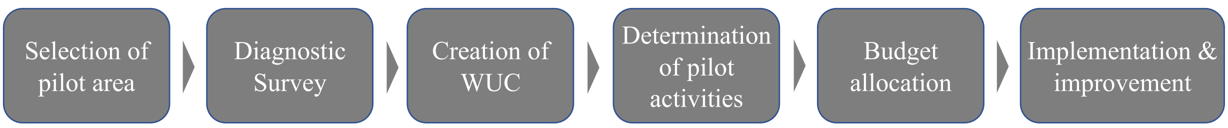


Figure 6.2-2 Standard Process of the Bara IWRM Model

- It would be impossible to tackle the water issues of a large target area at once. Therefore, it would be sensible to select an area as a pilot area first and to pursue an IWRM approach suitable for that area. The selection criteria would include the water supply-demand balance, the readiness of the community in applying a participatory approach and the existence of any planned state government project. In the event that there is a social conflict issue, the applicability of the IWRM approach should be seriously considered.

- It would be important to capture the overall water situation in the pilot area before specifying the pilot activities. The IWRM unit should collect information on water resource conditions from different perspectives by communicating with villages, locality officers, NGOs and other ministries, as well as referring to statistical data.
- The IWRM unit will then discuss the creation of a WUC with local community leaders. The way that the WUC would participate in water resources management would differ from area to area depending on the water resources endowment and water use pattern. An appropriate means of cooperation between the state government and water users should be pursued and the WUC designed accordingly.
- Pilot activities could be determined in a participatory manner with the participation of water users and with the technical support of the IWRM unit. It would be desirable for pilot activities to be linked to any projects or activities planned by the state government to make a positive impact and enhance efficiency.
- Once the IWRM unit and the WUC reach an agreement on the pilot activities, the IWRM unit will prepare a proposal and submit it to the TC for discussion. With necessary modifications, it will be submitted to the SWRC for approval.
- Once the budget is allocated, the IWRM unit will start supporting the WUC and the target community in implementing the pilot activities. The lessons should be collated and considered for improvement of the applied approach.

(3) Step-Wise Dissemination of the IWRM Approach

IWRM should be disseminated in North Kordofan State in a step-wise manner. The following measures are proposed:

- First Step: to make the IWRM model take root and function sustainably in the pilot activity area and the entire El Bashiri Sub-Basin area
- Second Step: to expand the application of the Bara IWRM Model to the other regions of the Bara Aquifer area and improve the model
- Third Step: to apply the Bara IWRM Model to other areas outside the Bara Aquifer area, especially those with more serious water problems, and improve the model

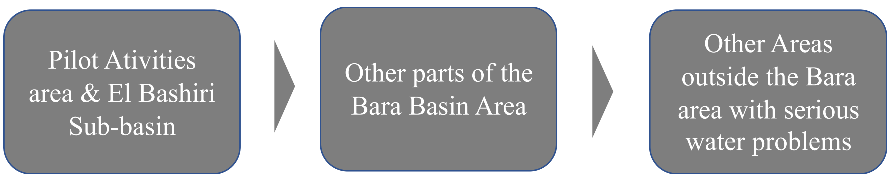


Figure 6.2-3 Expansion of the Bara IWRM Model

Table 6.2-1 presents the approaches required at each of the three steps for respective subjects of IWRM promotion.

The recommendations presented in sub-section 6.2.1 are prepared, assuming the application of the Bara IWRM model. The Bara IWRM Model will be able to be applied with minimal modifications at the 1st step for the Al Bashiri area and at the 2nd step for the entire Bara area because GW is the main source of water and the problems to be tackled would be similar in these areas. The application of the Bara IWRM model at the 3rd step, however, will require careful review before application, because the main source of water in the basement rock area and Nubia sandstone area is surface water, and this fact affects how water is supplied and in what way the government and water users can cooperate with each other. Development of water supply facilities would play an important role. A new IWRM model may be needed for the 3rd step referring to the experience of the Bara IWRM Model.

A set of comprehensive and general recommendations for IWRM promotion could be prepared once an appropriate IWRM model for the 3rd step is created and integrated with the Bara IWRM model.

Table 6.2-1 Step-Wise IWRM Dissemination in North Kordofan State

<table>
<tr><th rowspan="2">Subject</th><th colspan="3">Target Area of IWRM Promotion</th></tr>
<tr><th>(1st Step) El Bashiri Sub-Basin</th><th>(2nd Step) Bara Basin</th><th>(3rd Step) Other Areas</th></tr>
<tr><td rowspan="2">SWRC/TC</td><td rowspan="2">Maintain the existing structure</td><td colspan="2">Add new localities to TC</td></tr>
<tr><td>Modify Bara IWRM Model, if needed</td><td>Select an appropriate IWRM Model</td></tr>
<tr><td rowspan="2">WUC</td><td rowspan="2">Strengthen the self-management capability of Bara WUC</td><td colspan="2">Support establishing new WUCs</td></tr>
<tr><td>Modify Bara IWRM Model, if needed</td><td>Find out an appropriate government-water users cooperation form and design WUCs accordingly</td></tr>
<tr><td rowspan="2">Monitoring</td><td rowspan="2">Maintain the existing monitoring and technical analysis</td><td colspan="2">Install automatic recorders and undertake monitoring of water quantity and quality where GW is available</td></tr>
<tr><td colspan="2">Undertake surface water monitoring where surface water is available</td></tr>
<tr><td>Database</td><td>Expand the existing database by integrating scattered data and monitoring results</td><td>Expand the database by integrating the data additionally collected</td><td>Expand the database by integrating data additionally collected including surface water</td></tr>
<tr><td rowspan="2">Water-saving irrigation</td><td>Conduct second-round water-saving irrigation experiment</td><td>Conduct water-saving irrigation experiment to find an appropriate water-saving method matched to the local natural condition</td><td>Same as the 2nd stage, if there are irrigation farmers</td></tr>
<tr><td colspan="3">Disseminate the experiment results to irrigation farmers</td></tr>
<tr><td>GW licensing</td><td>Complete the pilot introduction and move on to full application</td><td colspan="2">Find the areas where the risk of groundwater depletion is high and apply the GW licensing system, first on a pilot basis, then on a full scale</td></tr>
</table>

6.2.2 Recommendation for IWRM Promotion in North Kordofan by Step

(1) (1st Step) Recommendations for Continuation and Intensification of Bara IWRM Model Application in the El Bashiri Sub-basin Area

A set of recommendations are proposed, as shown below, for the continuation and strengthening of the Bara IWRM Model application in the El Bashiri Sub-Basin area, including the pilot project area.

1) SWRC and WUC

Recommendations for the SWRC and WUC

- Need for awareness raising of state-level decision-makers
- Need for continuous support of state initiatives by the MIWR
- Focus required to make an impact on the ground
- Enhancement of the operational capability of the IWRM unit
- Strengthening of the WUC
- Capacity-building of the IWRM unit to support the WUC
- Continuation of practical actions
- Networking of the WUC and water users through the SWRC
- Information sharing with water users

1-1) Need for Awareness Raising of State-Level Decision-Makers

Awareness raising for state-level decision-makers is required. The understanding and support of the decision-makers are indispensable in sustaining the pilot activities. Awareness raising among the decision-makers should be continued by a bottom-up approach, as applied in the JICA IWRM Project, as well as engaging in federal level initiatives, such as the revitalization of the NWRC.

The fact that the North Kordofan State formally established the SWRC and the WUC illustrates its heightened awareness of the need for such a system. At the operational stage, however, awareness raising is needed to nurture an understanding of the decision-makers regarding the bottom-up approach. While the WUC-TC-SWRC cycle is understood by the IWRM unit members and the MIUD Director General, this understanding should be nurtured among TC and SWRC members. The decision-makers of the SWRC, in particular, are expected to understand this cycle and respond to the requests from the TC, based on the consensus reached within the TC, WUC and IWRM unit.

1-2) Need for Continuous Support of State Initiatives by the MIWR

The support of the MIWR is indispensable in sustaining North Kordofan's IWRM initiative successfully. It was often observed in the JICA IWRM Project that there are gaps in the technical and management levels between the state and federal C/Ps. The new mechanism under preparation at federal level including the revitalization of the NWRC and the creation of a Federal-State IWRM Partnership Committee assumes close cooperation between the federal level ministries and state governments to tackle water issues together. North Kordofan's IWRM initiative should take advantage of this federal level initiative to fill the technical and managerial gaps and sustain its activities successfully. This could constitute a model of federal-state cooperation, which could promote the transfer of the IWRM initiative to other states.

1-3) Focus Required to Make an Impact on the Ground

The impact of the pilot activities was observed in a community where the well operator was determined to shorten the time of distributing domestic water to local residents in response to the advice of the IWRM unit to halve the total pumping rate to reduce the risk of GW depletion. The message from the IWRM unit to the WUC members was transmitted to ordinary water users. In order to sustain and expand the IWRM activities, all activities such as monitoring and technical analysis should be aligned with the ultimate goal of making an impact at the water users' level. When small impacts like this are replicated and result in the halving of total GW extraction, the objective has been achieved. It is important for state and locality officers to promote these successes and to undertake the IWRM activities with a clear sense of orientation.

1-4) Enhancement of the Operational Capability of the IWRM Unit

<u>Expansion of the IWRM Unit</u>

The number of human resources in the IWRM unit will need to be increased in the event that the SWRC activities are undertaken across the entire North Kordofan State. Human resources should be expanded in a step-wise manner in accordance with the expansion of SWRC activities, as explained in sub-section 5.2.1. A balance between the demand for additional work and existing human resources should be carefully examined before expanding the IWRM unit. Knowledge-building in the areas of GW, SW, water supply, water quality, agriculture and livestock is needed, as well as capabilities in planning, facilitation, presentation, monitoring and evaluation.

The expansion of the IWRM unit, however, should be planned and realized in such a way that the ongoing and existing activities of the MIUD are improved by integrating the IWRM principles, especially the concept of coordination and participation, rather than initiating entirely new activities under the concept of IWRM. This could minimize the need to increase the human resources' budget of the IWRM unit.

Strengthening Specific Operational Capabilities

While various activities were undertaken during the JICA IWRM Project to encourage knowledge development among the C/Ps, the following capabilities need to be strengthened further for existing IWRM unit members.

(i) *Computer skills*: capabilities in utilizing various types of software, such as Word, Excel, Power Point and e-mail needs to be strengthened to ensure smooth communication with stakeholders, an accurate and efficient analysis of technical subjects, preparation of presentation materials and appropriate recording of data.

(ii) *Operation of individual meetings*: capabilities in planning and managing individual TC and SWRC meetings should be enhanced as regards the compilation of the agenda, time management, agreement on resolutions and the preparation of minutes of meetings.

(iii) *SWRC-TC-WUC cycle management*: the cycle of WUC-TC-SWRC established during the JICA IWRM Project should be properly managed. The challenges include sufficient communication between the IWRM unit and the WUC, the scheduling of TC and SWRC meetings at an appropriate time, the drafting of an appropriate agenda, the preparation of proposals for the SWRC addressing the right issue at the right time and the continuation of the WUC-TC-SWRC cycle with regular improvements.

(iv) *Ensuring close cooperation with the MIWR:* the support of the MIWR is indispensable in sustaining North Kordofan's IWRM initiative successfully. It was often observed in the JICA IWRM Project that there are gaps in the technical and management level between the state and federal C/Ps. The new mechanism under preparation at federal level, including the revitalization of the NWRC and the creation of a Federal-State IWRM Partnership Committee assumes close cooperation between the federal-level ministries and state governments, with the aim of tackling water issues together. North Kordofan's IWRM initiative should take advantage of this federal-level initiative to fill the technical and managerial gaps and sustain its activities successfully. This could constitute a model of federal-state cooperation in extending the IWRM initiative to other states.

1-5) Strengthening of the WUC

(i) *Membership*: the WUC is required to bring together representatives of different water user groups in the target area, to exchange views and make decisions. The IWRM unit, together with the WUC, needs to continuously improve the representation of the WUC, in order for the WUC to be inclusive of a wide range of water users. The Project was not successful in involving women, youth and nomads in WUC. Historically and culturally, young people and women have been marginalized in the decision-making process, but after the revolution, there is a trend in Sudan to include them in social activities. It is necessary to make trial attempts to encourage them to participate in the WUC. Although the government has lost its association with the FFC, the WUC is now led by non-government members, therefore, these members can take the initiative in communicating with the FFC and other groups to strengthen membership. Sudan has been

undergoing a period of political change, however, the WUC and the government has begun to build trust. The government officers can also give advice to the WUC.

The WUC is planning to create sub-committees within the WUC to have representatives from the villages in the aquifer. The IWRM unit should support this if the need arises.

During the dictatorship, the establishment and activities of NGOs were restricted by the government. If environmental and community development NGOs start their activities in the target area in the future, these NGOs could be considered as candidates for WUC membership.

(ii) *Support of the WUC by the IWRM unit:* the IWRM unit should support the WUC to operate and take action as planned in the 6th WUC meeting. The IWRM unit is expected to provide support, such as collecting members' fees and deciding how the money is to be used. WUC members have already made requests to the government through the WUC meetings, such as the installation of solar panels and modern irrigation equipment, and the government has responded to some requests. The WUC is now requesting to remove mesquite trees. The IWRM units should coordinate with the relevant directorates and plan how to respond.

The IWRM unit should also support the WUC in making action plans with a time schedule, so that everybody can understand the objectives of the WUC and the support it needs to take action. The WUC is ready to save irrigation water therefore, the IWRM unit should provide guidance in order to formulate a plan.

1-6) Capacity-Building of the IWRM Unit to Support the WUC

The capacity of the IWRM unit is not sufficient to support the WUC, although the Project has built some capacity. Some members of the IWRM unit are not proficient in making plans, taking minutes, analysing findings and learning lessons from actions taken. Therefore, the MIWR officials should support and build capacity through on-the-job training.

1-7) Continuation of Practical Actions

The Project undertook practical actions to manage water resources, such as the experiment relating to saving irrigation water and issuing trial GW licenses in the Project's last year. These practical actions have heightened the interest of the WUC members. Therefore, this kind of practical action should be continued to promote the participation of the WUC and water users. The IWRM unit should formulate a plan to ensure the continuation of these actions.

1-8) Networking of the WUC and Water Users Facilitated by the SWRC

The WUC established by the Project does not have any members who live outside the basin, however, they use water from this area, such as the citizens of El Obeid, who use drinking water from the basin and the inhabitants of Al Mazroub where water is scarce. Moreover, the AfDB is planning to transfer water from Al Bashiri. The SWRC should listen to the voices of those who are not represented and provide a platform to coordinate the different interests of different groups.

1-9) Information Sharing with Water Users

The WUC has a limited number of members. Therefore, the state government should plan a method of sharing information on a larger scale. The pandemic prevented the Project from holding a workshop targeting water users on a large scale to share information on water resources. If government officials were able to explain the current condition and future prospects of water resources, the impact would be greater. The IWRM unit should organize workshops or general meetings for as many water users as possible and the government should use media, such as radio, to disseminate information.

2) Monitoring and Technical Application of the Monitoring Results

<u>Monitoring and Technical Application of the Monitoring Results</u>

- Formalization and strengthening of the monitoring system established in the pilot activities
- Active and continuous utilization of automatic GW recorders
- Further promotion and realization of the conjunctive use of northern GW and southern SW

2-1) Formalization and Strengthening of the Monitoring System Established in the Pilot Activities

After four years of pilot activities, the implementation system for GW and SW monitoring has been established. This monitoring system should be formalized and strengthened, capitalizing on the experiences of the pilot activities. Specifically, the state C/P team were able to identify the monitoring sites, observation methods, mobilization and deployment of observers, methods of organizing and analysing observation data and its interpretation, and the budget and contribution methods necessary for monitoring. Monitoring should continue based on this broad framework. Monitoring, however, should be continued flexibly, for example, by reducing the volume of monitoring during periods of low budget. A clear sense of the purpose of monitoring would ensure the motivation of state officers to continue to use the budget sparingly. Current state government C/Ps who were involved in the JICA IWRM Project are able to continue monitoring with a high level of commitment. There will come a time, however, when these C/Ps will retire, and it is necessary to ensure that their skills are passed on to younger technicians.

2-2) Active and Continuous Utilization of Automatic GW Recorders

Ten automatic GW recorders for the shallow wells in Bara and two automatic recorders installed in Al Sidir Wellfield should be actively and continuously used to capture the accurate level of GW, so that appropriate measures can be taken and a water resources management plan, matched to the actual situation, can be prepared. The Project has installed 10 self-registering, water-level gauges in shallow wells in the Bara area to conduct highly accurate GW level observations. In response, the federal government will install two self-registering water-level gauges in deep wells and will begin observations in April 2023. The relationship between the shallow aquifer and the deep aquifer will be determined by monitoring both aquifers with self-registered water level gauges. The results will influence not only the relationship between the irrigation wells in the Bara area and the Al Bashiri well complex, but also the nature of the conjunctive use of southern SW and northern GW. It also allows for the verification of the effectiveness of various actions in achieving the target of reducing the amount of GW extracted. The state C/Ps should ensure that monitoring of both continues.

2-3) Further Promotion and Realization of the Conjunctive Use of Northern GW and Southern SW

A reduction target for GW use in North Kordofan State was developed. This is based on the framework of the conjunctive use of GW and SW, and aims to ensure the sustainability of the water supply to El Obeid, as well as sustainable irrigation and domestic water uses in the Bara area. The state government C/Ps should implement the management of northern GW pumping and southern SW withdrawal, with the aim of putting this goal into practice. Specifically, this means reducing the amount of water pumped from the Al Sidir well complex, as well as the water used for irrigation in the Bara area, and adjusting the amount of water withdrawn from the Sikeran Wadi. To achieve this, comprehensive measures should be planned and implemented, including encouraging water users to conserve water and improve facilities.

3) Water-Saving Irrigation

Recommendations for Water-Saving Irrigation

- Continuation of the water-saving experiment
- Improvement of the organizational structure and roles of the General Directorate of Agriculture
- Collaboration with and follow-up of the WUC and NRMC on saving irrigation water
- Development of statistics

3-1) Continuation of the Water-Saving Experiment

The General Directorate of Agriculture, with the cooperation of the IWRM unit should continue the experiment as proposed in chapter 4. There are two kinds of experiments:

Reduction of irrigation volume each time

This is a relatively safe approach and water can be reduced to 20L per m^2 (water depth of 2cm in a plot) given the water-holding capacity of the soil. This can be adaptable to all crops.

Reduction of irrigation frequency

For root vegetables and fruit vegetables, it is suggested that the irrigation frequency is changed in the late stage of growth.

The JICA IWRM Project has developed a guideline on how to undertake subsequent experiments, so, the General Directorate of Agriculture can use this guideline. The General Directorate of Agriculture should modify its actions by supporting irrigation farmers according to the soil type and crops cultivated in future.

3-2) Improvement of the Organizational Structure and Roles of the General Directorate of Agriculture

It is necessary to allocate human resources and a budget to support irrigation agriculture at the General Directorate of Agriculture. The expansion of irrigation land is continuing in the state, so the state government should act promptly. Regarding the water saving experiment, it is necessary to consider not only the continuation of the experiment but also the way in which the General Directorate of Agriculture should collect date and disseminate the information collected through the experiment.

3-3) Collaboration with and Follow-Up on the WUC and NRMC As Regards Saving Irrigation Water

From the perspective of the General Directorate of Agriculture, the WUC and NRMC are the contact bodies for irrigation farmers. The General Directorate of Agriculture and the WUC have already started working together along with the banks and the private sector in January 2023 (explained in the WUC section of Chapter 4). This type of cooperative work should continue. The General Directorate of Agriculture and the IWRM unit should also follow up on the activities of the WUC and the NRMC, as one farmer has already started his own experiment and others may follow. The WUC and the NRMC are also planning to evaluate the results of the introduction of drip irrigation and sprinkler irrigation. The officers of the IWRM unit and the General Directorate of Agriculture should maintain communication with them to follow up on their activities and to give the necessary advice and support.

3-4) Development of Statistics

The General Directorate of Agriculture, with the support of the MIUD and the IWRM unit, should start discussions on how to collect statistics on irrigation agriculture. The format of the Groundwater Regulation requires applicants to fill out details on the number of wells and the pumping rate, but this form does not ask about harvested crops or irrigation methods. It is important to know how irrigation agriculture is practised and how much water is used to control irrigation water. The IWRM unit and the directorate should consider how they can work together to integrate the necessary data between the two ministries and how they should collect such data from irrigation farmers.

4) GW Licensing

Recommendations for GW Licensing

- Strengthening the North Kordofan office of the GWWD
- Improving the application format
- Reviewing the application process and the roles of the relevant officers
- Licensing for new wells

4-1) Strengthening the North Kordofan Office of the GWWD

The state GWWD should develop an organizational structure to grant a license and register wells. Only one officer joined the pilot activity from the state GWWD. To continue to grant licenses, the state GWWD should recruit staff and allocate clear roles to them. The state GWWD office covers three Kordofan states but human resources are very limited, without the allocation of new staff for a considerable period of time. The budget from the federal government is also very limited, therefore, there are no computers and no essential equipment for monitoring in the office. The MIWR should consult with the state GWWD on how to strengthen the state GWWD.

4-2) Improvement of the Application Format

The application format should be revised to enable applicants to fill out the application form easily after the pilot activity. The federal GWWD should be flexible with regard to changing the format because this regulation will have no impact if water users do not apply because of difficulties in completing the application form. The federal GWWD officers do not usually communicate with applicants. The opinions of water users and state officers should be reflected when revising the format of the application form. The format should be simple.

4-3) Review of the Application Process and the Roles of Officers Involved

The application process and roles of the officers involved should be reviewed by referring to the experiences of the pilot activity. Unfortunately, officers at locality level were not involved and only one officer from the state GWWD participated in the pilot activity. It is not practical that a limited number of officers from the state GWWD are responsible for issuing licenses for the Bara Aquifer. The IWRM unit should discuss again how to involve officers at locality level and how to cooperate with other departments such as the WES and the rural water supply unit, as they have more staff.

4-4) Licensing for New Wells

The federal and state GWWD should undertake more trial licensing for new wells because the process is more complex than that of existing wells. Providing guidance to the drilling companies who actually drill, is considered to be more efficient and effective than campaigning to the general public. If the drillers who actually carry out the drilling works understand the Groundwater Regulation and abide by this regulation, they can also explain the benefit of licenses to customers.

5) Database

Recommendations for Database Creation

- Dissemination of Bara database model to other states

Dissemination of Bara Database Model to other States

The foundation for three databases has been completed: i) a database of well registrations, ii) a database of monitoring results and iii) a database of well registers. The databases are significant in terms of their use. The well registration database was created in response to the well registration system and is the only database of its kind in Sudan. As well registrations become more widespread, similar databases may emerge, which may cause difficulties with regard to data sharing. To avoid this, the state government C/Ps should collate experiences of using this database, prove its effectiveness and disseminate it to other states. Monitoring results will be inputted into the database to ensure that observation data are continuously being added to the database. As for the well registration, this covers almost all existing wells in the Bara region, and data will be collected regularly from the relevant organizations (WES and MIUD) and added to the database. The purpose of this well inventory is to manage GW in the Bara Aquifer, and the data will be used to check GW availability regularly and to update GW reduction targets.

6.2.3 Bara IWRM Model Application in the Bara Aquifer Area (2nd Step)

The following points should be noted when extending the application of the Bara IWRM Model to the entire Bara Aquifer area.

- The application of the Bara IWRM Model in other areas within the Bara Aquifer area, outside the Al Bashiri Sub-Basin area, would be important because of the high possibility of GW depletion, as well as the need for the overall management of the total GW in the Bara Aquifer area.
- Once the Bara IWRM Model gets on track, the initiative could be expanded to other parts of the Bara Aquifer area outside the Al Bashiri Sub-Basin. Modifications of the Bara IWRM Model, if any, would not be significant because of the similarities in GW resources endowment and the resultant water use pattern. During this expansion process, the areas with a higher risk of GW depletion should be given priority.
- WUCs need to be established in the new areas. These should be designed taking into consideration local conditions such as leadership structure, socio-economic conditions, water resources and the water utilization situation. The selected WUC members should be added to the TC.
- Monitoring is the basis of technical analysis and rational consensus-building, therefore, it is very important under any circumstances. Monitoring should be planned and undertaken, considering the nature of water problems in the area.

- Data collected in the new areas should be accumulated and assembled as a database.
- Water-saving irrigation should be promoted in the areas where GW is used as the water source. The same kinds of experiments, conducted as part of the pilot activities, should be undertaken to identify ways of reducing irrigation water utilization and GW extraction in a manner which is suited to local, natural conditions.
- The GW licensing system should be introduced to areas in the Bara Aquifer where the risk of GW depletion is high.

6.2.4 IWRM Promotion in Other Areas of North Kordofan State (3rd Step)

The following points should be noted when expanding the application of the Bara IWRM Model to other areas outside the entire Bara Aquifer area.

- Expansion of the Bara IWRM Model to other areas will follow. Areas such as the basement rock area and the Nubian sandstone area have different characteristics in terms of hydrogeology and water use due to a scarcity of GW and a higher dependence on SW. The approach in these areas may be closer to the supply-side-oriented approach with a greater focus on the water supply side considerations. The ways in which the government can support water users is different in that hafirs and dams would be the major water source facilities.
- The Bara IWRM model was created for the management of GW resources with a higher focus on demand-side management. While such elements as technical analysis, coordination between sectors and participation of water users could be applied, it is highly likely that the Bara IWRM Model needs modification to suit the local condition, especially in the way in which water users and the state government cooperate with each other. The application of an IWRM model such as the Bara IWRM Model, thus, requires a review of its applicability in consideration of the local conditions and modifications are made accordingly.
- WUCs need to be established in the new areas and should be designed in accordance with local conditions, such as leadership structure, socio-economic conditions, water resources and the water utilization situation. The way in which the WUC could participate in water management would differ from the situation in Bara, as the hafir or dam would be the main source of water for water users where SW is the main water source. In some cases, a common water source facility is shared, as opposed to Bara, whereby many water sources in the form of wells are operated by different water users. Naturally, the way in which the WUC could contribute to better water resources management would differ from Bara. The management of these issues, such as the separation of people and animals and grass-root maintenance of the hafir could be a potential agenda for the WUC.
- Monitoring is the basis of technical analysis and rational consensus-building, therefore, it is very important under any circumstances. Monitoring should be planned and undertaken, considering the nature of water problems in the area. It is envisaged that SW monitoring will be the main activity.
- Data collected in the new areas should be accumulated and assembled as a database.
- The need to promote water-saving irrigation would be limited in this area, as no irrigation takes place by utilizing GW. There may be a need for it where SW is used for irrigation but this is subject to confirmation.
- The need to introduce the GW licensing system would be negligible in this area because of the very limited availability of GW.

6.3 Recommendations on IWRM Promotion in Sudan

6.3.1 Strengthening of the IWRM Promotion Structure at Federal Level

(1) Strengthening of the MIWR's Organizational Structure

<u>Linkage Between the MIWR's Ongoing Initiatives</u>

An institutional structure needs to be established in order to promote IWRM in Sudan. It is proposed that the ongoing initiatives of the MIWR be linked with one another and used as a basis for this purpose, rather than being promoted separately. From a legal perspective, the 1995 Water Resources Amendment Act was passed and publicized in August 2021. This stipulates the revitalization of the NWRC and the functions of the WRTO. From a policy perspective, the Sudan Water Sector Strategy 2021-2031 was launched on 4 October, 2021. It comprises three pillars covering irrigation, water supply and water resources management at national level. These two initiatives are closely related and complement one another, therefore, should be promoted hand in hand.

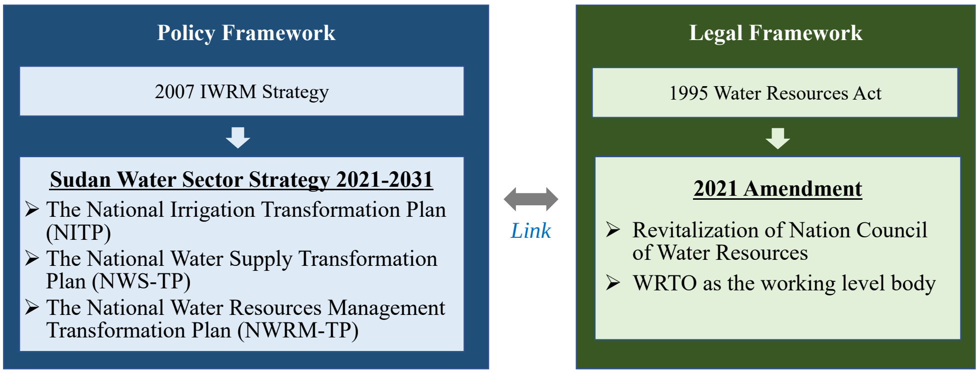


Figure 6.3-1 Policy and Legal Frameworks for IWRM Promotion in Sudan

Among the six functions of the NWRC, two of them are related to IWRM promotion. These are "approval of general policy on water resources" and "approval of a long-term federal program of water resources". The WRTO is in a position to submit a proposal on these two issues to the NWRC for approval. The Sudan Water Sector Strategy 2021-2031, on the other hand, focuses on IWRM promotion in Sudan as the third pillar. The NWRC and the WRTO are in the best position to function as vehicles to implement the Sudan Water Sector Strategy 2021-2031.

<u>Organization Structure for IWRM Promotion</u>

In this vein, the organizational structure shown in Figure 6.3-2 is proposed. Three new units will be created within the WRTO, corresponding to the three pillars proposed by the Water Sector Strategy 2021-2031, one of which is the IWRM unit. The WRTO will play a facilitative and coordinating role and will prepare national policies and programmes by mobilizing the resources of other general directorates within the MIWR and submitting them to the NWRC for approval.

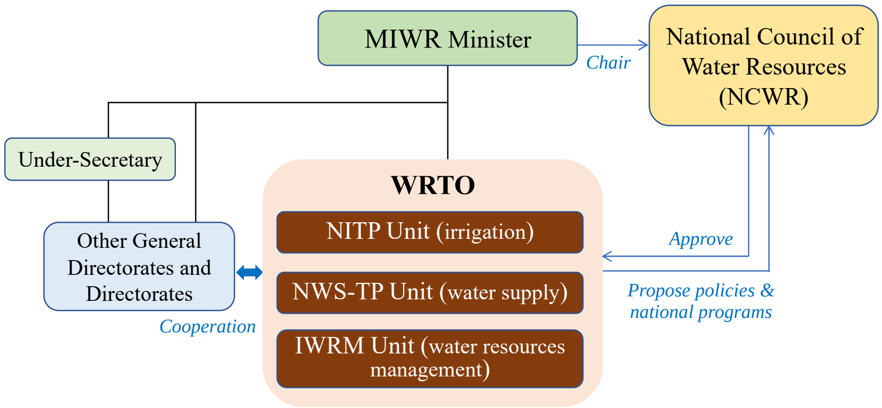


Figure 6.3-2 Proposed Organizational Structure for IWRM Promotion

There are a number of issues requiring coordination and adjustments within the MIWR before this structure is introduced, as shown below:

- The IWRM unit in the Groundwater Basin Department of the General Directorate of Wadi and Groundwater, established in 2012, has been reported to be inactive. It is recommended that the IWRM unit is relocated to the WRTO.
- The demarcation of this body should be clarified between the WRTO and the newly established Partnership and Resource Mobilization Unit (PRMU), in relation to the implementation of the Sudan Water Sector Strategy 2021-2031. The PRMU was in charge of launching the Water Sector Strategy 2021-2031. The WRTO could be responsible for the upstream portion, such as policy, programme and project formulation, whereas the PRMU could be in charge of the downstream portion of mobilizing resources from within and outside Sudan. The two units, needless to say, should work together to disseminate IWRM in Sudan.
- One of the mandates of the Policy and Planning Directorate of the MIWR is to prepare policies and plans for water resources. Its functions seem to be overlapping those of the WRTO, specified in the 1995 Water Resources Amendment Act.
- The MIWR C/Ps who participated in the JICA IWRM Project gained valuable experiences in applying the IWRM approach on the ground. They will be able to provide guidance to their MIWR colleagues in their efforts to disseminate IWRM in Sudan and to the state-level officers in the water sector, when introducing IWRM. They, therefore, should constitute the main body of the IWRM unit.

(2) Revitalization of the NWRC

One weakness in the 1995 Water Resources Amendment Act is the absence of a mechanism in which state representatives directly communicate with the NWRC. The amendment includes the Ministry of Federal Governance as its member, representing all the states, but does not ensure the direct involvement of state representatives. There should be an additional mechanism to ensure good cooperation and coordination between the NWRC, the MIWR、 the WRTO and the 18 state governments. The Sudan Water Sector Strategy 2021-2031 expects "*standardization of oversight, facilitative means and alignment of competencies and policies between federal and state level*" as one of its impacts. An organizational structure, shown in Figure 6.3-3, is proposed to supplement the weakness of the amendment and to strengthen the cooperative relationship between federal and state levels. This mechanism was proposed by the JPT and agreed to by the federal C/P team.

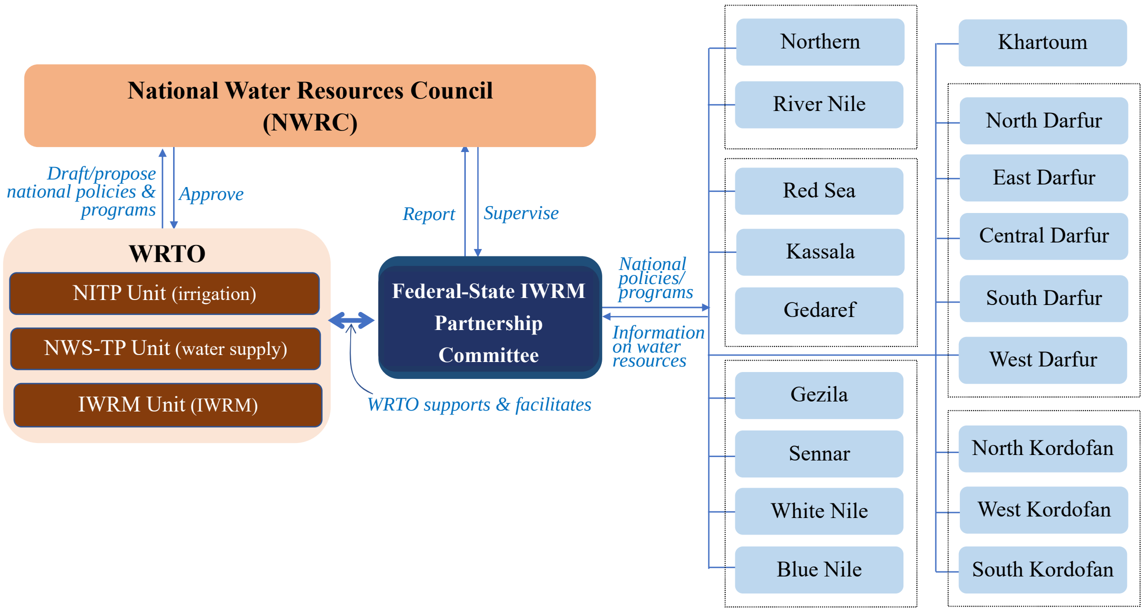


Figure 6.3-3 Organizational Structure to Strengthen the Federal-State Cooperative Relationship

A committee, titled the Federal-State IWRM Partnership Committee is proposed to be established as one of the functions of the NWRC, following the clause in the 1995 Water Resources Amendment Act "*forming specialized committees to assist in performing the NWRC's duties*". The function of the committee is to enable the federal and state representatives to share information on national policies and programmes, as well as the water resources situation on the ground at state level, discuss proposals for the improvement of the water sector and cooperate to implement the agreed measures. The committee meetings could take place twice a year prior to the NWRC meetings. Within this structure, the NWRC and the MIWR will be able to collect sufficient information on the conditions of water resources in each state, which is extremely important when formulating policies and programmes to address the needs on the ground appropriately. The state governments will provide a channel through which information can be transmitted from state level to federal level, ensuring that national policies and programmes are implemented more easily.

6.3.2 Need for Stage-Wise Approach and Action Plan Preparation for IWRM Promotion in Sudan

Stage-Wise Approach

A stage-wise approach is proposed whereby IWRM promotion and the initiation of activities commence in model states first, then are replicated in neighbouring states later. Table 6.3-1 below shows an example of the selection of model states and neighbouring states in each region of Sudan. A step-wide process in this sense would be more practical than trying to initiate the IWRM activities all at once for each of the 18 states.

In the Kordofan region, North Kordofan can take the initiative because of its experience in the JICA IWRM Project. In other regions, the selection of model states and neighbouring states should be carried out carefully, taking account of the historical relationships between the states and the nature of water-related problems: if the application of IWRM is more relevant and can create a model, the state is more likely to commit to the IWRM promotion initiative.

Table 6.3-1 Example of Stage-Wise Promotion of IWRM Activities in Sudan

Region	Model State (Initial Stage)	Neighbor States (Subsequent Stage)
Kordofan region	North Kordofan	South Kordofan
		West Kordofan
Eastern region	A	B
		C
Darfur region	D	E
		F
		G
		H
Southern region	I	J
		K
		L
Northern region	M	N
Capital	Khartoum	-

Creation of an Action Plan for IWRM Promotion

A practical way of initiating the promotion of IWRM in Sudan, under an organizational structure, is to prepare an action plan for IWRM promotion activities. **Figure 6.3-4** shows an example of the promotion of a model IWRM action plan. Items 2. to 9. are to be determined as a result of item 1. They are presented here temporarily to give an overview of the action plan.

Figure 6.3-4 Example of an Action Plan for IWRM Promotion in a Model State

Table 6.3-2 below explains the considerations behind this sample action plan for IWRM promotion.

Table 6.3-2 Considerations behind the Sample Action Plan for IWRM Promotion

Activity	Considerations
Overall	There may be variations in the promotion of IWRM action plans among states, depending on the water resources' situation of each state.
1. Preparation of IWRM action plan/budgeting	An IWRM promotion action plan will be prepared, indicating the types of activities and timings of implementation and budgets.
2. Creation of consensus - building mechanism	The SWRC and the WUC are established and start operating as a forum to share and discuss all IWRM-related issues.
3. Strengthening monitoring system	The compilation of accurate data forms the basis of all the activities, therefore, the monitoring system will be strengthened considerably over the first five years across the entire state.
4. Database creation	The existing data will be integrated into the initial database during the first two years, followed by its expansion to incorporate the results of monitoring in the third year.
5. Preparation of water resources development and the management plan	A water resources development/management plan will be prepared for basins or aquifers considered high priority in the initial two years, utilizing the data compiled in activities 3. and 4. Plans for other basins/aquifers in the state will be prepared subsequently.
6. Introduction of an environmental assessment system	Practical ways to introduce an environmental impact assessment (EIA) and strategic environmental assessment (SEA) will be established first for the high-priority basins/aquifers selected in activity 5. These will be applied to the plans for other areas subsequently.
7. Enforcement of laws and regulations	Three regulations enacted in 2016 for GW, SW and irrigation water control will be introduced on a pilot basis from limited areas. Their application will expand to other areas subsequently.
8. Demand side management	Water-saving irrigation will be initiated on a pilot basis. Its application in other areas will follow with improved methods found through pilot experience. The introduction of a water metering system will be introduced in the major cities during the initial three years.
9. Capacity-building	The WRTO IWRM unit mobilizes the technical resources available within the MIWR as trainers and arranges capacity-building programmes for state officers. The technical support starts with the promotion of an IWRM action plan and extends into each of the specific activities. International resources may be mobilized to support the WRTO IWRM unit.

6.3.3 Recommendations on Strengthening IWRM Promotion Activities and Water Resources Management Activities in Sudan

(1) Support from the WRTO IWRM Unit in Establishing an IWRM Structure Within State Governments

The WRTO IWRM unit will play a key role in supporting and leading the MIWR's initiative to disseminate the IWRM approach throughout Sudan. The core members of the WRTO IWRM unit will be the MIWR's C/Ps, who participated in the JICA IWRM Project for six years. Their experiences in supporting the North Kordofan officers in establishing the SWRC and revitalizing the NWRC would be highly valuable, therefore, should be applied widely. The following section presents the considerations that the WRTO IWRM unit officers should be aware of when supporting state governments in establishing an IWRM promotion structure.

1) Support to Establish the SWRC

The SWRC initiative at state level is proposed to proceed in four steps, as shown in Figure 6.3-5 below:

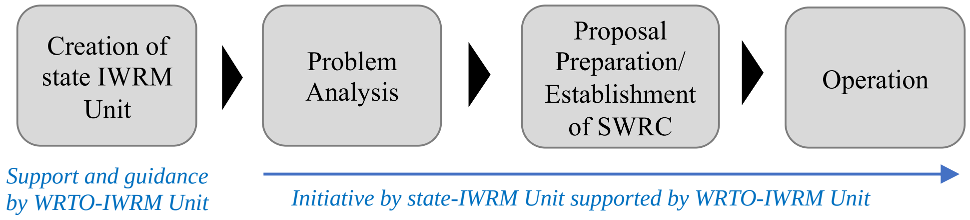


Figure 6.3-5 SWRC Creation Process

Creation of State-Level IWRM Unit

A state-level IWRM unit will be formed initially with the support and guidance of the WRTO-IWRM unit. A group of five to 10 state government officers will be selected as members. The officers of the ministry in charge of the water sector will be the core members, whereas other ministries responsible for agriculture, livestock, forestry, investment and environment will also participate.

The main task of the IWRM unit is to lead the subsequent process of problem analysis, proposal preparation, establishment of the SWRC and initiation of its operation.

The state IWRM unit will be the main focal point for communication with the federal MIWR. The state IWRM unit could request the support of the MIWR for consultation and advice through the WRTO IWRM unit

Problem Analysis

Activities following the establishment of the state IWRM unit will mainly be undertaken by the state IWRM unit with the support of the WRTO IWRM unit. The state IWRM unit will analyse the problems in order to identify water issues within the state, especially those requiring coordination among sectors and participation by users. There could be variations within a state in terms of hydrogeological and water use characteristics. Problem analyses could, therefore, be undertaken for each area with distinctive water characteristics. An overall picture of the water situation in the state could be established, by integrating these problem structures in each area. The types of problems and their inter-relations would clarify which kind of consensus-building mechanism is needed for each area of the state, therefore, providing a broad framework of the SWRC suited to that state.

Proposal Preparation

The state IWRM unit will prepare a proposal on the establishment and management of the SWRC, referring to the results of the problem analysis. The proposal should highlight the objective and functions of the SWRC, structure, membership, frequency of meetings, budget and the official status of the IWRM unit as the secretariat. The following considerations should be taken into account:

(i) *Objective/functions*: the objective and functions of the SWRC need to be defined, based on the problem analysis results. While a general objective could be the promotion of coordination among sectors within a state, with neighbouring states and with the federal MIWR, as well as the participation of water users in water resources management, specific functions may vary from state to state, reflecting the water resources' conditions and the nature of problems requiring coordination. These issues should be considered appropriately when determining the specific functions of the SWRC.

(ii) *Structure*: the state IWRM unit should lead the discussion among the relevant state officers regarding the appropriate structure of the SWRC. There could be opposing views, e.g., in North Kordofan, one individual advocated a single-layer structure, limiting the role of the SWRC to decision-making, while an opposing view supported a multi-layer structure, according to which decisions are made by the SC, whereas working level coordination is undertaken by TC. Both methods are possible, and decisions should be made state by state considering the complexity of the water problem, the level of coordination usually practised and other relevant factors.

(iii) *Membership*: An important consideration in relation to the SWRC is the selection of a chairperson. Certain individuals believe that the governor should chair the SWRC, whereas others advocate the appointment of a minister in charge of water. There are advantages and disadvantages regarding both options. In the event that the governor chairs the SWRC, coordination among sectors will be easier because of the considerable authority of the governor, however, meetings may be held less frequently, as governors are usually involved in all kinds of issues in the state, not specifically the water sector. Appointing a minister in charge of water as chair would mean a lower level of coordination of activities between sectors but a greater availability for meetings. There is no definitive answer and decisions should be made by each state in consideration of the relative importance of the water issues in the state, the willingness of the governor, the balance between the need for a certain level of authority and the level of availability of the chairperson, etc.

The members of the SWRC would not be so different among states. Important stakeholders would include the ministries in charge of water, agriculture, livestock, forestry, the environment, investment, academia and representatives of the WUCs. Their level of engagement in the SWRC, however, may differ from state to state, reflecting the types of available water resources and the nature of the water problem.

(iv) *Frequency*: the frequency of SWRC meetings needs to be determined. In the case of North Kordofan, SWRC meetings are to take place twice a year, whereas TC meetings are to be held four times a year. The frequency of the SWRC meetings was determined to be twice a year, in line with the two typical seasons in the region: the rainy season and the dry season. The TC meets twice more during the periods in between, to share the monitoring results. One important factor determining the frequency of SWRC meetings would be the pattern of seasonal fluctuations of water resources and other natural resource phenomena.

(v) *Budget*: a budget should be finalized as an important element of the proposal. The budget should include costs, such as activity costs (in the case of North Kordofan: monitoring, database creation, GW licensing system introduction, WUC meetings, promotion of water-saving irrigation), the IWRM unit operation cost (salaries), meeting costs (honorarium, lunch, tea) and other costs (stationery, office rehabilitation). Transportation costs, including vehicles and fuel, generally account for a large portion of the activity cost.

It has been proposed that more than one budget option should be prepared to reflect an idealistic budget and a more cost-saving budget. It is often the case that a serious problem for state governments is a chronic shortage of budget. Under such circumstances, it may be sensible to propose a cost-saving budget in order to maximize the possibility of the proposal being approved.

(vi) *Establishment of the SWRC and the IWRM uni*t: whether or not the SWRC proposal is officially approved will be highly affected by the political will in each state. This is out of the control of working-level officers. It is proposed, however, that working-level, water resource-related officers adhere to a bottom-up way of thinking, by which they prepare and propose the SWRC initiative, applying their best knowledge of water issues on the ground for approval by the governor. This approach is in contrast with the widely practised top-down approach, by which the governor makes the decision and his/her staff waits for instructions from above. There is, of course, a limitation to the bottom-up approach, however, this method has potential to increase the likelihood of the proposal being approved.

Operation

A number of points should be kept in mind when initiating and operating SWRC meetings as follows:

(i) *Regularity of agenda*: there should be regularity with regard to the agenda of the SWRC. The agenda should be arranged in such a way that it can be routinely reported on and shared at each SWRC meeting; the sharing of monitoring results and their implications is an example of such an agenda. This kind of routine agenda provides the foundation and other topics can be added as required. This kind of arrangement would enhance the sustainability of SWRC meetings because the state IWRM unit would not need to be concerned about the agenda before each SWRC meeting and would simply update the monitoring results and prepare them to be shared at the SWRC meeting.

(ii) *Continuous water resources management activities and results sharing at the SWRC*: holding SWRC meetings and having discussions alone does not lead to solving water problems. These aspects should be accompanied by other important activities, such as monitoring, database creation, the planning of water resources management, the creation of a regulatory environment and demand-side management. SWRC meetings should constitute an opportunity to share the progress of these activities, discuss them and agree on collaborative efforts for solving water problems. The state government should, therefore, be ready to share information on these issues with the representatives of other sectors and water users. The SWRC is not simply a means of voicing opinions or raising complaints, but a platform where constructive discussions take place.

(iii) *Good time management*: good time management is necessary for each SWRC meeting. Presentations should be summarized so that the participants are able to capture the important points easily and there is sufficient time for discussion. The maximum meeting time should usually be two hours unless there is any special agenda requiring in-depth discussion.

2) Support in Establishing the WUC

Preparation for the Establishment of the WUC

Following the problem analysis by the IWRM unit above, the target area should be decided. Then, an analysis of the socio-economy and stakeholders in the target area should be undertaken. The data and information relating to the target area should be collected in order to understand the society and the economy, as well as the nature of stakeholders involved, by clarifying who uses water for which purpose or whether any conflicts over water exist. In the case of stakeholders, the IWRM unit should first meet officers at locality level, as they usually have information on the local areas and connections with important local figures. It is recommended that the IWRM unit members meet key informants such as traditional leaders, representatives of farmers and pastoralists or women and youth groups, not only to collect information but also to explain the need to create a WUC. There may be difficulties when involving certain social groups, such as women, in culturally and religiously conservative areas. However, the IWRM unit should try to involve such groups, which tend to be excluded from decision-making processes in communities, not necessarily at the preparation stage but after the creation of the WUC.

Establishment and Operation of the WUC

The IWRM unit should discuss the appointment of members to the WUC with identified representatives of different water user groups and social groups. The decision to finalize the selection of members should be taken by the water users and the IWRM unit. Then, the WUC should discuss the following issues.

- ✓ The structure of the WUC, including the important position of chairperson: it is important for the WUC to have a degree of ownership and to depend less on the government.
- ✓ The roles of the WUC: the WUC should function as a body connecting the government and water users, and this should be explained to the WUC members by the IWRM unit. Other roles can be added depending on the water problems that need to be solved and the stakeholders involved.
- ✓ The representatives of the WUC who will attend the SWRC: representatives of the WUC should be selected to work closely with the SWRC in order that water users are involved in the decision-making of the government.

During the first WUC meetings, the government should provide information on water resources and current problems, using scientific data as a starting point, to facilitate an understanding of the current conditions among WUC members and to raise their awareness. The WRTO-IWRM unit should guide state officers on how to prepare easy-to-understand presentations for water users through the use of scientific data. The presentation material prepared during the Project could serve as a good example.

Then, the WUC and the IWRM unit should work together to take practical action to solve the water problems in the target areas, such as how to save water, how to control water use, how to improve the water supply or how to allocate water among different water users' groups.

The results of these practical actions should be analysed and shared in WUC and SWRC meetings, so that next actions can be improved and continued.

Sharing the Experiences of Different WUCs

The structure, roles and actions of each WUC can differ. The WRTO-IWRM unit should collate the experiences of various WUCs and analyse its findings. These should then be shared with other WUCs and the Federal-State IWRM Partnership Committee, so that the WUC and IWRM units in each state can learn from the experiences of others.

(2) Monitoring and Technical Analysis Using the Results

Dissemination of Experiences in Monitoring and Technical Analysis to Other Areas

The valuable experiences of monitoring and technical analysis, accumulated in North Kordofan, should be widely disseminated and shared with other states in Sudan. The WRTO-IWRM unit under proposal can facilitate the sharing of information with different states by taking advantage of the Federal-State IWRM Partnership Committee and supporting individual communication.

Monitoring is the basis for implementing water resource management based on scientific information. As part of the knowledge building process of the C/Ps, they were given guidance on how to use the monitoring results to estimate GW, and how to use this to plan GW management and analyse the safe pumping yield. In addition, a long-term rainfall-runoff analysis was conducted using the wadi monitoring results, and a method to analyse the long-term wadi runoff was presented. The results were synthesized and used to coordinate and operate a facility plan to ensure a sustainable water supply. The pilot activity in North Kordofan State used the results of a “Water Balance Analysis of Phase-1 of the Project”. This can be applied easily in other regions with different hydrogeological and rainfall conditions. It is strongly recommended that other regions in Sudan should use the results of the “Water Balance Analysis of Phase-1”, as in North Kordofan State, with the assistance of C/Ps of the WRTO.

Dissemination of Various Monitoring Methods Including Participatory Monitoring

The experience of participatory monitoring within the pilot activities is extremely valuable. This experience should be widely shared with other states through the new NWRC mechanism under preparation. It is important to share not only the positive side, but also the negative side, such as the limitation in accuracy and the limited applicability in terms of well structure. Nevertheless, there should be many cases in which participatory monitoring could contribute to the awareness raising of well operators and capture the GW situation without advanced and costly technologies.

Two methods of GW monitoring in North Kordofan State were used: participatory monitoring and monitoring with automatic recorders. Participatory monitoring was conducted by the well users themselves, which helped them become aware of the finite nature of GW resources and the need to conserve water. On the other hand, the accuracy of the monitoring remained a problem, which was solved by introducing automatic recorders. Determining which method (or combination of methods) is best depends on factors such as the purpose of well use, well construction, the GW environment and well owner awareness. It has been suggested that the lessons learned in North Kordofan State be used as a guide, enabling other states to plan and implement GW monitoring in a way that involves well users. As in North Kordofan State, GW is declining in many parts of Sudan, due to excessive pumping. GW resources are steadily declining while the actual situation remains unclear. Monitoring should be initiated before it is too late.

Replication of Long-Term Wadi Flow Analysis Throughout Sudan

The experience in North Kordofan in undertaking long-term wadi flow analysis should be replicated throughout Sudan. This is essential especially in terms of overcoming the problem of planning and designing facilities without a technical base, which is the problem often pointed out by water resources' planners and engineers in Sudan.

SW monitoring requires long-term wadi flows to plan for sustainable water use in the wadi. In North Kordofan State, the long-term flow of the wadi was calculated by combining i) four years of measured wadi flows, ii) 32 years of rainfall data and iii) a rainfall-runoff prediction model. This approach should also be used to analyse long-term flows in other regions. This analysis method is easy to use, and the federal C/Ps performed all the analysis. Therefore, the federal C/Ps can provide guidance on this analysis method. In this Project, wadi flows were calculated using long-term rainfall (32 years) for each of the 177 sub-basins in the country. This data can be used in other regions and should be actively used. All data needed for the analysis have already been prepared for all sub-basins in Sudan and can be obtained by contacting the federal C/Ps of WRTO.

Promotion of Conjunctive Use of GW and SW Based on Technical Analysis

Using the results of monitoring in North Kordofan State, the GW and SW potential were calculated and a conjunctive use plan for GW and SW was developed. In Sudan, where the rainy and dry seasons are clearly separated, the conjunctive use of GW and SW is essential for the sustainable use of water resources. However, the need for conjunctive use varies from region to region; the more scarce the water resources, the greater the need for conjunctive use. It has been proposed that the method of assessing water resource availability and the conjunctive use of GW and SW in Northern Kordofan State be used as a reference for other states to develop their own plans.

(3) Water-Saving Irrigation

Promotion of water saving irrigation matched to local conditions with the influence of the Ministry of Agriculture at federal and state levels and facilitation by the WRTO-IWRM unit is required. Similar to the Bara area, some areas irrigated with GW may face the risk of GW depletion. Modern methods such as drip irrigation are a promising option for farmers with financial and human resources to spare, but for many farmers, this is a difficult method to adopt because of its limitations, such as high investment costs, limited applicability of crops and high maintenance cost. On the other hand, customary irrigation methods, such as those found in Bara, can save irrigation water relatively easily.

However, because natural conditions vary from region to region, the amount of irrigation water that can be saved also varies. The expertise of agricultural and irrigation specialists should be mobilized to set water conservation targets for each area where irrigation is practised. It is recommended that the Ministry of Agriculture or Agriculture Directorate in each state and the branches of the Federal Agricultural Research Centre conduct similar experiments and disseminate the results of these with the aim of improving irrigation efficiency in Non-Nile areas.

The WRTO-IWRM unit should provide guidance and advice to state agencies to take such actions. It is recommended to strengthen cooperation between the WRTO-IWRM unit and the Federal Ministry of Agriculture and to carry out awareness activities at federal level, explaining the experiences in North Kordofan, so that the Federal Ministry of Agriculture can work with and guide the Ministry of Agriculture or the Directorate of Agriculture within the states.

(4) GW Licensing System

Based on the 2016 Groundwater Regulation, the following recommendations have been made for the dissemination and establishment of the GW licensing system throughout Sudan. The GWWD of the MIWR is responsible but will be supported by the WRTO-IWRM unit, once it is officially established.

- The MIWR should prepare sufficient human resources, budget and equipment, and establish a support system to facilitate activities at state level.
- The MIWR should integrate state-level hydrogeological information, obtained through the GW licensing system, into a federal-level database, develop guidance materials on the GW licensing system for the states and create a mechanism to check the status of implementation and promotion of the GW licensing system at state level. Data forms, the licensee format and database forms relating to licensing, as well as other assistance, should be provided.
- Lessons learned from the experimental trial in Bara of North Kordofan State should be used by the MIWR to expand the Groundwater Regulation to the other states in Sudan, but a phased rollout is desirable.
- In the future, issuing licenses for new wells could be a problem, and in such cases, well drillers should be given priority over the general public in explaining and educating the public. If organizations such as the WUC are active, awareness-raising through such channels should also be conducted at the same time.
- The well licensing system should not be enforced uniformly throughout the country; priority should

be given to areas where GW levels are declining, due to excessive pumping.

- It is also recommended to prioritize those facilities which use a large amount of water, such as factories and large-scale irrigation farms, then continue with small-scale water users.

(5) Database Creation

Dissemination of the North Kordofan Database Format as a National Model

The sharing of water resource data is fundamental to water resource management. Each agency has its own well database with its own format, in line with the purpose of its activities. However, from the perspective of water resource management, a unified format is desirable. As an example, the IWRM unit of the SWRC in North Kordofan State has created three databases: i) a database of registered wells, ii) a database of the existing well inventory and iii) a database of monitoring data, which the SWRC uses to formulate water resource management policies. The databases of registered wells and monitoring data are the first of their kind in Sudan. A pilot registration of the database has been started in the Bara region of North Kordofan State. The application for wells will be expanded to the whole of North Kordofan State and then to the whole of Sudan. It is recommended that other states use the North Kordofan State database to record and manage information on registered wells. This will allow for easy sharing and the management of data on registered wells in each state. The database for monitoring was also created in North Kordofan State ahead of the other states. It is recommended that the contents, creation methods and operation and maintenance methods of the three databases created in North Kordofan State be used as a reference to create similar databases in other states.

6.4 Further Supports from Donors for IWRM Promotion in Sudan

Taking advantage of the achievements by JICA IWRM Project, it is recommended to provide further support for the capacity building of Sudanese officials in technical and social scientific areas, and at the same time, to strengthen the NWRC-SWRC structure in order to consolidate the foundation of Bara IWRM Model and promotion of IWRM in Sudan.

In addition to technical cooperation, the synergistic effects of assistance can be expected by combining this technical cooperation Project with the financial cooperation necessary for the development of the physical environment, required for the promotion of IWRM, such as the procurement of monitoring equipment.

Table 6.4-1 shows an example of the proposed technical cooperation project outline. The following are points to be noted:

- ✓ Provide both technical and social science support.
- ✓ Select model states for assistance, rather than covering all states
- ✓ Target Non-Nile states as model areas. Non-Nile states are defined as the states through which the Nile does not flow: five Darfur states, Kassala, Gedaref, Red Sea, South Kordofan, West Kordofan and North Kordofan.
- ✓ Consider certain districts through which the Nile River flows, as some districts depend on water sources other than the Nile River.
- ✓ As a basic stance, the international experts will make a TOT to the WRTO-IWRM unit to strengthen their capacity to assist the states.
- ✓ The PRMU, established in 2021, will serve as the international aid window for the MIWR. The WRTO, which is the core of the NWRC-SWRC structure, will cooperate closely with the PRMU to link aid projects with water sector improvements.

Table 6.4-1 Examples of Technical Cooperation Projects Through International Cooperation

Background	The Project for the Enhancement of Integrated Water Resources Management was implemented by JICA from August 2016 to March 2023. In this Project, after conducting a water balance analysis and problem analysis for the entire country, a model for IWRM promotion in Sudan was created, including the establishment and operationalization of the SWRC and the WUC in North Kordofan State. A set of IWRM promotion measures were recommended for Sudan based on this experience. In North Kordofan State, SWRC and WUC activities were undertaken in the Bara area, where GW is the main source of water. Future expansion to other areas with different water source conditions and water use patterns, such as basement rock areas and Nubian sandstone areas, is a challenge. The introduction of advanced technology through international cooperation is expected to accelerate the realization of the proposal by the JICA IWRM Project.
Objectives	(1) Support for the promotion of IWRM in Sudan (2) Support for a state-wide IWRM rollout within North Kordofan State
Activities	(1) Support for the promotion of IWRM in Sudan • Support to strengthen the organizational structure of the WRTO (guidance in setting up and managing the WRTO-IWRM unit) • Preparation of the Sudan IWRM Promotion Strategy • Preparation and operation of the NWRC • Organization and management of the Federal-State IWRM Partnership Committee • Selection of provinces for pilot project implementation (Non-Nile and states other than North Kordofan State) • Support for the establishment and operation of the IWRM structure in pilot states • Capacity-building support for technical and institutional issues in pilot states (monitoring, water balance analysis, conjunctive use of SW and GW, data management, water-saving irrigation, introduction of licensing system, etc.) (2) Support for a state-wide IWRM rollout within North Kordofan State • Development of a state-wide IWRM expansion strategy • Support for SWRC and WUC deployment throughout the Bara district • Support for SWRC and WUC development in the basement rock region • Support for SWRC and WUC deployment in the Nubian sandstone region and Sikeran Wadi Basin
Cooperation period	Five years
Support themes	Institutional organization building, participatory consensus building, legal promotion (GW law, SW law, irrigation law in effect from 2016), monitoring (GW, SW, water quality), water balance calculation, GW/SW conjunctive use, water-saving irrigation, data management
Notes	It is necessary to confirm the availability of the C/P fund on the part of the Government of Sudan.

Chapter 7 Training in Third Countries and Japan

7.1 Training Programmes in the Project

For the capacity development of the C/Ps, the Project has four training programmes as shown in Table 7.1-1.

Table 7.1-1 Training Programmes in Third Countries and Japan

No.	Training Type	Month/Year	Place	Trainee
1	Third country training	May 2017	Morocco	federal C/P
2		October 2018	Tunisia	federal C/P, state C/P
3	Training in Japan	November 2022	Japan-Saijo	1-2 federal C/Ps, 1-2 state C/Ps
4		January 2021	Japan-Kumamoto	another 1-2 federal C/Ps, 1-2 state C/Ps

7.2 Third Country Training

7.2.1 Training in Morocco

(1) Training Course and Objectives

- Training course: basin water resources management for sustainable water use course
- Objectives
    1) To upgrade the knowledge and awareness of the C/Ps on IWRM
    2) To establish independence and strengthen the sustainability of the Project implementation by the Sudanese side

Third Country training in Morocco was planned into the policy, that is, the technology and lessons from the training will be utilized in IWRM in Sudan, and the training should contribute to sustainable water resources management considering the current conditions/situation in Sudan.

Another training objective involved trainees learning the practical technology and knowledge regarding water resources management for independent and sustainable water management. The target trainee will be the person in charge of water resources management after completion of the Project by the government, the community and the main stakeholders.

(2) Time Period and Place

- Training Period: 14 May to 28 May, 2017
- Place: Agadir, Morocco

There are three advantages of training in an African third country. Firstly, the trainee can learn the good practice of independent efforts to improve and solve the problems in another country. Secondly, the training country has similar meteorological and hydrological conditions, including rural/urban supply conditions, such as taking water from GW, wadis and hafirs. Thirdly, trainees in the third country can give lessons in a similar language, taking account of the religion, culture and appropriate engineering technology, and considering the environment, culture, customs and socio-economical background of the community/stakeholders.

Having evaluated the aforementioned advantages, the Project selected Morocco and Tunisia (following programme) as the location for the training.

The training schedule in Morocco is shown in Table 7.2-2.

(3) Participants (Trainees)

The trainees were divided into three groups, as shown in Table 7.2-1.

Table 7.2-1 Trainees and Group

No.	Name	Group	Remarks
1	Dr Ahmed Adam	Group (A)	
2	Mrs Suzan Sedahmed		
3	Ms Safaa Abdel Wahab		
4	Ms Zohaira Mohammed		
5	Mr Mohamed Eldow		
6	Mr Deyab Hussein	Group (B)	
7	Ms Hind Massoud		
8	Ms Marwa Faisal		
9	Mr Ahmed Abdalla		Project translator
10	Mr Abd El Mohsen Hago	Group (C)	
11	Mr Mohammed Eltayeb		
12	Mr Omer Elsunni		
13	Ms Sahar Ahmed		
14	Mrs Hunayda Bakri		JICA Sudan office staff

Table 7.2-2 Training Schedule in Morocco

Date	Time			Form	Contents	Lecturer, Organization	Location
5/14(Sun)	1:55	～	5:25	KRT - DOH	Khartoum - Doha - Casablanca - Agadir (Qatar Airways, Royal Air)		via Doha
	9:15	～	15:25	DOH - CAS	Arriving @ Casablanca		via Casablanca
	19:50	～	21:10	CAS - AGA	Arriving @ Agadir		Agadir
5/15(Mon)	9:00	～	9:30	Opening ceremony	Opening ceremony and Orientation	ONEE, ABHSM	Agadir
	9:30	～	13:00	Introduction / Question	Introduction "Current and Future Water Uses" in Sudan "Overview of water supply (including Hydrological background and etc.)" in Morocco	Sudanese C/P, ONEE	Agadir
	14:00	～	16:00	Introduction / Question	Introduction of general conditions regarding IWRM of both countries: 1) Overview of water supply (including Hydrological background and etc.)	Sudanese C/P	Agadir
5/16(Tue)	9:00	～	14:00	Lecture	Moroccan Rural Water Program - Strategy to achieve general water access, Technical and management adapted approach	ONEE, Agadir	Agadir
	15:00	～	16:00	Discussion / Group work	Explanation of Action Plan considering the IWRM	JPE	Agadir
5/17(Wed)	8:30	～	14:30	Field Trip / Lecture	Waste water retreatment plant for Agriculture water use and water user association / Water distribution station for agricultural water use	ONEE / IEA, Agadir Tiznit	Agadir
	15:30	～	17:00	Lecture	Rural water supply/Master plans and financial aspects - Master plans (Planning, implementation and evaluation of rural projects), financial aspects	Sudanese C/P, ONEE	Agadir
5/18(Thu)	8:30	～	15:00	Field Trip / Lecture	Visit of case study of rural small water production infrastructure (Water User Association, reservoir for irrigation)	ONEE Taroudant, SAEP	Agadir
	16:00	～	18:00	Field Trip / Lecture	Visit of case study of rural small water production infrastructure (Water treatment plant)	ONEE Taroudant, SAEP	Agadir
5/19(Fri)	9:00	～	11:30	Lecture	Rural water supply/Communication and Management approaches Evaluation of the 1st week training by trainees	ONEE, Agadir	Agadir
	11:30	～	13:30	Discussion / Group work	Comparison between the situation in Sudan and in Morocco	Sudanese C/P, ONEE	Agadir
	15:30	～	17:00	Discussion / Group work	Comparison between the situation in Sudan and in Morocco Presentation by 3 groups	Sudanese C/P, ONEE	Agadir
5/20(Sat)		～					Agadir
		～					Agadir
5/21(Sun)	9:00	～	12:00	Group work	Preparation for Action Plans (Divided into 3 teams)	Sudanese C/P	Agadir
	13:00	～	16:00	Group work	Preparation for Action Plans (Divided into 3 teams)	Sudanese C/P	Agadir
5/22(Mon)	9:00	～	10:30	Opening Introduction	Opening remarks by ABHSM, Introduction of general conditions regarding IWRM by Sudanese C/P	ABHSM / ORMVA / Agrotech	Agadir
	10:45	～	13:00	Lecture	Moroccan National water Strategy, Souss Massa Water Master Plan	ABHSM	Agadir
	14:00	～	17:30	Discussion / Group work	Comparison / Discussion / Presentation about "Water strategy and formulation of master plan", Preparation for Action Plans (Divided into 3 teams)	Sudanese C/P, ABHSM	Agadir
5/23(Tue)	9:00	～	13:00	Lecture / Short discussion	Organization and Management of Public Irrigated Perimeters, Collective Reconversion and Localized Irrigation of Perimeters and so on	ABHSM / ORMVA Sudanese C/P	Agadir
	14:00	～	18:00	Field Trip	Visit of Taroudant Area Public irrigated perimeters	ABHSM / ORMVA	Agadir
5/24(Wed)	9:00	～	13:00	Lecture / Short discussion	Water economy and Water management at regional level (Institutional frame work), Discussion about "Water economy and institutional framework"	Agrotech / ABHSM	Agadir
	14:30	～	18:00	Field Trip / Field Trip	Visit of Agadir Area Agro-meteorological network [Agrotech], Visit of Monitoring network, Tachfine Dam and water museum [ABHSM]	Agrotech / ABHSM	Agadir
5/25(Thu)	9:00	～	13:30	Lecture	Water management in Souss Massa Basin, The role of smart telemetry as relevant tool for decision makers, Sous Massa Monitoring network	ABHSM / ORMVA	Agadir
	14:30	～	17:00	Discussion / Group work	Preparation for Action Plans (Divided into 3 teams)	ABHSM, Sudanese C/P	Agadir
5/26(Fri)	9:00	～	12:30	Lecture / Discussion	Moroccan water law, Chtouka groundwater contract Preparation of Action Plans (Divided into 3 teams)	ABHSM, Sudanese C/P	Agadir
	14:00	～	16:20	Presentation	Presentation of Action Plans: Group 1 (14:35 – 15:10), Group 2(15:10 – 15:45), Group 3 (15:45 – 16:20)	Sudanese C/P, ABHSM / ORMVA / Agrotech	Agadir
	16:20	～	17:00	Meeting Closing	Table round (Wrap up / evaluation meeting [of training by Sudanese Trainees]) and diploma ceremony	Sudanese C/P, ABHSM / ORMVA / Agrotech	Agadir
5/27(Sat)	8:50	～	9:55	AGA - CAS	Agadir - Casablanca - Doha - Khartoum (Royal Air, Qatar Airways)		via Casablanca
	13:50	～	23:40	CAS - DOH	Leave for the airport (via Doha)		Doha
5/28(Sun)	8:45	～	12:45	DOH - KRT	Arrive at Khartoum		
		～					

(4) Content of Training: Lecture

The trainer from ONEE-IEA (Institut International de l'Eau et de l'Assainissement under l'Office National de l'Electricité et de l'Eau Potable) and ABHSMD (Agence du Bassin Hydraulique de Souss Massa et Draa) gave the following lectures as shown in Table 7.2-3:

Table 7.2-3 Lectures and Content

No	Lecture	Content
1)	Overview of regarding water supply in Agadir	➢ Meteorological and hydrological background ➢ Cultural and agricultural background regarding water supply
2)	Moroccan Rural Water Program	➢ Strategy to achieve general water access ➢ Technical and management adapted approach
3)	Rural water supply/Master plans and financial aspects	➢ Planning, implementation and evaluation of rural projects ➢ Financial aspects
4)	Communication and Management approaches	➢ Communication / social aspects ➢ Management approaches / water users associations ➢ Operation and maintaining ➢ Recovery and billing ➢ Water User / Irrigation Association
5)	Role of ABHSM	➢ Role of ABHSM ➢ Financial source ➢ Operation and maintenance, database, and monitoring & evaluation ➢ Public relations and information disclosure
6)	Development of the water resources master plan	➢ Development of the water resources master plan ➢ Implementation of the measures based on the Master plan ➢ Role of each organization or agency ➢ Coordination among related organizations / Consensus building
7)	National Agricultural Strategy	➢ Organization and Management of Public Irrigated Perimeter ➢ Management of water resources and economy of agricultural water in the area of Souss Massa ➢ Collective Reconversion and Localized Irrigation of Perimeters
8)	Water economy and management in agriculture and at regional level	➢ Basic principles, advanced technologies and Management ➢ Institutional frame work ➢ Factors affecting water consumption and crop water requirement ➢ Drip irrigation technologies ➢ Holistic management using Soil-Plant-Water continuum ➢ Regional consortium, the example of Agrotech ➢ Agro-meteorological data collection and processing ➢ SMS services via mobile phone technology
9)	Monitoring and Data management	➢ The role of smart telemetry as relevant tool for decision makers
10)	Water low and contract	➢ Moroccan water low ➢ Chtouka groundwater contract

The main purposes and key subjects of training were associated with the “Practical IWRM approach”, “Coordination/cooperation among multi-stakeholders” and “Consensus-building” for sustainable water use. The trainers and the Japanese expert encouraged the trainees to consider, “How to apply the lessons learned in Morocco to the situation in Sudan” and “Picking out the information which can be utilized for the action plan, project activity and ordinary work form a wide variety of training contents”. Moreover, the Japanese expert motivated the trainers and the trainees to ask and think about the applicability to Sudan, depending on the situation in order to promote understanding.

(5) Content of Training: Site Visit

Wastewater Retreatment Plant

The plant is used for agricultural/environmental water reuse, rural water production infrastructure, irrigation reservoirs, water treatment plants and some user associations.
The trainees learned and understood the importance of water users/irrigation association for the efficient operation and maintenance of the water supply facility and how to optimize the limited water resources. Moreover, the trainees understood the importance of public awareness, since each facility has an explanation panel for public awareness, in order to gain the cooperation of local residents and to encourage capacity development for sustainable activity.

Irrigation Reservoir and Irrigation Association/Site of Drip Irrigation/The Tachfine Dam and the Water Museum

The trainees learned and understood the importance of partnership among multi-stakeholders, including the private companies, to optimize and save water and energy for agricultural production and water management. Moreover, the trainees understood the situation regarding the water supply facilities in Morocco and the facility for the public awareness, such as the water museum.

(6) Output

The training output can be seen in the results of the group discussion and the prepared action plan, shown in Table 7.2-4 as follows;

Training Objective 1. To upgrade knowledge and awareness

- ✓ Learning about technology and knowledge relating to water resources management (such as basin management, consensus-building, organizational structure, etc.) from the good practices and lessons in the third countries (case study/individual output)
- ✓ Learning from the comparison with the Sudanese situation (individual output)

Training Objective 2. To establish independence and strengthen sustainability

- ✓ Learning from the comparison with the Sudanese situation (individual output)
- ✓ Making a practical action plan of the IWRM, based on the understanding of the current situation in Sudan and the lessons learned from the training (organizational output)

Table 7.2-4 Training Output (Action Plan)

	Issues in Sudan	Learning in Morocco	Action Plan
Group A	• Social and institutional frameworks	• The water use institutions work at basin level with: - a clear responsibility - good coordination - engagement - transparency • The associations are very active	• The role of federal and state organizations should be clear • Formation of Water User Associations (WUAs) (water supply and irrigation) and the need to capacitate and support them to take up their role of managing and using water efficiently • Awareness campaigns for stakeholders to engage them in participatory work
	• Financial resources	• Their capacities have developed by preparing the requirements of international funding agencies • Private sector involvement in financing is considerable	• Create programmes to develop the capacity of officers for the preparation of documents required by international funding agencies. • Involve the private sector in fundraising • Encourage the private sector to invest in the water infrastructures
	• Scientific research	• Morocco improved water use	• Research findings to be implemented in

	Issues in Sudan	Learning in Morocco	Action Plan
		efficiency and water productivity utilizing the findings of research • Choice of crops depends on the availability of water • Innovative technologies (sensors, etc.) for water saving	water saving • Encourage farmers to adopt the directives of irrigation officers • Elaborate on the implementation of the HRC pilot project of the satellite-based ICT project
Group B	• Capacity development and public awareness (local communities and WUAs)	• More than 15 years' experience • WUAs received training from multi donors (UN, Belgium, Germany and others)	• Initiate WUA • Capacity building for engineers and technicians (SWC and Dam Implementation Unit (DIU) provide training for technicians and local communities) • Adopt a participatory approach in decision-making
	• Difficulties in data acquisition and processing	• Automatic monitoring system which is linked to a server (farmers obtain data through SMS)	• Provide training for technicians, who obtain data from the field • Apply modelling techniques for better results • Suggest the application of an automatic gauging system
	• Budget/funding for water resources management	• Governmental support and agency cooperation • Foreign donors	• Centralize the budget for water resources management • Involve the private sector, NGOs and foreign donors in investments in water projects
Group C	• Raising awareness of community-based management for water supply facilities	• Local communities participate in the management of water supply facilities and collection of tariffs, and are involved in project management	• Establish community associations governed by laws and legislations. 
	• Re-evaluation of water supply situation and community associations	• There are institutions that are responsible for carrying out regular evaluations (e.g., ONNE)	• Establish institutions to evaluate community activities related to water supply.
	• Adopt a bottom-up approach in addition to the top-bottom approach in governance	• A bottom-up approach has been proven to be very successful	• Promote thinking and innovation at community level in finding solutions for challenges

7.2.2 Training in Tunisia

(1) Training Course and Objectives

- Training course: IWRM, Considering Limited Water Resources and Development
- Objectives
  1) To promote efficient management techniques and sustainable water resource use, based on hydrology
  2) To consider efficient farming with regard to water resources management in arid areas, which can be applied to the agricultural sector, the dominant water user in Sudan.

Since Tunisia faces the challenge of water resource limitation and the lowering of GW, the people make an effort to use water efficiently and to utilize non-conventional water resources. These case studies can be

utilized to assume the future water problem in Sudan and to examine the countermeasures for it.
In addition, the Tunisian central government cooperates with the state government (governorate officers) and research institutions to practice IWRM scientifically and in a self-sustaining way. This will contribute to the identification of the appropriate system of water resources management and measures for sustainable IWRM in Sudan.

(2) Time Period and Place

- Training period: 1 October to 10 October, 2018
- Place: Tunis and the surrounding area, Tunisia

Tunisia has different management systems for water resources from Morocco. The Federal Ministry of Agriculture has a responsibility for water resources management for the whole of Tunisia and has centralized control over management. In Morocco, each watershed management office is in charge of water resources management within the river basin. The trainees compared and examined which system (individual river basin management/unified central management) would be suitable/applicable to Sudan considering the situation in Sudan, such as governance with decentralization of power.
The training schedule in Tunisia is shown in Table 7.2-5.

Table 7.2-5 Training Schedule in Tunisia

Time frame	Session - DAY 1 October, 1st	Session - DAY 2 October, 2	Session - DAY 3 October, 3	Session - DAY 4 October, 4	Session - DAY 5 October, 5		Session - DAY 6 October, 8	Session - DAY 7 October, 9	Session - DAY 8 October, 10
08:45-09:30	Opening ceremony MARHP SE-A. Rabhi / Introduction of the programme	Recap Day 1	Recap Day 2	Recap Day 3	Recap Day 4	WEEKEND	Recap Day 5	Recap Day 6	Recap Day 7
Institution/ Trainer	CERTE / Coordinator	CERTE / Coordinator & Trainer	CERTE / Coordinator & Trainer	CERTE / Coordinator & Trainer	CERTE / Coordinator & Trainer		CERTE / Coordinator & Trainer	CERITE / Coordinator & Trainer	CERTE / Coordinator & Trainer
09:30-10:45	Session 1: Water Resources in Sudan	Session 3: Risk assessment and pollution monitoring	Session 5: Water supply (Exploitation, Treatment & monitoring)	Technical Visit: Water Transfer Medjerda-Cap-bon (Aroussia dam to Belli station)	Discussion Session: Comparison of the IWRM situation in Sudan and Tunisia 20-min Coffee break		Session 8: Rural Water Management	Session 10a: Wastewater management and reuse	Technical Visit Cetre Technique des Agruems
Institution/ Trainer	Sudan Participants	ANPE / Samir Kaabi)	SONEDE / Mohsen Kaabi				DGGREE (MARHP) Ridha Gabouj	ONAS Thameur Abdejaoued	
10:45-11:00	Coffee break	Coffee break	Coffee break				Coffee break	Coffee break	
11:00-12:30	Session 2a: Water Resources in Tunisia	Session 2c: Case Studies in Tunisia (surface Water)	Session 6a: Law and regulation frame [Standards]				Session 9a: Irrigation Water saving strategy	Session 10b: Case Study (Treated Waste water valorisation)	
Institution/ Trainer	BPEH (MARHP) / Hamadi Hbaieb	CERTE Sihem Benabdallah	ANPE Slim Daoued	SECADUNord / Ezzedine Bencheikh	Sundanese Participants & CERTE		DGGREE (MARHP) Mme Gharbi Najet	ONAS Thameur Abdejaoued	Cetre Technique des Agruems & CERTE
12:30-13:30	Lunch	Lunch	Lunch	Lunch (cold) 12:30-14:00	Lunch		Lunch	Lunch	Lunch
14:00-15:30	Session 2b: Master Plan for Water Management: History, Challenges	Session 2d: Case Studies in Tunisia (Groundwater Water)	Session 6b: Law and regulation frame [New constitution]	Technical Visit: continue Visit Water treatment plan / SECADUNord ~~Korba Wastewater~~ Plant & Artificial groundwater ~~recharge by treated wastewater~~	Session 7a: Soil and water conservation strategies		Session 9b: Cooperation among Stakeholders / consensus building	Session 10c: Local water management	Conclusion on water management for Sudan
Institution/ Trainer	BPEH (MARHP) / Hamadi Hbaieb	CERTE Feten Horriche	ANPE Slim Daoud		DGACTA (MARHP) / Slah		DGGREE (MARHP) Ridha Gabouj	CERTE Latifa Bousselmi	Sundanese Participants and Tunisian trainers
15:30-15:45	Break	Break	Break		Break		Break	Break	Break
15:45-17:30/ 18:00	Continued: Water Management: History, Challenges and Strategies	Session 4: Governance and Integrity	Session 6c: Law and regulation frame [Water Code]		Session 7b: Soil and water conservation strategies + Case Study		Session 9c: Water reuse	Session 10d: Case Study (Local water management)	Presentation of conclusion on water management for Sudan / Evaluation / Certificate / Closing ceremony
Institution/ Trainer	BPEH (MARHP) / Hamadi Hbaieb	Thouraya Mellah / Latifa Bousselmi	BIRH Lotfi Nacef	SECADUNord / Ezzedine Bencheikh	DGACTA (MARHP) / Slah		DGGREE (MARHP) Mme Gharbi Najet	CERTE Latifa Bousselmi	All the trainees MESRS SE K. Amiri

- CERTE: Centre de Recherches et des Technologies des Eaux (Centre for Water researches and technologies)
- ANPE: Agence Nationale de Protection de l'Environnement Tunisie (National Agency for Environmental Protection)
- SECADU Nord: Société d'exploitation du Canal et des Adductions des Eaux du Nord (Canal and Northern Water pipeline operating company)
- ONAS : Office National de l'Assainissement (The National Sanitation Utility)
- MARHP: Ministère de l'Agriculture, des Ressources Hydrauliques et de la Pêche (Ministry of Agriculture, Waetr Resources and Fishery)
- SONEDE: Société Nationale d'Exploitation et de Distribution des Eaux (National Water Distribution Utility)
- DG-ACTA: Direction Générale de l'Aménagement et de la Conservation des Terres Agricoles (Development and Conservation of Agricultural land)
- MESRS: Ministère de l'Enseignement Supérieur et de la Recherche Scientifique (Ministry of Higher Education and scientific research)
- BPEH: Bureau de la Planification et des Equilibres Hydrauliques (Office of planning and hydraulic balances)
- BIRH :Bureau Inventaire des Ressources Hydrauliques (Water Resource Inventory Office)
- DG-GREE: Direction Générale Du Génie Rural Et de L'Exploitation Des Eaux (Rural Engineering and Water Exploitation / Development)

(3) Participants (Trainees)

The trainees were divided into three groups as shown in Table 7.2-6.

Table 7.2-6 Trainees and Group

No.	Name	Group	Remarks
1	Dr Ahmed Adam	Group (A)	
2	Ms Zohaira Mohammed		
3	Ms Safaa Abd el Wahab		
4	Mr AbdelRahman		
5	Mr Farah		
6	Ms Samar		Project translator
7	Ms Suzan Sedahmed	Group (B)	
8	Ms Hind Massoud		
9	Ms Marwa Faisal		
10	Mr Mohamed Eldow		
11	Mr Abdalla Salah		
12	Mr Eltag		
13	Mr Deyab Hussein	Group (C)	
14	Mr Abd El Mohsen Hago		
15	Mr Mohammed Eltayeb		
16	Ms Sahar Ahmed		
17	Ms Kawthar		JICA Sudan office staff

(4) Content of Training: Lecture

The lectures were given by the Ministry of Agriculture, Water Resources and Fisheries, Agence Nationale de Protection de l'Environnement (ANPE), Centre de Recherches des Technologies des Eaux (CERTE) and others, as shown in the training schedule (Table 7.2-5).

The main purpose and key subjects of the training were "Sustainable water resources management considering the limited water resources and development". The trainees asked questions throughout the lectures and interactive opinion exchanges fostered a deepening of understanding. Moreover, the Japanese expert encouraged the trainers and trainees to ask and think about the applicability to Sudan, depending on the situation, which promoted a greater degree of understanding.

(5) Content of Training: Site Visit

Aroussia Dam, Surface Water Network, Water Treatment Plant

The trainees understood the situation regarding the water supply facilities in Tunisia, such as the nationwide surface water network.

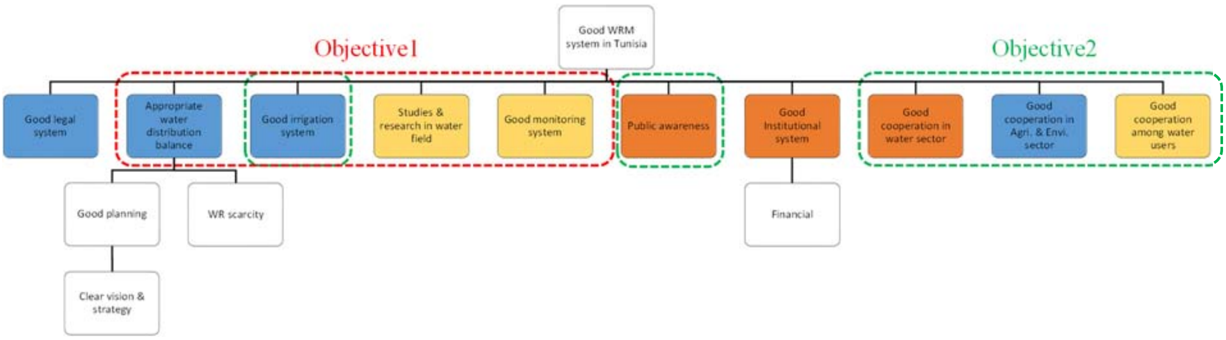
SECADUNord (Canal and Northern Water Pipeline Operating Company)

The trainees visited this company and were given an explanation about their water network operating system. They were also shown around the Water Temple and the aqueduct in Zaghouan, which are the ancient Roman structures to transport water from Zaghouan to Cathage, and the Aghalabid Basins in Kairouan, which were constructed in the 9th century to conserve rainwater. Throughout these visits, the trainees learned about and came to understand the system of water resources management and development in Tunisia.

In addition, the trainees visited Centre Technique des Agruems, which examines the water stress and optimal water usage of citrus plants and learned how the Tunisian people manage the water supply for agriculture and other uses.

(6) Output

In order to discuss the lessons and findings in the training, group discussions were conducted. Regarding efficient water resources management in Tunisia, the 10 key components (refer to Figure 7.2-1) were discussed. Then, a detailed cause analysis of each component, which were allocated to each group, was carried out. In Figure 7.2-1, the blue components were discussed by Group A, the yellow components by Group B and the orange components by Group C.

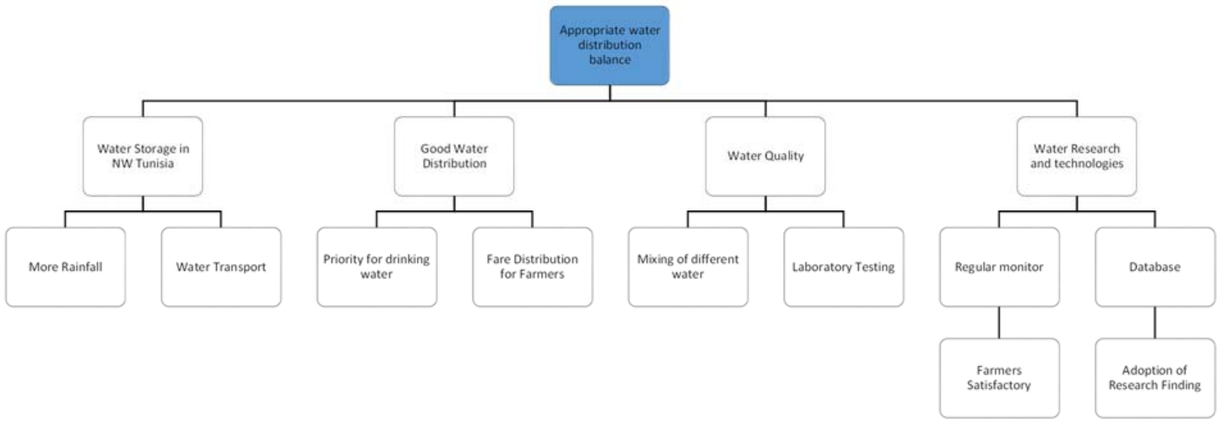


Training objective 1. To promote efficient management techniques

Training objective 2.To consider efficient farming methods in line with water resources management

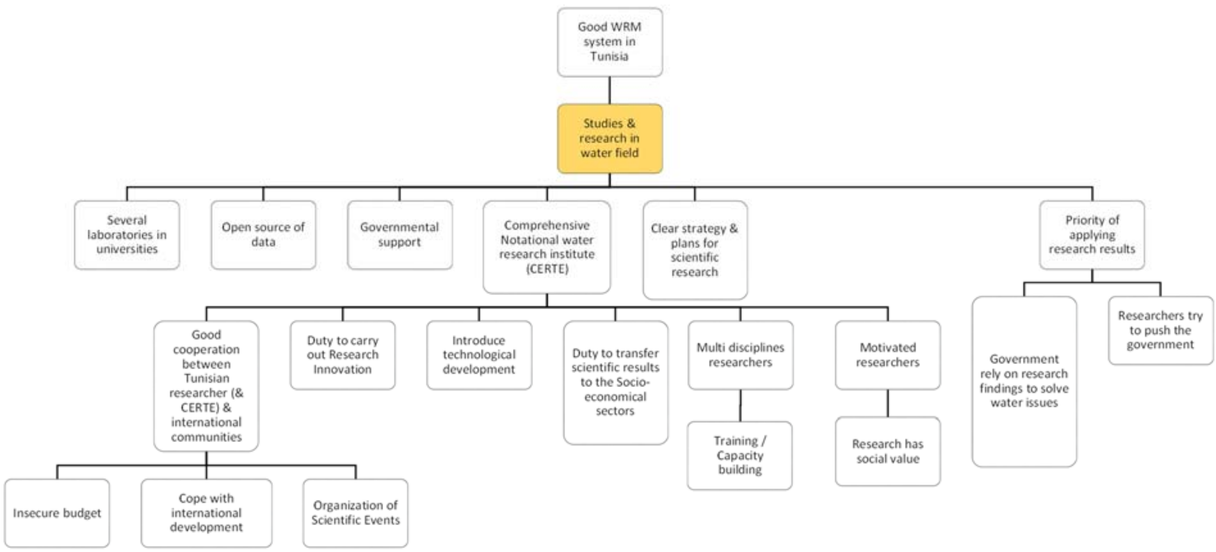
Figure 7.2-1 Major Components of Tunisia Water Management Considering the Training Objectives

Examples of the results of the cause analysis, which were discussed and prepared by each work group are shown in Figure 7.2-2 to Figure 7.2-4. Since some elements of the cause analysis, as well as the recommendations were unclear and required a more detailed examination, the trainees will re-analyse the cause analysis and review the recommendations.



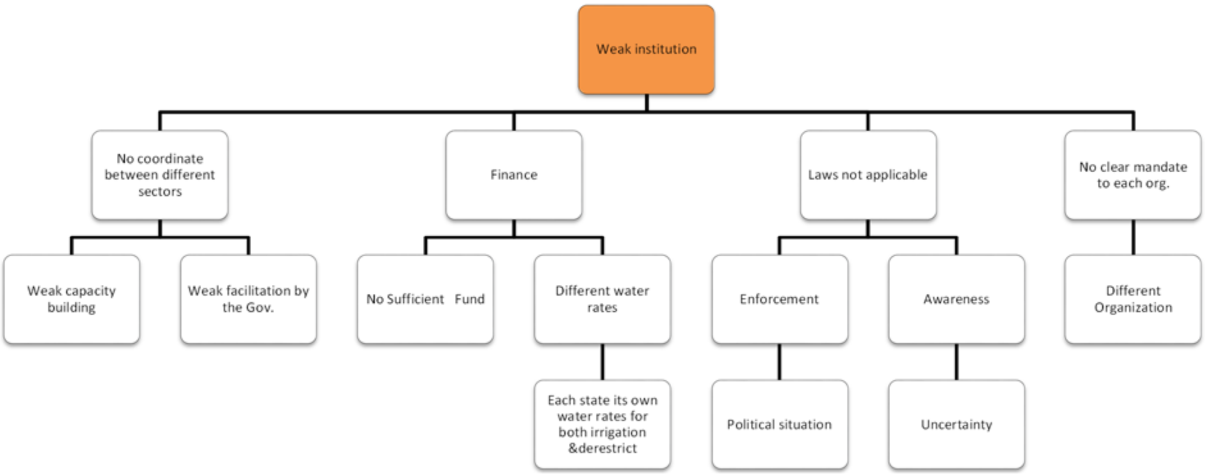
Recommendation for Sudan
• Keep working according to strategies, policies and plans. • Database, regular monitoring, modelling and application of Scientifics research. ➢Raise the awareness of decision maker and farmers of the importantancy of data. ➢Secure budget for monitoring and evaluation. • Revitalizing of National Water Resources Council(NWRC) • Establishment of Water Resources council at state level.

Figure 7.2-2 Example of Cause Analysis and Recommendation by Group A



- In order to solve the problems of difficulty in data acquisition, processing & monitoring we can use sophisticated technology; SMS service by HRC and universities.
- If we would like to improve the situation of insufficient of metrological stations in Sudan we should increase the number of metrological stations, especially in the non-Nile areas and installing devices for GW monitoring. Sudan Metrological Authority by securing international or national funding.

Figure 7.2-3 Example of Cause Analysis and Recommendation by Group B



❖ **Recommendations:**

1-The lows should be applicable
2-Exchange knowledge and experiences between different departments in the all levels centrals, states and international
3-Capacity building for all labors in institutions
4-Depends on the some of technologies in order to progress development
5- Good governance in the our institutions
6-Enhancement of integrated water resource management

Figure 7.2-4 Example of Cause Analysis and Recommendation by Group C

According to the output and evaluation results of the training, the trainees identified many positive aspects of third country training regarding IWRM and they believe that more improvement in the management of organizations and individual capacity in Sudan is required.

7.3 Training in Japan

7.3.1 Background to Japanese Training Planning

The training programme in Japan was planned to promote the pilot activity in North Kordofan State, based on two points; i) Building and strengthening the consensus building / policy making system such as the SWRC, ii) Building and strengthening tools for its functionalization (monitoring, database, formulation of water resources management plans, etc.), all of which have been widely implemented in Japan.

(1) Relationship Between the Activities of the C/Ps and the Content of the Training

When planning the training, the C/Ps consisted of 21 members, 12 from the federal government and nine from the state government. The C/Ps were divided into four groups according to their expertise. This is shown in Table 7.3-1 in comparison with the classification of the pilot activities described in i) and ii) above.

Table 7.3-1 Expertise of C/Ps and Classification of Activities within the Pilot Activities

Group	Expertise	Classification of Pilot Activity	Number of C/Ps (Trainees)		
			Federal	State	Total
1	SW	ii) Building and strengthening tools for its functionalization	3	2	10
	GW/database		3	2	

2	WUC/environment/irrigation water saving	i) Building and strengthening the consensus building/policy making system	3	2	10
	SWRC/well license		3	2	

As shown in Table 7.3-1, the C/Ps were divided into two programmes for the training in Japan, one relating to i) Building and strengthening consensus/policy-making systems and the other for ii) Building and strengthening tools, with training content appropriate for each objective.

(2) Content of Programme

Each training programme consisted of lectures on IWRM and a site visit (see Table 7.3-2).

Table 7.3-2 Content of Programme

Item	Content	City
Lecture	Lectures on IWRM will be given in person or online	Tokyo
Site visit	Saijo City (Group1) and Kumamoto (Group2) were visited after the lecture in Tokyo	Saijo/Kumamoto
Training evaluation	Group discussions were held to collate the results and lessons learned from the training and to express how they could be applied to future activities in Sudan	Saijo/Kumamoto

7.3.2 Training in Saijo (Group1 Programme)

(1) Training Course and Objective

- Training course: Integrated Management of Surface Water and Groundwater
- Objective

  Overall objective: to strengthen the functioning of the SWRC in North Kordofan State through an understanding of the techniques and knowledge of Japanese water resources management.

  Topic:

  1) To understand how water resources monitoring for GW and SW is carried out and how data are used
  2) To understand the content and methods of water balance analysis and how to prepare water resources management plans based on data
  3) To understand the conjunctive use of GW/SW for GW conservation
  4) To understand i) how to implement and evaluate a water resources management plan and ii) how to communicate the plan to the water users

(2) Time Period and Place

- Training period: 7 November to 20 November, 2022
- Place: Tokyo, Shikoku area including Saijo City and the Kagawa prefecture
- The training schedule is shown in Table 7.3-3.

Table 7.3-3 Training Schedule

Date		Time	Format		Theme	Lecturer/Host PIC		Location	Accommodations
						Name	Occupation/Affiliation/Position		
7-Nov	Mon	0:55 ～ 6:30	Move	-	Flight：TK681 (Khartoum → Istanbul)				
		～							
8-Nov	Tue	2:50 19:45	Move	-	Flight：TK198 (Istanbul → Haneda)				
			Move	In-person	Toward Hotel @ Tokyo				Hotel @ Tokyo
9-Nov	Wed	13;00 ～ 15:00	Briefing	Online	Orientation for staying in Japan		JICA Shikoku Center	YEC Headquarter 3F Training Room	
		15:15 ～ 16:30	Orientation	In-person	Orientation for Training/Project	Mr. NAKAMURA Hiroshi and others	JICA Project Team		Hotel @ Tokyo
10-Nov	Thu	9:00 ～ 10:30	Lecture	Online	Integrated Water Resource Management/Governance/Concensus Building	Mr, HAMASAKI Hironori	Associate Professor, Graduate School of Fisheries and Environmental Sciences, Nagasaki University	YEC Headquarter 17F Training Room 17F Conference Room 3&4	
		10:45 ～ 12:00	Lecture	In-person	Role of Government/Municipality/Residents on Water Conservation Policy	Mr. FUJIYOSHI Motō	Executive Director, Japan River Association Nonorary Advisor. Yachiyo Engineerting Co., Ltd.		
		13:30 ～ 16:00	Lecture	In-person	Practice and Problem-Solving of Integrated Water Resource Management	Mr. NAGATA Kenji	International Cooperation Specialist, JICAGlobal Environment. Department		
		16:00 ～ 17:00	Discussion	In-person	Discussion	Mr. NAKAMURA Hiroshi and others	JICA Project Team		Hotel @ Tokyo
11-Nov	Fri	10:00 ～ 12:30	Lecture	Online	Treand and Case Study in Japan: Groundwater Policy by Municipalities	Ms. CHIBA Tomoyo	Osaka Metropolitan University	YEC Headquarter 17F Training Room 17F Conference Room 3&4	
		14:00 ～ 15:30	Lecture	In-person	Groundwater Management by Administration	Mr. MORITA Masaru	Advisor. Yachiyo Engineerting Co., Ltd.		
		15:45 ～ 16:30	Discussion	In-person	Discussion	Mr. NAKAMURA Hiroshi and others	JICA Project Team		
		16:30 ～ 18:00	Lecture	Online	Transboudary Water System and Governance	Mr, HAMASAKI Hironori	Associate Professor, Graduate School of Fisheries and Environmental Sciences, Nagasaki University		Hotel @ Tokyo
12-Nov	Sat				Off day				Hotel @ Tokyo
13-Nov	Sun	13:00 ～ 14:00	Move	-	Toward Haneda Airport			Hotel @ Tokyo	
		14:00 ～ 17:30	Move	-	Flight：JL483 (Haneda → Takamatsu)				
		17:30 ～ 18:00	Move	-	Toward Takamatsu City				
		18:00 ～ 18:15	Move	In-person	Briefing(Check tomorrow's schedule, etc…)	Mr. TAHARA Bunta	JICA Project Team	Hotel @ Takamatsu	Hotel @ Takamatsu
14-Nov	Mon	9:00 ～ 10:30	Move	-	Toward Kagawa Yousui Commemorative Park			Hotel @ Takamatsu	
		10:30 ～ 12:00	Inspection	In-person	History on Kagawa Yousui (Lecture＋Tour)		Director, Kagawa Yousui Commemorative Park	Kagawa Yousui Commemorative Park	
		13:30 ～ 14:30	Lecture	In-person	Wide-Range Watershed Management on Kagawa Yousui		Japan Water Agency	Kagawa Yousui Commemorative Park	
		14:30 ～ 16:30	Move	-	Toward Saijo City				Hotel @Saijo
15-Nov	Tue	9:00 ～ 9:30	Move	-	Toward Saijo City				
		9:30 ～ 10:00	Discussion	In-person	Purpose of training in Saijo City	Mr. NAKAMURA Hiroshi and others	JICA Project Team	SAIJO BASE	
		10:00 ～ 11:30	Lecture	In-person	Water Issues and Ordinance Revision in Saijo City	Mr. TOKUMASU Chikara	Saijo City Officer	SAIJO BASE	
		13:00 ～ 14:30	Lecture	Online	Abstract and Analisys on Groundwater Conservation Management Plan	Mr. TAKASE Keiji	Visiting Professor (Hydology), Ishikawa Prefectural University	SAIJO BASE	
		14:45 ～ 15:00	Inspection	In-person	Inspection on Groundwater Artesian Well (*Uchinuki*)	Mr. TOKUMASU Minoru	Saijo City International Communications Association	Uchinuki Plaza(Behind City Hall, On foot)	
		15:15 ～ 15:45	Inspection	In-person	Groundwater Artesian on Countryside(Inspection on Shuso Plain)	Mr. TOKUMASU Minoru	Saijo City International Communications Association	Shuso Plain	
		15:45 ～ 16:00	Move	-	Toward Hotel, Check tomorrow's schedule	Mr. NAKAMURA Hiroshi and others	JICA Project Team		Hotel @Saijo
16-Nov	Wed	9:00 ～ 9:15	Move	-	Toward Archaeological Museum				
		9:15 ～ 9:45	Inspection	In-person	Observe geographical feature and water sources of Saijo City	Mr. TOKUMASU Minoru	Saijo City International Communications Association	Saijo City Archaeological Museum (Observatory)	
		10:00 ～ 11:00	Inspection	In-person	Use and Conservation of Groundwater by Residents (On foot)	Mr. TOKUMASU Minoru	Saijo City International Communications Association	Aquatopia Water system (Culture hall → City hall)	
		11:00 ～ 12:00	Inspection	In-person	Use and Conservation of Groundwater by Residents (Bus)	Mr. TOKUMASU Minoru	Saijo City International Communications Association	*Kobo* Water→Kamo River Left Bank *Uchinuki* Park	
		13:30 ～ 15:00	Inspection	In-person	·Practive and Evaluation on Groundwater Conservation Plan ·Conflict on Groundwater	Mr. TOKUMASU Minoru	Saijo City International Communications Association	SAIJO BASE	
		15:00 ～ 15:30	Discussion	In-person	Discussion			SAIJO BASE	
		15:30 ～ 16:15	Move	-	Toward Hotel, Check tomorrow's schedule	Mr. NAKAMURA Hiroshi and others	JICA Project Team		Hotel @Saijo
17-Nov	Thu	8:30 ～ 9:00	Move	-	Toward Saijo City				
		9:00 ～ 10:30	Inspection	In-person	Groudnwater Conservation Way①：Prevention of Water Overuse by Citizen(Domestic water・Agricultural Water)		well owner	Well owner house in Saijo City	
		11:00 ～ 12:00	Inspection	In-person	Groudnwater Conservation Way②：Water Intake and Recharge of Kamo River (Irrigation Water)		farmer	Along Kamo River	
		14:00 ～ 14:30	Inspection	In-person	Groudnwater Conservation Way③：Flow Control of Kamo River by Kurose Dam	Mr. NAKAMURA Hiroshi	Project Team Leader, Yachiyo Engineerting Co., Ltd.	Kurose Dam	
		15:30 ～ 16:30	Inspection	In-person	Groudnwater Conservation Way④：Conservation and Management of Reservoir as Alternative Water Resource		farmer	Reservoir in Saijo City	Hotel @Saijo
18-Nov	Fri	9:00 ～ 12:00	Discussion	In-person	Group work, Presentation	Mr. NAKAMURA Hiroshi	Project Team Leader, Yachiyo Engineerting Co., Ltd.	SAIJO BASE	
		13:30 ～ 14:30	Discussion	Online	Evaluation Workshop	Mr. NAGATA Kenji	International Cooperation Specialist, JICAGlobal Environment. Department	SAIJO BASE	
		14:45 ～ 15:15	Discussion	Online	Closing Session	MR. KAJI Takashi	JICAGlobal Environment. Department, Water Resource Group	SAIJO BASE	
		15:15 ～ 16:00	Briefing	In-person	Briefing for travel	Mr. NAKAMURA Hiroshi	Project Team Leader, Yachiyo Engineerting Co., Ltd.	SAIJO BASE	Hotel @Saijo
19-Nov	Sat	10:30 ～ 12:30	Move	-	Toward Matsuyama Airport				
		12:30 ～ 15:50	Move	-	Flight：NH592 (Matsuyama → Haneda)				
		22:50	Move	-	Flight：TK199 (Haneda → Istanbul)				
20-Nov	Sun	～ 6:25	Move	-					
		20:55 ～ 23:55			Flight: TK680 (Istanbul → Khartoum)				Home

(3) Participants (Trainees)

As mentioned in Table 7.3-1, the C/Ps with knowledge of the pilot activity relating to ii) coordinating the tools for its functionalization were selected as trainees for the Group1 Programme. A detailed participant list is shown in Table 7.3-4.

Table 7.3-4 Trainees for Group1 Programme

No.	Organization	Name	
1	Federal	Mr	Mustafa Abdalrhim
2	Federal	Ms	Sahar Ahmed
3	Federal	Ms	Suzan Sedahmed
4	Federal	Mr	Abdalla Salaheldeen
5	Federal	Mr	Mohammed Eltayeb
6	Federal	Mr	Abdelmohsen Hago
7	State	Mr	Mohamed Yousif
8	State	Mr	Farah Adam
9	State	Ms	Mona Mohammed
10	State	Mr	Awad Elradi Bashir

(4) Content of Training: Lecture

The trainees of both Group1 and Group2 attended lectures on IWRM given by researchers with detailed knowledge of IWRM and engineers with administrative experience in water resources management. A summary of each lecture is provided below:

IWRM Practice (Dr Hamasaki)

Dr Hamasaki introduced recent research results on the definition and theory of IWRM. While there is much research on the theory of IWRM, there are few examples of its success in practice. The coupling of practice and theory in IWRM is important. Dr Hamasaki introduced a successful case study of night irrigation in Turkey. In this case study, IWRM was successfully implemented at field level through collaboration between IWRM researchers and local stakeholders. The importance of this success story was reported.

Administration of Water Resources Management in Japan (Lecturer Fujiyoshi)

Lecturer Fujiyoshi covered a wide range of topics, providing comprehensive explanations on water resources management in Japan, the water cycle and governance, river management and the importance of constructing water resources development infrastructures. Previously, Mr Fujiyoshi was an official of the central government in charge of water resources development and management in Japan and was able to introduce the current status of water resources administration in Japan from a perspective close to that of the trainees. The trainees understood the similarities and differences between Japan and Sudan in water resources administration.

Groundwater Ordinance (Dr Chiba)

Dr Chiba explained Japan's GW policy in an easy-to-understand manner. She introduced the historical evolution of the legal status of GW in Japan, then she explained the division of roles between the central government and local governments in GW policy. In this context, she categorized the GW ordinances of local governments throughout Japan into around 50 categories. She explained that the GW issues to be addressed by ordinances and the efforts of local governments differ greatly from region to region in Japan. She also provided a very clear definition of GW governance.

Land Subsidence (Dr Morita)

Dr Morita explained the mechanism and countermeasures for land subsidence. The land subsidence that occurred in Japan's coastal alluvial plains from the early to mid-Showa period was extremely serious. As a result, it had a significant impact on the policy of water resource development in Japan during the following years. The land subsidence triggered restrictions on large-scale GW development for industrial and office use. Instead, SW development became mainstream, and many dams were constructed in various regions.

Environmental Conservation and Development (Dr Nagata)

Dr Nagata introduced the fact that industrial development without regard for the water environment caused serious pollution and constituted a health hazard for the local population. Similar disasters could occur in Sudan if industrial development is carried out without regard for water environment conservation. It was suggested that the decision on whether or not to implement development lies with the trainees themselves, who are in charge of water resource management and development in Sudan.

(5) Content of Training: Site Visit

A site visit was arranged with the Group1 trainees, focusing on the technical findings in the pilot activity. The trainees learned about the conservation, management and use of water resources in the Saijo Plain and the Shikoku area.

GW Management Plan

Professor Takase explained the framework of the GW management plan of Saijo City and its theoretical background of water balance analysis. In the water balance analysis, a tank model connecting river and GW was created and analysed. Using this model, Professor Takase analysed the relationship between river flow, GW recharge rate and GW level in the Kamo River. As a result, the river flow rate of the Kamo River was calculated to prevent the lowering of the GW level and seawater intrusion into the aquifer. This is an example of effective conjunctive use of GW and SW to sustain the water use of Saijo City.

Inspection of Saijo City

Over a period of three days, the trainees inspected Saijo City and the city officials explained the current status of GW management in Saijo City. The trainees understood that the GW management plan of Saijo City is based on the actual status of water resources and water use in Saijo City, as a result of scientific monitoring and analysis.

Artesian Wells in the City

In the Saijo Plain, shallow and deep aquifers are separated by clay layers. GW from wells that penetrate the clay layer and reach the deep aquifer becomes artesian wells, GW flowing to the surface without pumping. The trainees observed such artesian wells at many locations in the city to understand their hydrogeological structure.

Groundwater Ordinance

The trainees were briefed on the GW ordinance of Saijo city. This explanation was followed by a question-and-answer session and the differences between Sudanese and Japanese GW laws were discussed. In Sudan, GW is defined as public water and is managed by the federal government. In Japan, GW is recognized as private water and is managed by the local governments. Since the legal status of GW in Sudan and Japan is different, a simple comparison between the two countries is not possible. The Japanese case study will raise the awareness of the trainees and serve as a reference for the improvement of the GW law in Sudan.

(6) Output

The trainees were divided into two teams and discussed what they learned in the training and what they will do in Sudan (see Table 7.3-5). After the discussion, the team leader gave a presentation on what had been concluded according to the training objective topic from 1) to 4).

Table 7.3-5 Important Lessons Learned from the Training

Topic No.	Lessons and Action Plan Commented on by the Trainees
Topic 1)	In Japan, there are many studies related to water balance, recharge storage and hydraulic structures. Some studies have already taken place in Sudan, however, more detailed studies are still needed. The recharge areas for the basins are not well known, as GW studies in Sudan have not been conducted. We learned about the positive aspects of the monitoring system in Japan such as: 1) Raising the awareness of the committee on the importance of monitoring to secure the allocated budget 2) Establishing an authority responsible for the monitoring and setting up a funding scheme for this purpose We noticed that there is good cooperation between the governments, the private sector and academia in Japan, and we would like to apply this in Sudan.
Topic 2)	In Japan, the water resources management plan is set based on the water balance analysis. In Sudan, a limited number of studies have been conducted and none of these studies quantified any of these components of the water cycle. We will establish the water balance analysis for SW and GW in North Kordofan State (Bara Basin, Al Bashiri Aquifer and Sikeran Wadi) and formulate a plan for water resources management based on the existing studies. We will implement a strategy with the different entities concerned and will share it with the stakeholders, involving local communities in the planning process and establishing the cooperation of the local communities as regards protecting and sustaining the water resources
Topic 3)	Similarities exist between Saijo and El Obeid in terms of using GW and the SW. We are thinking of increasing the capacity of the hafirs in North Kordofan and making better use of them, by applying what we learnt from the Japanese experience in this field (Saijo and elsewhere). In Saijo there are different committees for water users, but in Sudan, we do not have such committees. However, thanks to the JICA IWRM Project, initiatives have been undertaken recently to implement such committees. In the future, we are planning on activating a WUC and making good use of it in water resources management, as is the case in Saijo City.
Topic 4)	We can make the best use of the SWRC and WUC by establishing a complementary relationship between these two entities to better manage the water resources of North Kordofan State. In order to prevent conflicts within the SWRC and the WUC, the government needs to provide authority to these committees. Regarding monitoring, we need to implement technology programmes in this context. Implementing short- and long-term strategies for the state to make the best use of the monitoring results is a necessity.

7.3.3 Training in Kumamoto (Group2 Programme)

- Training Course: Functionalization of a Multi-Stakeholder Partnership and Promotion of Public Participation in Groundwater Management
- Objective
  Overall objective: to strengthen the functioning of the SWRC in North Kordofan State by understanding the techniques and knowledge of Japanese water resources management (same as Group1 Programme).
  Topic:
  1) To understand the roles and responsibilities of government at different administrative levels and how to coordinate various administrative organizations.
  2) To understand how to involve and collaborate with stakeholders (especially irrigation farmers)
  3) To understand the management method of the Kumamoto Groundwater Foundation (KGF), which has the same function as the SWRC, including the securing of a budget.
  4) To understand how to make the management of water resources more effective on the part of local government, such as the establishment of ordinances for GW management and conservation, the implementation of GW management plans, etc.

(2) Time Period and Place

- Training Period: 15 January to 29 January, 2023
- Place: Tokyo, Kumamoto area including Kumamoto City and Aso City
- The training schedule is shown in Table 7.3-6.

Table 7.3-6 Training Schedule

Date	Time			Format		Theme	Speaker/Person in Charge		Location	Accomodation
							Name	Affiliation, Position		
15-Jan(Sun)	18:10	～	21:00	Move	－	Flight：ET347 (Khartoum → Addis Ababa)				
16-Jan(Mon)	23:55	～	12:40	Move	－	Flight：ET608 (Addis Ababa → Bangkok)				
17-Jan(Tue)	22:50	～	6:30	Move	－	Flight：ET1403 (Bangkok → Haneda)				
				Move	－	Move to Hotel in Tokyo				Hotel Mystays ASakusabashi@ Tokyo
18-Jan(Wed)	10:00	～	12:00	Briefing	Online	Orientation; Staying in Japan		JICA Kyusyu	YEC Headquarter 17F 171 Meeting Room	Hotel Mystays ASakusabashi@ Tokyo
	13:30	～	14:30	Orientation	Facing	Training and project orientation	Nakamura,etc	Expert Team		
19-Jan(Thu)	9:30	～	12:00	Lecture	Facing	Groundwater Issues and Manegement	Mr.Morita	YachiyoEngineering.Co Advisor	YEC Headquarter 17F 171 Meeting Room	Hotel Mystays ASakusabashi@ Tokyo
	13:30	～	15:00	Lecture	Facing	River and Water Resources Administration in Japan	Mr.Fujiyoshi	YachiyoEngineering.Co Advisor		
	15:00	～	16:00	Discussion	Facing	Discussion	Nakamura	YachiyoEngineering.Co		
20-Jan(Fri)	9:30	～	12:30	Lecture	Online	Groundwater Policy in Japan	Mr.Chiba	Osaka Metropolitan Univ	YEC Headquarter 17F 171 Meeting Room	Hotel Mystays ASakusabashi@ Tokyo
	14:00	～	15:15	Lecture	Facing	Discussion	Nakamura,etc	Expert Team		
	15:45	～	17:00	Discussion	Facing	Integrated Water Resources Management Practices	Mr.Nagata	Global Environment Division, JICA International Cooperation Specialist		
21-Jan(Sat)					－	Holiday				Hotel Mystays ASakusabashi@ Tokyo
22-Jan(Sun)	10:00	～	10:50	Move	－	Move to Haneda Airport				ARDEN Hotel Aso
	12:45	～	14:40	Move	－	Flight：JAL631 (Haneda → Kumamoto)				
	15:00	～	15:50	Move	－	Move to Aso				
	16:00	～	16:15	Move	Facing	Briefing (confirmation of next day's schedule, etc.)	Tahara	YachiyoEngineering.Co	ARDEN Hotel Aso, Lobby	
23-Jan(Mon)	9:00	～	12:00	Lecture	Online	integrated water resources management and governance and consensus building, Transboudary water and governance	Mr.Hamasaki	Nagasaki Univ	ARDEN Hotel Aso, Conference room	ARDEN Hotel Aso
	13:00	～	13:30	Discussion	Facing	Objective and schedule of field training, distribution of materials	Nakamura	YachiyoEngineering.Co		
	13:30	～	15:00	Lecture	Facing	Japanese and water, Kumamoto area water	Prof. Oshima	(Former) Deputy Mayor of Kamitamakusa City		
	15:15	～	16:30	Lecture	Facing	Current status and issues of groundwater administration in Kumamoto Prefecture (comprehensive groundwater conservation plan, etc.)	Eguchi assistant manager	Kumamoto Prefecture Environmental Promotion Division		
24-Jan(Tue)	8:30	～	9:00	Move	－	Bus guide	Ijima	YachiyoEngineering.Co	Inspection	ARDEN Hotel Aso
	9:00	～	9:50	Inspection	Facing	Aso and its surrounding topography (from Daikanbo)	Prof. Oshima	YachiyoEngineering.Co		
	10:40	～	11:30	Inspection	Facing	Inspection of Aso Volcano (groundwater structure)	Mr.Toyomura	Curator, Aso Volcano Museum		
	12:00	～	13:00	Lunch	－	Halal Restaurant @ Kusasenri				
	13:00	～	15:00	Inspection	Facing	Aso Volcano Museum (spring water mechanism and conservation activities)	Mr.Toyomura	Curator, Aso Volcano Museum		
	15:00	～	16:00	Move	－	Summary of today's events and tomorrow's schedule	Nakamura	YachiyoEngineering.Co		
25-Jan(Wed)	8:30	～	9:00	Move	－	Bus guide			Morning: Inspection Afternoon: Otsu Town Hall, Conference Room One chapel room is reserved	GreenRichHotel@ Kumamoto
	9:00	～	10:20	Inspection	Facing	Shirakawa River water source (environmental conservation, irrigation)	Ijima	YachiyoEngineering.Co		
	10:20	～	11:10	Move	Facing	Move to Otsu (travel time: 50 minutes)				
	11:10	～	11:40	Inspection	Facing	Winter-flooded rice fields (groundwater conservation by farmers)	Mr.Kira	Chairman of the Maki Winter Waterlogging Project Council		
	12:00	～	13:00	Lunch	－	Otsu Town Hall, Conference Room				
	13:00	～	16:00	Discussion	Facing	Theme: Healthy Water Cycle and Efforts to Conserve the Water Environment (Role and Challenges of the Groundwater Foundation)	Director General Katsuya, Groundwater Foundation (Participation by the Environmental Conservation Division of the Town of Otsu)	Kumamoto Groundwater Foundation		
	16:00	～	16:20	Move	－	Fill out to prepare for evaluation meeting				
	16:20	～	17:00	Move	－	Summary of today and tomorrow's schedule(in the car)				
26-Jan(Thu)	8:50	～	9:00	Move	－				Inspection	GreenRichHotel@ Kumamoto
	9:00	～	11:00	Inspection	Facing	Facilities Related to Water Operation Center Kengun water source (well)	Mr. Makihara(Chief Director) Mr. Kuroki	Planning and Public Relations Team, Management Planning Division, General Affairs Department, Kumamoto City Water and Sewerage Bureau	Kumamoto City Water and Sewerage Bureau 6th Floor →Kengun Water Source	
	11:00	～	13:00	Lunch	－	Parking at Kumamoto City Hall, Lunch			Kumamoto City Hall Conference Room	
	13:00	～	14:30	Discussion	Facing	Kumamoto City Hall Lecture: Kumamoto City Water Administration	Mr.Kanayama(Chief Executive Officer)	Kumamoto City Water Conservation Division		
	14:40	～	16:30	Inspection	－	Walking from City Hall Tour of Kumamoto Castle and commemorative photo			Kumamoto Castle	
27-Jan(Fri)	8:30	～	9:00	Move	－	Today's Training Schedule				GreenRichHotel@ Kumamoto
	9:00	～	9:30	Inspection	Facing	Water Science Museum (Public Information and Awareness Facilities) Introduction and Tour of Facilities	Mr.Sakata	Water and Sewerage Bureau Water Science Museum Deputy Director	Water Science Museum	
	9:30	～	10:30	Lecture	Facing	Summary and Recommendations	Prof. Kojima			
	10:45	～	12:00	Discussion	Facing	What we learned in this training	Nakamura			
	13:00	～	14:00	Discussion	－	Evaluation board	Mr.Kaji	JICA HQ		
	14:00	～	14:30	Discussion	－	Completion Ceremony	Mr.Nakatsukasa	JICA Kyusyu		
	14:45	～	15:45	Discussion	－	Project Orientation for next SWRC	Mr.Yamane	JICA Project Team		
	15:45	～	16:15	Move	－					
	16:15	～	16:45	Inspection	－	Courtesy visit to Kumamoto Groundwater Foundation office	Hashimoto Section Chief		Kumamoto Groundwater Foundation office	
28-Jan(Sat)	8:15	～	9:00	Move	－					Checkout
	11:00	～	12:30	Move	－	Departure at Kumamoto:11:00 - Arrival at Haneda:12:30, NH0644				
	12:30	～	15:30	Move	－	to Narita				
	18:40	～	0:05	Move	－	Flight：ET1411 (Narita → Bangkok)				
29-Jan(Sun)	1:35	～	6:05	Move	－	Flight：ET629 (Bangkok → Addis Ababa)				
	9:35	～	10:25	Move	－	Flight：ET344 (Addis Ababa → Khartoum)				

(3) Participants (Trainees)

The C/Ps with knowledge of the pilot activity i) Building and strengthening the consensus building/policy making system were selected as trainees for the Group2 Programme. A detailed participant list is shown in

Table 7.3-7.

Table 7.3-7 Trainees for Group2 Programme

No.	Organization	Name
1	Federal	Mr Elmagzoub Ahmed Taha
2	Federal	Ms Zohaira Mohammed
3	Federal	Ms Hind Massoud
4	Federal	Ms Safaa Abdelwahab
5	Federal	Ms Marwa Faisal Salman
6	Federal	Mr Siddig Alkhateeb
7	State	Mr Muawia Adam
8	State	Mr Ibrahim Yagoub
9	State	Mr Mozamil Abdalla
10	State	Mr Mohamed Ajaban

(4) Content of Training: Lecture

Lectures were conducted using the same content as the Group1 Programme.

(5) Content of Training: Site Visit

GW Recharge from Rice Fields

In the Kumamoto Plain, GW is recharged from rice fields. In recent years, the number of rice fields has decreased due to the decrease in rice consumption. As a result, the GW recharge from paddy fields has decreased and GW levels have declined. This is one example of the way in which social and economic changes affect the availability of water resources. Kumamoto city established the KGF and the government, companies and citizens worked together to solve the problem. One of the measures to solve the problem was to promote GW recharge from the rice fields during the winter season. In addition, citizens were encouraged to consume local agricultural products, as agricultural promotion in GW recharge areas contributes to GW recharge.

Fund for the Operation of the Groundwater Foundation

The KGF was established by integrating three organizations that had previously worked separately into one. As a result, the KGF has been able to effectively promote GW conservation policies. The operating funds of the KGF are provided by the Kumamoto Prefecture, 11 municipalities, private companies and citizens. The KGF conducts four activities to conserve GW, as shown below:

i) visualization of GW flow

The key to building consensus among stakeholders is the sharing of scientific data. Based on this idea, a database of GW level observation is compiled, visualized in an easy-to-understand manner and available to the public. In addition, the results of GW flow analysis, which cannot be directly observed, are visualized and introduced to the public.

ii) recharge GW from the rice field

iii) conserve water quality

Fertilizers and livestock production tend to increase the nitrogen concentration (NO_3) in GW. Rice cultivation is recommended because of the denitrification effect of paddy fields.

iv) promote public awareness

Public awareness is needed to promote GW conservation among citizens. The KGF recommends activities such as essay competitions on water conservation for elementary school students and holiday farm work in rice paddies for citizens.

(6) Output

The trainees were divided into two teams and discussed what they learned during their training and what they will do in Sudan (see Table 7.3-8). After the discussion, the team leader gave a presentation on the conclusions of the training, according to the training objective topics from 1) to 4).

Table 7.3-8 Important Lessons Learned from the Training

Topic No.	Lessons and Action Plans Commented on by the Trainees
Topic 1)	There are different regulations at different levels for GW management. At government level, regulations are introduced, then the municipalities adapt the regulations depending on the characteristics of the region. This is due to the heightened awareness of people who believe that water brought by the volcano is the source of life and needs to be protected.
Topic 2)	In Japan, there is cooperation and coordination between the different entities and awareness is high, due to the efforts made by those entities, such as including water education in schools from an early age. Efforts are even made at local level, as farmers are involved in maintaining GW levels by using rice fields to help increase the recharge of aquifers. In Sudan, there are regulations at government and locality levels. However, these regulations are not completely adopted by the different committees and awareness is not high. At state level, we will use the established committees to convince the stakeholders, who need to be involved, of the need to raise awareness using the media and other means.
Topic 3)	The operation of the KFG and the way in which it manages and allocates its budget was understood. The function of the KFG in managing GW resources through the different regulations was also learnt. Based on its long-term efforts since 1977, the KFG has formulated action plans and established committees in which there is coordination at different levels. Following the activity of the KFG, it is important to reproduce the regulations and impose tariffs, which will be dedicated to the SWRC activity.
Topic 4)	As a result, we realized that there are similarities between Japan and Sudan in terms of water problems. In Japan, the awareness is high, and regulations are set for each municipality, depending on the characteristics of each location. In Sudan, there is a law that has been implemented by the federal government to organize the GW sector. However, there is no coordination between federal and state levels. We should organize coordination between these two sides. A lesson learnt is that Sudan has similar problems to Japan, but Japan has acted differently. The Japanese have implemented an effective management strategy for GW use, making efforts to reach their goals which should be replicated in Sudan.

Chapter 8 Strategic Environmental Assessment

8.1 Environmental Laws and Policies

8.1.1 Environment Protection Act (2001)

(1) Outline of the Act

The EPA (2001) replaces the HCENR Act of 1991. In its present state, the EPA only stipulates the role of certain authorities and the responsibility of the competent organizations, so it will need to be amended and revised to add the specified items which is expected to deal with comprehensive issues of the environment in much more detail. As of September 2017, the amendment and revision have been completed according to the Ministry of Environment. However, it is not yet published.

As specifically described in the act, the HCENR has the function of drawing up general policy on natural resources, in coordination with the competent authorities, including the development and rationalization of the environment's use, management and protection from deterioration.

(2) Environmental Objects

This act sets outs the environmental objects that the competent organizations should achieve;

- ✓ Protection, purity, natural balance and preservation of the basic elements of the environment, and related social and cultural systems, for the benefit of current and future generations
- ✓ Promotion of the environment, and the rational and sustainable use of natural resources, for the purpose of development and conservation
- ✓ Facilitation of a link between environmental and developmental issues
- ✓ Clarification of the responsibility of the competent authority for the protection of the environment and the serious efforts needed to achieve such protection
- ✓ Activation of the role of the competent authority and the organizations under its remit, as well as the prevention of poor and ineffective performance

(3) Penalty on Contravention

Regarding the water sector, the source of deterioration and contamination is specifically described, namely, the pollution of water sources (such as rivers, seas, lakes, ponds, channels, canals, courses, and natural and artificial water storage and reservoirs) where water is kept for human and animal use (Section 20). Whoever contravenes the provisions of Section 20 shall except to be punished with either a prison term not exceeding three years or a fine, or both. The court may, in cases of conviction, partially or totally suspend the project, establishment or site that is the source of the contravention, or even totally or partially revoke the relevant license.

8.1.2 Integrated Water Resources Management Policy and Strategy (2007)

This strategy was developed by MWIE in 2007. Three particular sections of this strategy deal with the main policy areas related to the environment:

(1) Environmental Protection and Conservation

The policy on environmental protection is to ensure environmentally sustainable development by integrating and strengthening environmental values, as well as taking them into account in the context of water resources planning, management and development. Furthermore, there is a strategy to materialize policy for environmentally sustainable water resources management by maintaining reserve flow levels in reservoirs and rivers at all times in order to protect biodiversity, sensitive environments and important species in the ecology and socio-economy. In particular, as a possible solution, the application of an EIA, and the control of the over-exploitation of SW and GW resources and water quality, are suggested. The activities related to this strategy are described below:

- ✓ Prepare environmental management, protection and implementation plans to protect ecosystems, fight pollution, weeds and hyacinth, control sedimentation in the tributaries, reservoirs, canals, inlets, and manage hazards related to water
- ✓ Carry out a survey of and map critical water bodies for environment conservation
- ✓ Enforce the EPA (2001)

(2) Water Quality and Pollution Control

The policy in this section emphasizes the importance of the formulation of standards and guidelines for the disposal of undesirable elements in water. It also calls for regular reviews of water abstraction and disposal licenses, as well as the introduction of effluent discharge levies as instruments of pollution control. The level of the levies should be set in order to cover the costs of treatment required to deal with individual effluent discharges in line with the principle that the polluter should burden the costs on their own (the so-called ‘polluter-pays principle’). The related strategies are given below:

- ✓ Establish effective water quality and effluent discharge standards and guidelines and an enforcement system for water quality and pollution control
- ✓ Strengthen the capacity to monitor and enforce water quality and waste water discharge standards
- ✓ Ensure the implementation of related activities for classifying water bodies according to quality
- ✓ Raise awareness of the effects of pollution

(3) Disaster Management: Floods, Droughts and Erosion

Ensuring effective flood, drought, desertification and erosion management through sustainable water resources management should reduce vulnerability to climate change and water-related natural disasters. Disaster management for floods and erosion is divided into soft measures and hard measures. Delaying surface runoff, implementing appropriate land use management and raising awareness of vulnerable areas are suggested as soft strategies. Meanwhile, developing infrastructure is categorized as a hard measure.

Drought and desertification pose much higher risks than other disasters and are deeply related to the water sector. Strategies for the prevention and mitigation of drought and desertification are described below.

- ✓ Undertake watershed management activities so as to improve soil infiltration and GW storage
- ✓ Put in place an advisory services system for drought-prone areas in order to increase resistance to drought effects, particularly in relation to borehole drilling for water supplies
- ✓ Develop long-term strategies for the planning and construction of infrastructure to increase the per capita storage of water in arid areas and ensure food security

8.1.3 Sudan Post-Conflict Environmental Assessment (2007)

(1) Outline of the Environmental Assessment

The Sudanese Government requested the UNEP to conduct a post-conflict environmental assessment of Sudan. The goal of the assessment was to develop a solid technical basis for medium-term corrective action in the field of environmental protection and sustainable development. The post-conflict environmental assessment process for Sudan began in late 2005, beginning with an initial appraisal and scoping study, while fieldwork was carried out between January and August 2006. The parties involved also interviewed and consulted, among others, representatives of federal, state and local government, NGOs, academics, community leaders, farmers, pastoralists, foresters and businesspeople.

(2) Review of the UNEP assessment

The UNEP assessment report covers a wide range of environmental impacts in Sudan. In particular, it states that both existing and planned dams offer enormous potential for developing the economy, while also contributing to further environment deterioration. For instance, the movement of sand and sediment deposition caused by existing dams are the most significant consequences for the ecosystem and sustainable environmental management of the downstream areas.

This assessment suggests that environmental concerns, including desertification, may exacerbate any conflict in Sudan. As conflict and environmental issues are therefore closely related to each other, the IWRM project should ensure that protecting the environment is given the highest priority.

The lack of solid methodology for environmental management is a significant concern in Sudan, given the scale of natural resources and cultural heritage. As their protection is closely related to the water sector, this should be managed carefully alongside the preservation of fresh water.

8.2 Environmental Impact Assessment Process in Sudan

The conduct of an EIA in Sudan for projects that have potential environmental and social consequences is required under the EPA (2001). However, after more than a decade since its enactment, it remains uncertain whether it is being correctly operated, as it is assumed that EIA procedures and guidelines are not being issued and made available to regulators at all levels of governance, sector ministries, project developers/owners, and EIA drafters and practitioners. Figure 8.2-1 describes the EIA administrative process in Sudan. In Sudan, the structure of ministries, including their names and responsibilities, are likely to be changed. Therefore, it is necessary to constantly obtain the latest information.

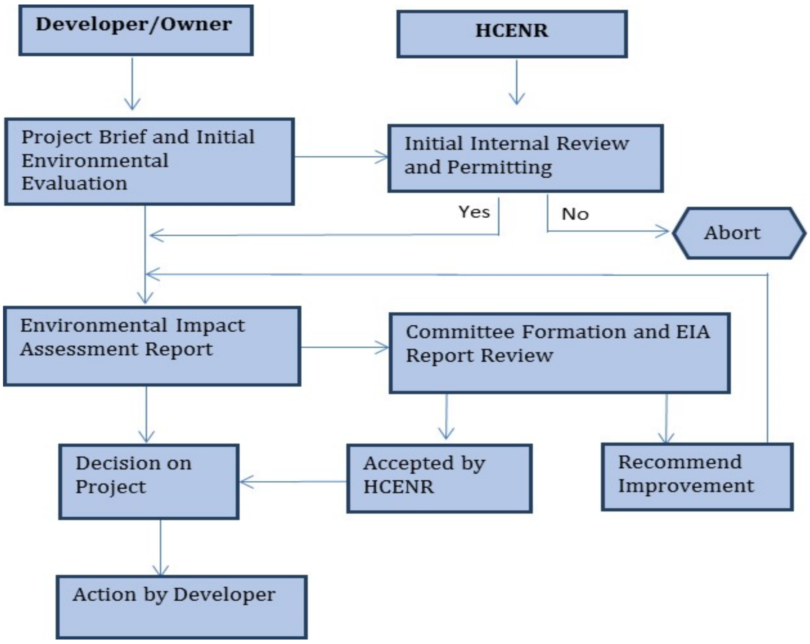


Figure 8.2-1 EIA Procedure in Sudan

8.3 Comparison of Alternatives Based on the SEA Concept

8.3.1 Overview of a Strategic Environment Assessment

(1) What is an SEA?

An SEA is applied at higher levels of any developmental intervention, such as policy and program levels, as opposed to project-wise environmental assessments, such as IEEs and EIAs. Inevitably, an SEA is applied from the early stages of development interventions, typically in relation to policy formulation and master planning.

An SEA assesses a wider range of possible impacts, both temporal and spatial, while a project-wise EIA mainly considers the marginal effects. That is, an SEA assesses the long-term, as well as short- and medium-term, effects and effects on a larger geographic area. It is also applied to a wider scope of works, covering all the different sectors and interests that may be affected by any developmental intervention.

In sum, an SEA represents effective planning for environmental development, where 'environment' is taken in the broadest sense. This is in sharp contrast to other economy-oriented developments, where environmental and social concerns are put on the sidelines at best. Meanwhile, an SEA assesses cumulative and complex effects, while foregrounding environmental and social concerns in the framework of development.

To satisfy all these conditions effectively, an SEA must be conducted by involving a wide range of stakeholders from the early stages of any developmental intervention. This is realized by the facilitation of (1) stakeholders' meetings and (2) disclosing and sharing relevant information.

(2) Why is an SEA Necessary for IWRM?

An SEA is imperative in the evaluation of water balance in Sudan. Firstly, it will need to consider the objectives of water resource management by setting up a wide range of alternatives, followed by determining general direction for political interventions and planning. The direction as presumed at present is shown in Table 8.3-1.

Table 8.3-1 Presumed Direction for Political Interventions and Planning

Evaluation level	Main factor
Political interventions	Promotion of industrial issues (structure of industry, conversion of industrial structure) Putting in place water rights, water fee structures, legislation related to cost sharing Promotion of environmental initiatives (energy and water saving, recycling etc.)
Planning	Water resource development (balancing the Nile and non-Nile systems, facilitating interregional balance) Industrial development planning: agriculture and livestock Key infrastructure development planning (SW and GW development, water supply facilities, large-scale irrigation etc.)

Source: JICA Project Team

Furthermore, an SEA would be a useful method for reaching consensus among the many stakeholders for IWRM, while its concept is applicable to activities involving complexity at the national and local levels.

(3) The scope of an SEA

The most important part of any SEA is its comparison of alternatives. Generally, in the process of setting up alternatives, three aspects (economic, environmental and social) should have been thoroughly considered. In the case of an alternative focusing on economic considerations, for example, irrigation water could be diverted for highly productive industrial development, while, in the case of an alternative focusing on social considerations, it could be appropriate to increase the everyday water supply level. Regarding environmental considerations, the introduction of energy and water saving, as well as recycling technology, could be implemented.

When considering each alternative, a social and economic framework, which is able to identify population characteristics, the employment situation, GRDP etc., will be informative. At the same time, a spatial development framework could be adapted when setting up each alternative. Such framework methods have been frequently used in regional development planning.

8.3.2 Strategic Environmental Assessment Methodology

Due to the absence of any national legal and institutional framework for an SEA in Sudan, original methodology, which is comprehensive and adapted to the context, had to be defined for the purposes of conducting an SEA for IWRM. This experimental methodology has been introduced to the C/Ps, while its implementation will allow for improving operational and conceptual details related to environmental management.

(1) Methodology Guidelines

The following guidelines have been taken into account for elaborating the methodology of the SEA:

- JICA Guidelines for the Confirmation of Environmental and Social Considerations (hereinafter referred to as the "JICA Guidelines") dated 2010. The following 10 components required by the JICA Guidelines will be implemented as part of the SEA:

  Review of alternatives to achieve the objectives of the project
  Review of the content of policies and elaborated plans
  Implementation of scoping
  Confirmation of natural and social conditions for reference
  Confirmation of environmental regulations and institutions
  Estimation of environmental impacts
  Assessment of the impact on the environment and review of the alternatives
  Confirmation of mitigation measures
  Confirmation of monitoring method
  Attendance at meetings with stakeholders

- Guidelines of the Strategic Environmental Assessment of the OECD (hereinafter referred to as the "OECD Guidelines") dated 2006, which represent a major reference source for the establishment of SEA legal frameworks in various countries. For regional development projects, the OECD Guidelines indicate that an "SEA applied to spatial/regional plans or programmes provides an important recommendation to integrate sustainable development approaches within the decision-making process", while its framework advocates the recognition of the following fundamental questions:
  i) What are the priority environmental problems in the area in question? Is there a danger that these problems could be exacerbated by the proposed programs/plans?
  ii) Have any relevant cumulative issues been taken into account?
  iii) Are the proposed developments likely to be vulnerable to the impacts of climate change?

- Directive 2001/42/EC of the European Parliament and of the Council of 27 June 2001 on the assessment of the effects of certain plans and programs on the environment (hereinafter referred to as the "European SEA Directive") and its explanatory guidelines, which represent a proven international reference source and a major knowledge base regarding various aspects of strategic assessment. The implementation process involving various distinctive stages, as well as the establishment of SEA objectives and other aspects recommended in this directive, will be implemented by the SEA.

- According to the JICA Guidelines, any project that takes environmental and social considerations into account, must demonstrate that there is no conflict in its SEA operationalization and processes with the World Bank's Environmental and Social Safeguards (hereinafter referred to as the "World Bank's Safeguards").

(2) Methodological Framework

Taking into account the 10 components required by the JICA Guidelines, the three principles outlined in the OECD Guidelines described above, and some structural aspects recommended by the European SEA Directive and World Bank Safeguards, the methodological framework for the SEA is presented in Figure 8.3-1.

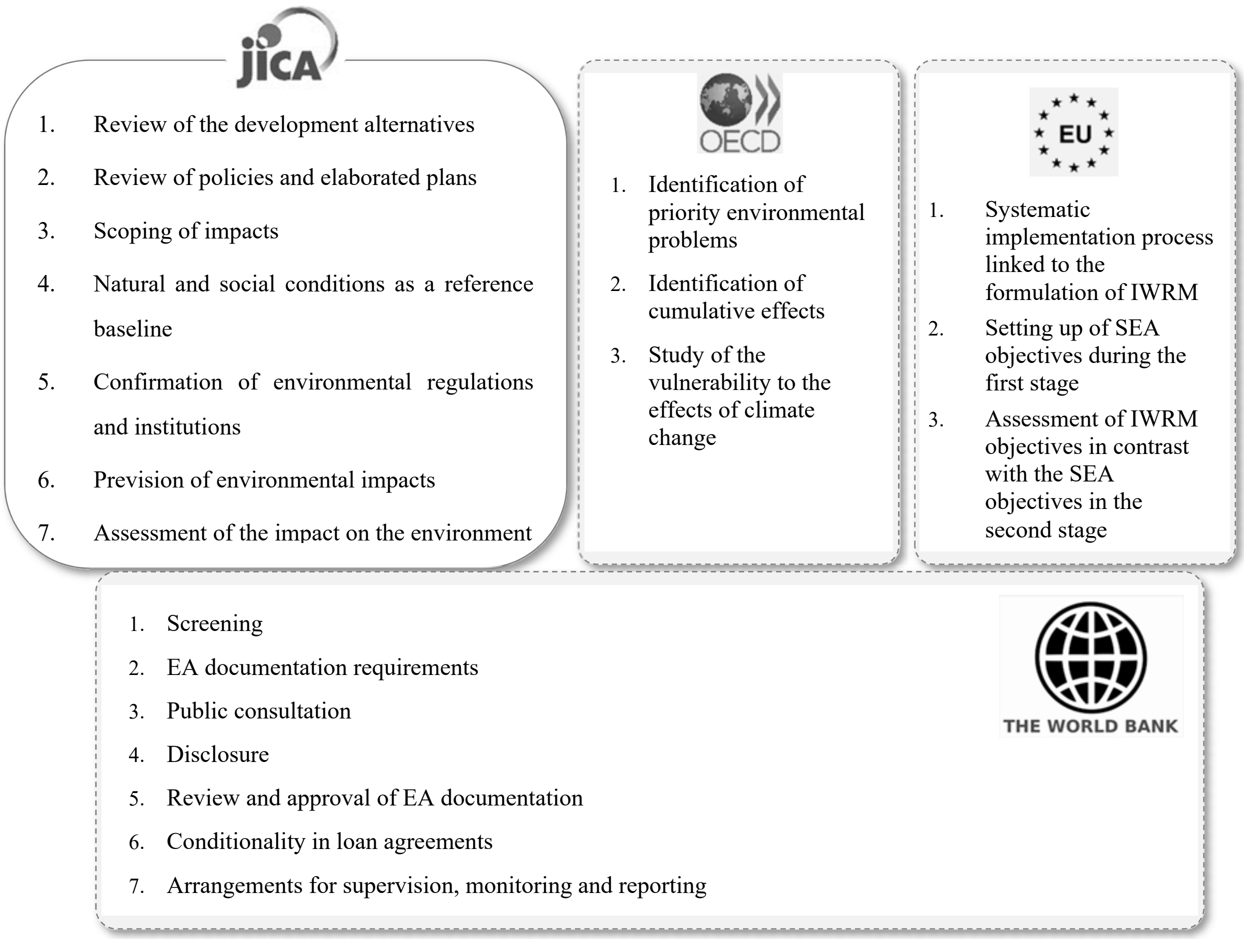


Figure 8.3-1 Methodological Framework of SEA

Source: JICA Project Team

8.3.3 Application of Environmental Assessment for IWRM in Sudan

This project would not prepare any master plans, and there are not specific SEA regulations in Sudan. So, as one of the activities for capacity development for the C/PS, the project developed a draft provisional procedure of SEA in Sudan, and applied it to a process of IWRM under an assumption that IWRM would be implemented in Sudan nationwide.

(1) The Abstraction of the SEA Essence

The SEA will be conducted based on the water balance analysis and the problem analysis. The JPT has held workshops on nine occasions in each related department or organization and conducted a series of field survey in Khartoum and other rural area. As a result, the JPT has found numerous problems related to the water sector. These problems are organized as problem trees prepared by the JPT experts and counterpart team members. This process is called Problem Analysis and is used for the extraction of important issues and the description of the relationship between each problem. These analyses can show clearly some important environmental issues caused by the water sector consisting of SW, GW, urban and rural water supplies, irrigation and livestock activities and water pollution. Moreover, the relationships among these sectors could be identified visually by the description of causes and effects related to water issues. Implementation of SEA in this project would be conducted referring to the result of these analyses and some field surveys to collect environmental information.

(2) The SEA Procedure for IWRM

Based on "8.3.2 Strategic Environmental Assessment Methodology", the draft of general SEA procedure developed in the project is shown in Figure 8.3-2. This procedure could be modified by considering the progress of technical analysis for water balance and the current situation in a real project. In particular, it can become an essential element in terms of how stakeholder meetings are held.

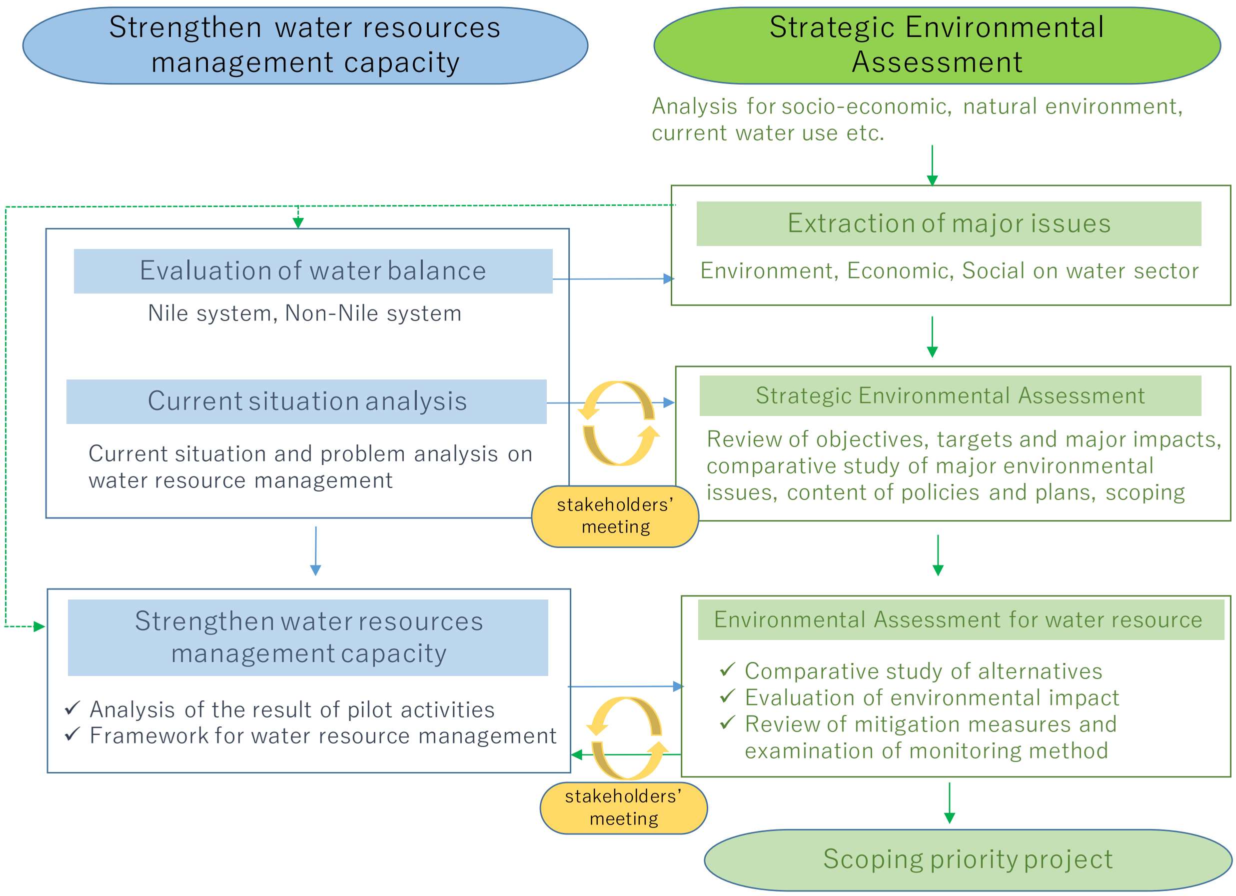


Figure 8.3-2 First Draft of SEA Procedure

Source: JICA Project Team

(3) The SEA Procedure Adopted in this Project

Referring to the draft of general SEA procedure mentioned above, it was necessary to consider concrete steps suitable for the project. Thus, based on European SEA directive guidelines, a stage-by-stage process was adopted for the implementation of the SEA. The process below summarizes the main stages in the SEA process, the purpose of each task, their relationships to each other, and the conformity to JICA requirements.

Considering the first draft of SEA procedure (Figure 8.3-2) and character of the IWRM, the SEA process is adopted in this project as below three stages.

First Stage: Setting the context and objectives, establishing the baseline and deciding on the scope.

1-1. Identification of other relevant plans, programs and environmental protection objectives

1-2. Collection of baseline information

1-3. Identification of major environmental problems

1-4. Development of SEA objectives

Second Stage: Developing and refining alternatives and assessing effects

2-1. Assessment of IWRM objectives against the SEA objectives

2-2. Development of strategic alternatives

2-3. Prediction and comparison of the effects of the different strategic alternatives

2-4. Evaluation of the effects of IWRM

2-5. Mitigation of adverse effects

Third Stage: Development of strategies, consultation and monitoring

3-1. Consultation of the stakeholders on the drafted IWRM and drafted SEA Report

3-2. Development of aims and methods for monitoring

8.3.4 Identification of Environmental Problems

Based on the three stages proposed above, SEA on IWRM under an assumption that IWRM would be implemented in Sudan nationwide was conducted as a trial. 8.3.4 corresponds to the first stage, 8.3.5 and 8.3.6 correspond to the second stage, and 8.4 corresponds to the third stage.

(1) Problem Analysis

The JICA Project Team has held workshops on nine occasions in each related department or organization since the beginning of this project. The aim of these workshops was to conduct a problem analysis on the respective water issue. The results of the analysis are described in Chapter 3.

Different from problem analysis, problem structure analysis is a method to comprehensively clarify these interrelationships in a visible way. The analysis allows for a broad perspective, usually undertaken during the initial stage of development planning. The problem structure analysis is applied through a series of workshops, with the problem structure based on the results of the problem analysis (i.e., problem trees).

The problem structure clarifies more important problem factors and phenomena expressed in generic terms to imply many detailed or sector-specific problems. It also shows causal relationships between the identified problems by focusing on the main interrelationships.

The problem structure (Figure 8.3-3) comprises many environmental problems extracted from problem trees mentioned above. Thus, this analysis can be a first step in the SEA procedure, i.e., the extraction of major issues regarding the environment.

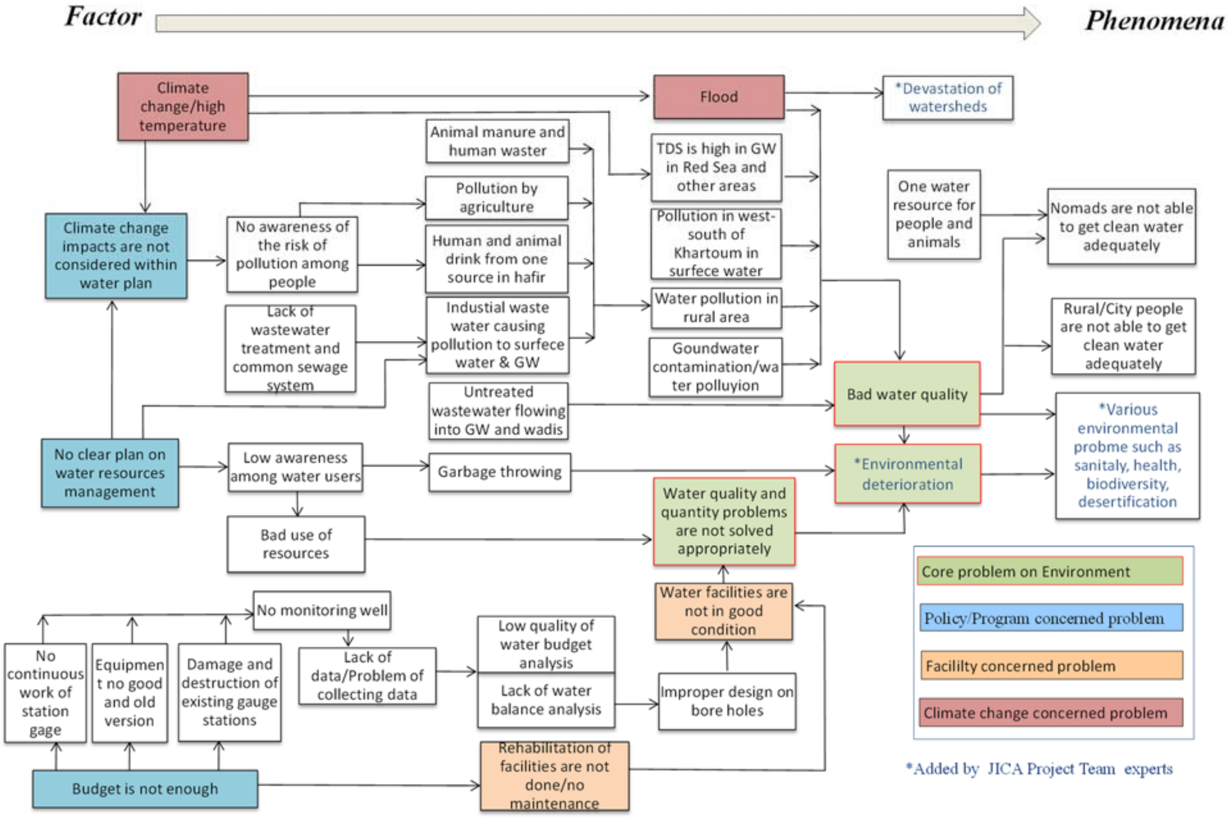


Figure 8.3-3 Water-Related Environmental Problem Structure

Source: JICA Project Team

(2) Identification of Major Environmental Problems

Identifying environmental problems is an opportunity to define key issues and improve the SEA objectives. The identification of environmental problems shall be based as much as possible on evidence related to baseline information, and on consultations with relevant agencies and stakeholders. In order for the identification of the environmental problems to fully benefit the formulation of SEA objectives, the several key strategic questions shown in Table 8.3-2 below shall be answered.

Table 8.3-2 Strategic Themes and Questions for Identification of the Environmental Problems

Strategic theme	Strategic question
Intensity	How good or bad is the current situation in comparison with other environmental issues and other locations of the target area?
Trend	Do trends show that it is getting better or worse?
Sensibility	Are particularly sensitive or important elements of the receiving environment affected, e.g. vulnerable social groups, non-renewable resources, endangered species, rare habitats?
Reversibility	Are the problems reversible or irreversible, permanent or temporary? How far is the situation to irreversible impact?
Remedy	How difficult would it be to offset or remedy any damage?
Cumulative / indirect effect	Have there been significant cumulative or synergistic effects over time? Are there expected to be such effects in the future?

Strategic theme	Strategic question
Indicator	How can the environmental problem be measured? How far is the current situation from any established thresholds or targets?

Source: JICA Project Team based on European SEA directive

(3) The Preliminary Scoping of SEA

The JICA guideline on environmental protection and the World Bank's Safeguard Policy describe the importance of the scoping of environmental issue. According to the result of problem analysis and field survey, preliminary scoping was conducted shown as Table 8.3-3, mainly referring to the result of Problem Analysis mentioned above. This project aims at developing integrated water management plan, therefore the preliminary scoping was not based on individual specific projects but was implemented from the viewpoint of necessity of consideration in formulating IWRM. In the process of the scoping, identification of existing major environmental problems would be set up. Furthermore, possible problems in the future should be identified based on the appropriate category classification.

Table 8.3-3 Preliminary Scoping of SEA

Category	Environmental Issue	Negative Impact	Cause
1.SW (Non-Nile)	1-01. Bad water quality	Lack of usable water (Hafir)	✓ Contamination of garbage and fodder of livestock ✓ No purification system ✓ Sand and earth are mixed. ✓ Containing excreta of livestock
	1-02. Sedimentation of sand into Hafir and small dam	Difficulty to secure the planned amount of water	✓ Lack of maintenance of facilities ✓ Lack of hydrogeology monitoring ✓ Lack of capacity enhancement
2.SW (Nile system)	2-01. Sedimentation of large scale dam	Difficulty to secure the planned amount of water	✓ Sediment discharge ✓ Deforestation ✓ Agricultural land expansion ✓ Inappropriate overgrazing
3.GW	3-01. Decline in GW level	Lack of GW to be pumped	✓ Inadequate of pumped water regulation ✓ Unregistered well ✓ Lack of hydrogeology data
4.Urban supply water	4-01. Bad water quality	Lack of usable water	✓ Contamination by waste water from factory and household
5.Rural supply water	5-01. Water quality deterioration at shallow wells	Lack of supply water at shallow wells	✓ Penetration of domestic waste water into shallow aquifers ✓ Inadequate household sewage treatment
6.Agricultural water	6-01. Water shortage during the drought period	Insufficient rainwater usage	✓ Changes of the amount of natural water ✓ Global climate change ✓ Lack of auxiliary reserved water
	6-02. Decline in GW level	Lack of GW to be pumped	✓ Illegal withdrawal ✓ Improper water distribution
7.Livestock	7-01. Blocking nomad route	Change of nomadic route	✓ Agricultural land expansion ✓ Mixing land ownership (Traditional and modern)
8.Water pollution	8-01. GW pollution	Lack of GW to be pumped	✓ Underground penetration of daily sewage ✓ Underground penetration of agricultural waste water ✓ Elution of salt in soil into GW ✓ Elution of salinity in the basement ✓ GW contamination by oil extraction ✓ Factory drainage regulations are not observed.

Source: JICA Project Team

(4) The Evaluation of Categorized Problems

According to Table 8.3-3, there are eight categorized environmental sectors related to water management in Sudan. In the case that the IWRM plan would not be properly implemented, the result of the evaluation can be described as Table 8.3-4. These elements and the contents of this table should be confirmed in the process of holding stakeholder meeting or workshops on relevant organizations.

Table 8.3-4 Description of Categorized Problems

Category	Environmental Issue	Intensity	Trend	Sensibility	Reversibility	Remedy	Cumulative/ Indirect effect	Indicator
1.SW (Non-Nile)	1-01. Bad water quality (Hafir)	Middle	Growing slightly	Low (except in case extinction of local species)	Reversible	Difficult to remedy	Cumulative sedimentation	Water quality monitoring system
	1-02. Sedimentation of sand into Hafir and small dam	Low	Growing slightly	Low	Reversible	Difficult to remedy	Cumulative sedimentation	Amount of usable water quantity
2.SW (Nile system)	2-01. Sedimentation of large scale dam	Middle	Growing slightly	Middle	Reversible	Possible to remedy (need large-scale budget)	Cumulative sedimentation	Amount of usable water quantity
3.GW	3-01. Decline in GW level	Middle	Unpredictable	Low	Reversible	Difficult to remedy (long term)	Amount of GW used	Amount of usable water quantity
4.Urban water supply	4-01. Nil	Middle	Growing slightly	Middle	Reversible	Possible to remedy (need proper regulation)	Cumulative waste	Amount of usable water quantity
5.Rural water supply	5-01. Water quality deterioration at shallow wells	Middle	Unpredictable	Low	Reversible	Difficult to remedy	Amount of GW used	Amount used per capita
6.Agricultural water	6-01. Water shortage during the drought period	Middle	Growing slightly	Low (except in case extinction of local species)	Reversible to Irreversible	Hard to remedy (related to climate change)	Amount of water used	Increase or decrease of irrigation area
	6-02. Decline in GW level	Low	Unpredictable	Low	Reversible	Difficult to remedy	Amount of GW used	Increase or decrease of farm area
7.Animal husbandry	7-01. Blocking nomad route	Middle	Growing slightly	High	Reversible to Irreversible	Difficult to remedy	Depending on the land issue	Change of agricultural land
8.Water pollution	8-01. GW pollution	Middle	Growing strongly	Low	Reversible to Irreversible	Difficult to remedy	Cumulative pollution	Change of industrial structure

Source: JICA Project Team

8.3.5 Development of SEA Objectives

An SEA objective is a statement of what is intended by conceived development intervention, specifying a desired direction of change. SEA objectives are a guiding path that allows organizations to effectively compare the effects of alternatives and to assess the environmental effects of IWRM.

The achievement of an SEA objective is measured by using indicators and quantified targets. SEA objectives, indicators and targets might be revised at the stakeholder workshops and meetings with relevant organizations as new environmental problems are identified.

The SEA objectives will be categorized into SEA topics in order to find the best possible scope of IWRM. The SEA topics will cover all the environmental and social assessment components required by JICA guidelines, but some adjustments and simplifications will be made in order to increase the conformity with the current SEA.

The target items of the SEA objectives will be set up concerning three major problems identified by problem analysis with a bit modification: water pollution, changes of natural resources and disaster management. Table 8.3-5 shows the SEA objectives and indicators.

Table 8.3-5 shows the possible environmental problems by category. On the other hand, considering these categories, three major environmental problems which should be to be set up SEA objectives and indicators with priority are described in below Table.

Table 8.3-5 SEA Objectives and Indicators

SEA Topics	SEA Objectives	SEA Indicators
Water pollution	✓ Reduction of burden on water quality ✓ Limit the excessive activities in agriculture and industry ✓ Diffusion of recycling technology for water treatment	✓ Quality of hafir and GW ✓ Proper production activity ✓ Innovation and improvement of recycling technology
Change of natural resources	✓ Prevention of GW contamination ✓ Resilience to fluctuation in water volume ✓ Awareness raising on water conservation ✓ To ensure sustainability on water resource	✓ Enhancement of water purification facilities ✓ Improvement of supply facilities ✓ Effect of promotional and educational activities
Disaster management	✓ Flexibility to climate change ✓ Resilience to severe drought ✓ Prevention of floods and erosion	✓ Improvement of monitoring systems ✓ Introduction of water saving technology ✓ Effect of promotional and educational activities

Source: JICA Project Team

8.3.6 Development of Strategic Alternatives

(1) The Concept of Strategic Alternatives

An SEA will be conducted based on the water balance analysis and the problem analysis.

Firstly, a set of alternatives will be established concerning future water resources management in Sudan. Several broad alternatives will be established: one for a zero option or no IWRM scenario, and others for scenarios involving IWRM. These alternatives are compared in the table below. For each scenario, a socioeconomic framework and a spatial water demand/supply framework will be established in order to indicate the level and geographical distribution of development in Sudan in the future. Common frameworks will be applied to all scenarios.

Water resources development will be undertaken for each scenario, but to different degrees. Investment in water resources development will be high in Scenario A because water supply facilities have to be systematically constructed in order to catch up with water demand, which continues to grow in the absence of control. The investment requirement in Scenarios B, C and D, however, will be lower due to measures on the demand and supply sides. This comparison will be technically carried out on the project.

While various measures are assumed for IWRM in Table 8.3-6, each of these measures will be considered in more detail on the project, as they represent the core part of the recommendations to be proposed by the project.

Impacts on the environment will be assessed for each scenario. While it is envisaged that these will be largest in Scenario A, this claim is subject to technical verification on the project. A water balance analysis should also be conducted for the established alternatives.

An essential element of an SEA is to undertake all these activities in a participatory manner involving all stakeholders.

Table 8.3-6 Comparison Table of Each Alternative

Scenario		Key development issue/measure
A	No IWRM alternative	✓ No change from the present situation ✓ Intensive promotion of infrastructure to meet water demand ✓ There is no adjustment between relevant sectors.
B	Environmental consideration alternative	✓ Conservation of water quality ✓ Conservation of ecosystem and biodiversity ✓ Avoid depletion and contamination of GW ✓ Reduce a risk of subsidence
C	Economic/Social consideration alternative	✓ Promotion of regional economic development ✓ Promotion of industrial development ✓ Increasing irrigation area
D	Balanced development alternative	✓ Well-balanced development between urban and rural area ✓ Integrate environment and economic/social considerations ✓ Supply and demand of water complementing each other

Source: JICA Project Team

(2) Characteristics of Scenario A

All alternatives except for Scenario A are elaborated on the basis of IWRM to be pursued. Scenario A would pursue a conventional development model without adjustment between relevant sectors, which means there would be no collective effort and elaboration on not only the supply and demand of water resources, but also with respect to SW and GW. Therefore, in the case of Scenario A, most of the mentioned problems in the water sector will remain without any solution. In other words, a large amount of the investment budget would be needed to meet the water demand by intensive promotion of water supply facilities. Even if it would be possible to promote an adequate infrastructure related to water supply, without IWRM various social and environmental issues must be happened in near future. An infrastructure development plan without any adjustment between related sectors has frequently caused fatal environmental and social issues such as GW contamination by excess pumping, and they might be irreversible.

(3) Summary of the Main Differences between Alternatives B, C and D

Table 8.3-7 summarizes the main differences between the three strategic alternatives elaborated. The model shows the basic direction for each alternative, and important means can describe how to meet the water demand and promote water management. In addition, development management shows the water management to be pursued, applied to each alternative.

Table 8.3-7 Summary of Main Differences between Alternatives B, C and D

Item	Alternatives		
	B	C	D
Model	• Self-sufficient environmental management	• Promoting economic and social activities by sufficient water resource	• Well balanced development between environment and economy/society
Important means	• Strengthening environmental management for water resource • Controlling waste water and sanitary water	• Upgrading water related infrastructure and utilities • Promotion of irrigation and industry water	• Development that does not rely on infrastructure • Agreement among parties concerning environmental issues
Development management	• Environmental management for surface and GW	• Meet the full demand of water resource	• Promotion of participatory planning for water management

Source: JICA Project Team

(4) Water Balance Analysis Related to Environmental Management

Water balance analysis has been conducted by the JPT experts and counterpart team members shown as Chapter 4 in this report. Water management methodologies can be divided into the Nile system and non-Nile systems, depending on whether or not they use the water of the Nile River. Moreover, water balance analysis should consider the demand and supply on water resources. The result of water balance analysis is a key to proceed with the SEA methodology, consisting of stakeholder meeting with relevant departments or organizations and the selection of the best alternative. Table 8.3-8 summarizes the outline of water balance analysis. This table shows only non-Nile area, because Nile system can mostly cover the current and future water demand.

Table 8.3-8 Summary of Water Balance Analysis (Non-Nile)

Supply Side	Demand Side (Existing/Future)	2015 Water Demand (/year)	2035 Water Demand (/year)
	SW/GW		
Water potential	SW (Demand/Potential<10%)	Sub-basins of 89% satisfy	Sub-basins of 70% satisfy
	GW (Demand/Potential<10%)	Sub-basins of 93% satisfy	Sub-basins of 81% satisfy
Required facilities	SW	Capacity of total 32 million m^3 is required	Capacity of total 195 million m^3 is required
	GW	8,600 wells are required	34,100 wells are required

Source: JICA Project Team

(5) The Main Target for Scenarios B, C and D Based on Water Balance Analysis

As mentioned above, Scenario A, namely, no IWRM is not realistic for integrated water management. Table 8.3-9 shows the main target for Scenario B, C and D. These targets should be refined through stakeholder meetings or workshops with relevant departments and concerned persons. In the process of implementation of an SEA, mutual agreements between them is vitally important for environmental management on water sector.

The characteristics of Scenario B focus on conservation of the natural environment of water resources. Therefore, most of these measures would involve a restriction of excessive activities in water-related sectors in order to conserve the natural environment, including water quality, drought, bio-diversity, eco-systems and so forth. However, it should not only pursue the restriction of activities. Based on the concept of IWRM, it should also maximize the adjustment between water supply and demand, or SW and GW. Conservation of the natural environment would be a key to keep the sustainable water resource development and management.

In the case of Scenario C, promotion of economic/social activities would be the priority. In the current situation of this country, the environmental consciousness of the people is not high. Their economic/social activities are the priority, rather than whole balance of natural resources. In addition, this scenario partly depends on new investment in infrastructure for water usage. In this Scenario, it should be regarded that sustainability on water resource is not secured.

On the other hand, the participatory approach must be employed to promote Scenario D. It is based on the agreement between concerned people and organizations to achieve adjustments between some sectors.

It is necessary in this scenario to deal with engineering aspects and socio-technical aspects at the same time, and should integrate both aspects. Especially, in Darfur, non-adjustment between sectors, unbalance of supply and demand on water resource, and lack of monitoring system of SW and GW could be one of the reasons to escalate regional conflicts. Therefore, in such kind of this region, IWRM would be more important for suitable and sustainable water resource management.

Table 8.3-9 Main Target for the Different Alternatives Based on Water Balance Analysis

Item		Alternatives		
		B	C	D
Water Demand	Urban water supply	• Diffusion of sewage facilities • Countermeasure against non-revenue water	• Increase of industrial water usage • Increase of living water usage for economic and social activities	• Diffusion of water saving consciousness • Reuse of sewage • Improve recycling rate • Countermeasure against non-revenue water
	Rural water supply	• Diffusion of sewage facilities	• Increase of industrial usage • Increase of living water usage for economic and social activities	• Diffusion of water saving technology • Reuse of sewage • Improve recycling rate
	Agricultur e/ Livestock	• Non-expansion of farmland and husbandry area • Irrigation water conservation technology	• Increasing irrigation area and farmland • Achievement of high yield by promotion of irrigation facilities	• Efficient use of irrigation water in the Nile-system • Efficient use of rain water • Regulation against GW development by large irrigation investment
Water Supply	SW (Non-Nile)	• Prevention of excessive water intake • Securing a certain water level	• Development of a new water source and facilities	• Promotion of conjunctive use of SW and GW • Proper maintenance work for Hafir
	SW (Nile system)	• Prevention of river deterioration	• Development of a new water source and facilities	• Watershed conservation by measures against sediment discharge
	GW	• Prevention of ground subsidence due to excessive water intake • Fossil water intake should be restricted.	• Proper management of water usage amount • Excavation of new water sources such as wells	• Proper management based on enhancement of GW monitoring • Enhancement of data sharing collection system • Strengthen maintenance of supply facilities
Water balance evaluatio n	Water demand	• Keep low level	• More than the current situation needed	• Maximize the efficiency of water usage
	Water supply	• Keep low level	• More than the current situation needed	• Adjustment between environment and economy

Source: JICA Project Team

(6) Prediction and Comparison of the Effects of the Different Strategic Alternatives

To keep the big issues clear, the alternatives considered at this early stage on environmental assessment need not be elaborated in too much detail. Only the main differences between the alternatives need to be considered and documented.

Only reasonable, realistic and relevant alternatives need to be put forward. It is helpful if they are sufficiently distinct, to enable meaningful comparisons to be made of the environmental implications of each.

The process of prediction and comparison of the effects of the strategic alternatives is realized in order to pursue the best realistic alternative. In this process, it is effective to hold the consultation meeting or workshop with relevant organizations which oversee not only environment but also other water-related sectors.

The assessment of alternatives may be made in broad terms against the SEA objectives, provided there is sufficient detail to identify the significant environmental effects of each alternative. Where appropriate, any cumulative, secondary and synergistic, short-, medium-, and long-term effects need to be highlighted, indicating whether they are likely to be permanent or temporary.

8.4 Preliminary Environmental Assessment for IWRM Strategic Issue

The IWRM being considered in the first phase consists of multiple Menus and Strategic Issues, and the IWRM Menu (total 64 menus) is configured as follows. In addition, Strategic Issue consists of 15 items.

Table 8.4-1 Format of IWRM Menu

Level of capacity development	Engineering Technology	Social technology
Social/ institutional	*Measures*	
Organizational	*Measures*	*Measures*
Individual	*Measures*	*Measures*

Source: JICA Project Team

The Strategic Issue is an analysis that extracts high-priority items from issues related to water resources while considering the IWRM Menu and adds a strategic interpretation. For this Strategic Issue, SEA is applied, and environmental, social, and economic evaluations are made. Negative checks are also made, and the degree of impact and priority are examined.

This evaluation should be done mainly by C/P's. The below table, however, shows the preliminary evaluation results implemented by JICA Project Team through the consultation with relevant stakeholders. Also, this evaluation includes the monitoring method.

Table 8.4-2 Preliminary Environmental Assessment for IWRM Strategic Issues

Strategic Issue	Environmental Aspect	Social / Economic Aspect	Others (Sustainability, sensibility, reversibility, remedy and so on)
① Promotion of conjunctive use of SW and GW	➢ Considering the impact on climate change to forecast the amount of rain fall in the future ➢ Promoting well-balanced use of SW and GW	➢ High cost of construction of new facilities which can develop GW ➢ Secure the quality of SW to use for everyday life	➢ Evaluation of deforestation due to excessive usage of GW ➢ Considering the depletion of GW
② Control of water demand distribution in regional planning	➢ It is necessary to consider environmental factor.	➢ It is necessary to consider the optimal allocation.	➢ Secure the proper plan and need to match with other plans
③ Promotion of unconventional water resource development in Red Sea State	➢ Biodiversity might be decreased due to modern facilities.	➢ High cost of construction of unconventional facilities ➢ "Control of future water demand" may restrain increase of the population and industry in Red Sea State	➢ M&O cost becomes high as unconventional facilities would be developed. ➢ Traditional culture may be deteriorated in the future.
④ Implementation of proper assessment for GW development	➢ There are various factors of environmental deterioration due to GW development.	-	➢ A skilled technician would be needed. ➢ Proper mechanism should be established.
⑤ Establishment of coordination mechanisms to solve water conflict in local city	➢ Considering the development of deforestation due to the change of mechanism	-	-
⑥ Regulation against GW development by large irrigation investment	➢ Institutional infrastructure should be established to protect natural environment. ➢ Farmers should understand environmental impact. ➢ Conserving ecosystem by proper management of irrigation facility	➢ Not rely too much on agricultural development for economic promotion. ➢ Excessive agricultural development might divide the people into the rich and poor.	➢ Large scale irrigation might promote the depletion of GW irreversibly.
⑦ Effective utilization of existing water supply facilities by maintenance	➢ Soil sedimentation in hafirs or dams may deteriorate ecosystem.	➢ Soil sedimentation have a possibility to reduce the volume of water storage. ➢ Proper maintenance can lead to avoid the natural disaster such as	➢ Proper maintenance system can minimize the possibility of malfunction of dam function.

Strategic Issue	Environmental Aspect	Social / Economic Aspect	Others (Sustainability, sensibility, reversibility, remedy and so on)
		flood or flash water.	
⑧ Enhancement of water-related data/information and its management	➢Also, environmental data accumulation is necessary. ➢Environmental data can contribute to avoid the influence of climate change and grobal warming.	➢Social and economic date in specific region should be associated with water-related data/information technically. ➢Monitoring social date can lead to appropriate water use.	➢Appropriate data collection system enhances the lifelong of facility by proper maintenance.
⑨ Promotion of monitoring data for proper planning and designing of water supply facilities of wadi	➢Promotion of monitoring wadi discharge data is necessary for not only water balance analysis, but also environmental protection. ➢Considering climate change influence due to grasping wadi discharge	➢The plan formulated utilizing monitoring data should be associated with social and economic data/information for macro analysis.	➢Promotion of monitoring data can be a good data accumulation for achievement of lifelong facility and proper allocation of budget.
⑩ Establishment of GW monitoring system of wells in operation	➢Monitoring of GW level of wells is vitally important for environmental preservation. ➢Flora and fauna would be partly affected by GW level.	➢Decreasing of GW level can affect the lifestyle of small farmers and nomads, especially. ➢Macro analysis of GW amount based on GW monitoring is effective for future economic forecast.	➢Depletion of GW might be irreversible depending on aquifer condition and GW potential storage.
⑪ Raising awareness of water saving	➢For urban residents, it might be difficult to associate water saving with environment. ➢However, environment preservation would be achieved by water saving system.	➢Wasteful water in urban water supply and horticulture production can affect rural area.	➢Cultivating awareness of water saving is not short action, but long-term initiative. ➢Sustainability of water usage will be enhanced by raising awareness of water saving.
⑫ Effective utilization of accumulated experience and knowledge	➢Accumulation of experience and knowledge enables to keep consistency on environmental measures.	➢Currently, accumulation of socially technical information related to water is not enough.	➢It is necessary for accumulation of experience to be ensured on cross-organization.
⑬ Organization reform	➢Environmental importance should be recognized in cross-	➢Social and economic measures including infrastructure should be done through proper	➢Sustainability should be enhanced by interference of different types of

Strategic Issue	Environmental Aspect	Social / Economic Aspect	Others (Sustainability, sensibility, reversibility, remedy and so on)
	organization.	demarcation of the organization.	organization.
⑭ Water resources management by River basin	➢ It is not necessary to consistent river basin with environmental situation. ➢ However, considering aquifer spreading is so important.	➢ River basin would be better associated with social and economic activity area.	➢ River basin is a basic unit for various activities. ➢ Awareness of importance on river basin should be cultivated for sustainable development.
⑮ Capacity development	➢ Cultivating the persons who can manage the environmental issue on water related organization	➢ Social and economic data/information should be dealt by experienced technicians due to deep relationship with water sector.	➢ GIS operation including DEM or other data is vitally important to keep sustainability on efficient water usage.

Source: JICA Project Team

8.5 Environmental Assessment for 10 cities as Capacity Development

Based on the water balance survey in Sudan conducted in Phase-1 of the project, the preliminary ideas to develop water resources in the 10 cities were prepared. As the capacity development activity, these ideas were elaborated carefully from the environmental viewpoint, and SEA was applied preliminarily. This environmental consideration has two major role such as enhancement of C/P's consciousness for environmental perspective in setting up the alternatives from environmental, economic, and social viewpoint.

This work was implemented mainly by the C/Ps, however initial introduction with collaborative work of C/P and JICA Project Team, taking Port Sudan for example, is shown as below. This SEA application is not fully implemented as a whole, but covers important essence of the SEA procedure. It is expected C/P to understand the application process by step.

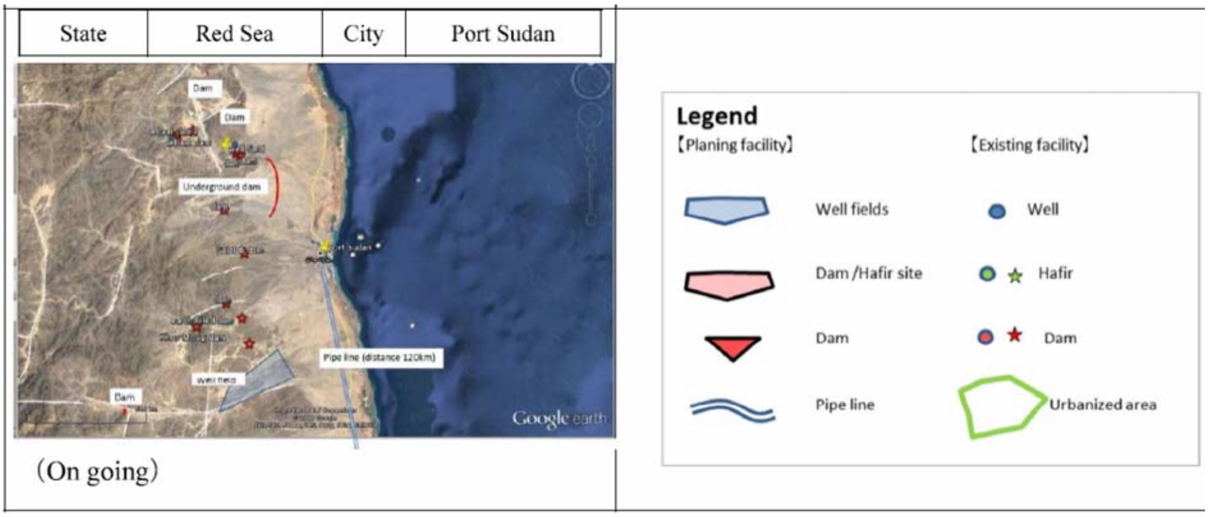


Figure 8.5-1 Proposed Water Resources Development Sites for Water Supply in Port Sudan

Source: JICA Project Team

Table 8.5-1 SEA Application for Port Sudan (RED SEA)

No	Theme	Analysis
1	**The Environmental Issues:**	1) Shortage of water 2) Climate change (global warming, floods, and overlapping seasons) 3) Water quality 4) Natural disaster (floods and high droughts) 5) Displacement: The details are as follows Displacement means that people move from drought-stricken areas to places where more water is available. An increasing number of people in specific areas could lead to water pollution and depletion of vegetation due to overgrazing and decrease in the number of livestock due to limitation of water. 6) Mining: The details are as follows Mining in the traditional way practiced in rural areas (such as gold mining) by illegal or non-scientific way has caused an environmental and health problem that has never existed before. Drilling for mining may cause GW contamination and may cause emissions of SW pollution.
2	**Analysis of the Environmental issue:**	
	1) SW (Non-Nile)	● Pollution of SW due to sea level rising and then mixing fresh water with sea water in the coastal area. Also, an increasing number of users in the water sources due to shortage of water led to conflict between users and pollution of the sources. ● The steep gradient of the basin Arbaat(Wadi), which is main sources of fresh water, has increased the sedimentation in the Arbaat dam lake, which can reduce the water storage in the dam, and lead to the failure to regulate the amount of water for the users (drink, animal and agriculture) ● Displacement as a result of drought.
	2) SW (Nile)	None

No	Theme	Analysis
	3) GW	● The wells are located in the high salinity area on the coast where the sea water was mixed with fresh water. ● Over pumping of GW lead to drop in GW after that to dry. ● The floods and high droughts lead to decrease water level of wells due to poor recharge during the droughts season. ● The deterioration of water quality has been caused by rising sea water level.
	4) Urban water supply	● Urban supply from GW and SW are suffering from limitation of water. ● Displacement has been happened as a result of drought.
	5) Rural water supply	● Rural supply from GW and SW are suffering from limitation of water. ● Pollution water due to mining in rural areas.
	6) Agriculture	● Lack of agriculture due to type of soil (rocky and salty). ● Lack of vegetation cover areas due to lack of rain precipitation and overgrazing
	7) Livestock water	● Overgrazing lead to deterioration of the soil and lack in vegetation cover areas
3	**Analysis of newly developed source:**	1) Project Red Sea Water Desalination: - Project location: Local Port Sudan. - The project is the supply of installation of a water station 30,000 m^3 including civil, mechanical and electrical works, water delivery from sea to station, water lines for network pumping and training – mechanisms and equipment - Period of project: 2017- 2020. - Types of facilities: Administration buildings, Hangers and fences - Current Progress of the project now under construction 2) Small dams and well field - Project Location: Rural area (another basin) - Other facilities: Purification system, water main pipe, reservoirs and tower tank, distribution pipe and pump station
4	**Associating dentified environmental issue with suggested facilities:**	Environmental problems in how to get rid of discarded water should be considered. Also, the planned desalination plant would be expected to cause other problem of environment such as follows; ● It would be necessary to expropriate the land by construction of desalination plant. ● The salinity concentration of the wastewater (liquid waste) from the plant might be returned to the sea with no treatment.
5	**Setting up the objectives on environmental aspects:**	● To secure the quality of wastewater for environmental management. ● To deal with environmental problems properly in how to get rid of wastewater (liquid waste).
6	**Considering alternatives:**	A: Red Sea Water Desalination B: Small dams and well field C: Desalination plant, small dams and well field *Comparison of alternatives is shown below table.

No	Theme	Analysis
7	**Selecting the best alternatives with reasonable ground:**	Measures that can be taken are the construction of drainage lines and a treatment plant for desalination plant.
8	**Suggestion:**	● Improvement of leakage rate by measures against non-revenue water. ● Suppression of demand by water demand management approach.

Source: C/P and JICA Project Team

Table 8.5-2 Comparison Table Between the Different Alternatives

Scenario	A: Red Sea Water Desalination	B: Small dams and a well field	A + B (Desalination plant, small dams and a well field)
Environment/social/economic impact	-Consider the drainage water quality (sanitary) from desalination plant -Social and economic impact is middle.	-Social and economic impact is low because facility location is far from city area. -Consider biodiversity due to construction of dams	-Possible to restrain the impact on environment with best combination -Social and economic impact is low
Cost (construction and maintenance)	**Middle**: -Main and distribution pipe is shorter than plan A. -Construction and maintenance cost would be high.	**High**: -Long main pile and distribution pipe are necessary. -Construction cost of dams would be high.	**Low**: -Possibility of appropriate combination with plan A and plan B
Total evaluation	2	2	3

Rating: 1 = Not good, 2 = Fair; 3 = Good

Source: Sudan C/P and JICA Project Team

8.6 Environmental Issues in the Pilot Activities Area

Pilot activities were conducted in the North Kordofan State. The environmental problems in the North Kordofan state were analyzed preliminary. Taking into account these problems, the pilot activities were implemented.

8.6.1 Climate Change

General overview

Definition of the climate change is, in general, as follows.

- Long-term shift in global or regional climate patterns, and
- Referring specifically to the rise in global temperatures from the mid-20th century to present.

Negative effects caused by global warming and climate change are 1) fluctuation of rainfall, 2) rising temperature, 3) expansion of desertification, 4) change of ecosystem, and 5) increase of natural disaster, and so on. The relationship between global warming and climate change is shown in Figure 8.6-1.

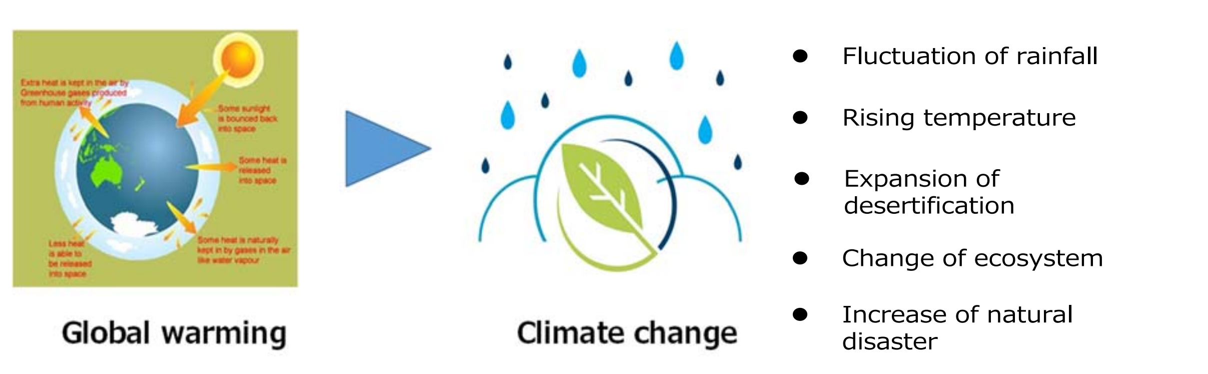


Figure 8.6-1 Relationship between Global Warming and Climate Change

Source: JICA Project Team

Climate change has caused many challenges in Sudan, including the North Kordofan state. The speed and intensity of climate change are outpacing the capacity of the people living in rural areas and societies in Sudan. IFAD (International Fund for Agricultural Development) reported the current status of climate change impact in 2013. The report described vulnerability to climate change, as shown in Table 8.6-1.

Table 8.6-1 Vulnerability to Climate Change in Sudan

Climate Change Impact	Vulnerable Area	Vulnerable Sectors	Vulnerable Communities
Temperature increase	• All of the country, especially those areas that will have a temperature increase by 2.5 degrees	• Rain-fed agriculture • Aquaculture • Natural ecology systems and biodiversity • Water resources • Energy • Community health care	• Poor farmers • Pastoralists (especially migrants) • Communities that rely on rain-fed agriculture
Floods, flash floods, and landslide	• Southern parts • Mountainous areas such as Northern East • South Eastern parts	• Agriculture • Aquaculture • Transportation • Water resources • Residential space • Health care and life • Trade and tourism	• Pastoralists • Communities living in flood plain areas • Poor farmers
Droughts	• Northern parts • Middle and Middle Western parts	• Agriculture and food security • Water resources • Waterways • Health care and life	• Poor farmers • Poor people, senior citizens, children, and women

Source: Sudan Environmental and Climate Change Assessment, IFAD

<u>Impact by Climate Change in North Kordofan State</u>

Also, IFAD shows the climate change impact on the state in Sudan. As for North Kordofan, it is described in Table 8.6-2.

Table 8.6-2 Expected Climate Change Impacts and Vulnerable Sectors in North Kordofan

State	Climate Change Impact	Vulnerable Sectors
North Kordofan	Frequent drought will result in loss of crops and livestock (food shortage), migration of pastoralists, and increased conflicts	Agriculture, livestock, water resources and health, rural areas, pastoralists, and forestry areas

Source: Sudan Environmental and Climate Change Assessment, IFAD

According to PhD study of "North Kordofan Climate Change", Sudan is presently engaged in a range of projects and processes which support a sustainable development trajectory. Yet, Sudan's vulnerability to climate change threatens to jepardize such efforts. Figure 8.6-2 shows the main indicators of climate change and variability as indicated by the local people. About 90 % of the interviewed sample asserted that fluctuation of rainfall in terms of intensity and distribution compared with the history of the study area is a criterion of climate change. Rains become sporadic in nature and vary significantly from one season to another with long period of episodes.

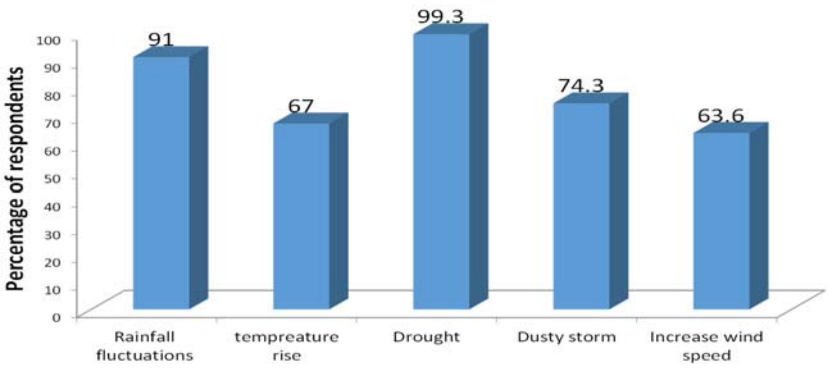


Figure 8.6-2 Indicators of Climate Change in North Kordofan

Source: PhD study of "North Kordofan Climate Change"

Another evidence of climate change in North Kordofan, as perceive by the local people is the sharp increase of temperature as indicated by 67% of the respondents. Other criteria of climate change is represented in frequent dust storms and increase of wind velocity as indicated by 74.3% and 63.6% of respondents, respectively.

8.6.2 Deforestation

According to the U.N. FAO, around 69,949,000 ha of Sudan is forested (29.4%, of its total surface). Out of the forested areas, 13,990,000 hab(20%) is classified as a primary forest which represents the most biodiverse and carbon-dense form of forests. Sudan had 6,068,000 ha of planted forests. In terms of change in Forest Cover, between 1990 and 2010, Sudan lost an average of 321,600 ha which corresponds to an annual rate of deforestation of 0.42% per year. In total, between 1990 and 2010, Sudan lost 8.4% of its forest cover (around 6,432,000 ha).

Deforestation has been one of the most severe problems in North Kordofan. In particular, the Bara area has been widely affected by this phenomenon. This problem is due to the rapid population growth as well as the increase of livestock. In addition to human activities, climate change, which causes a decrease and a fluctuation of rainfall, is suspected to be one of the main factors leading to deforestation.

Deforestation is strongly related to desertification. The Bara area in North Kordofan State is the very frontline of a desertification progress as shown Figure 8.6-3. This phenomenon causes the decrease in the biodiversity of fauna and flora as well.

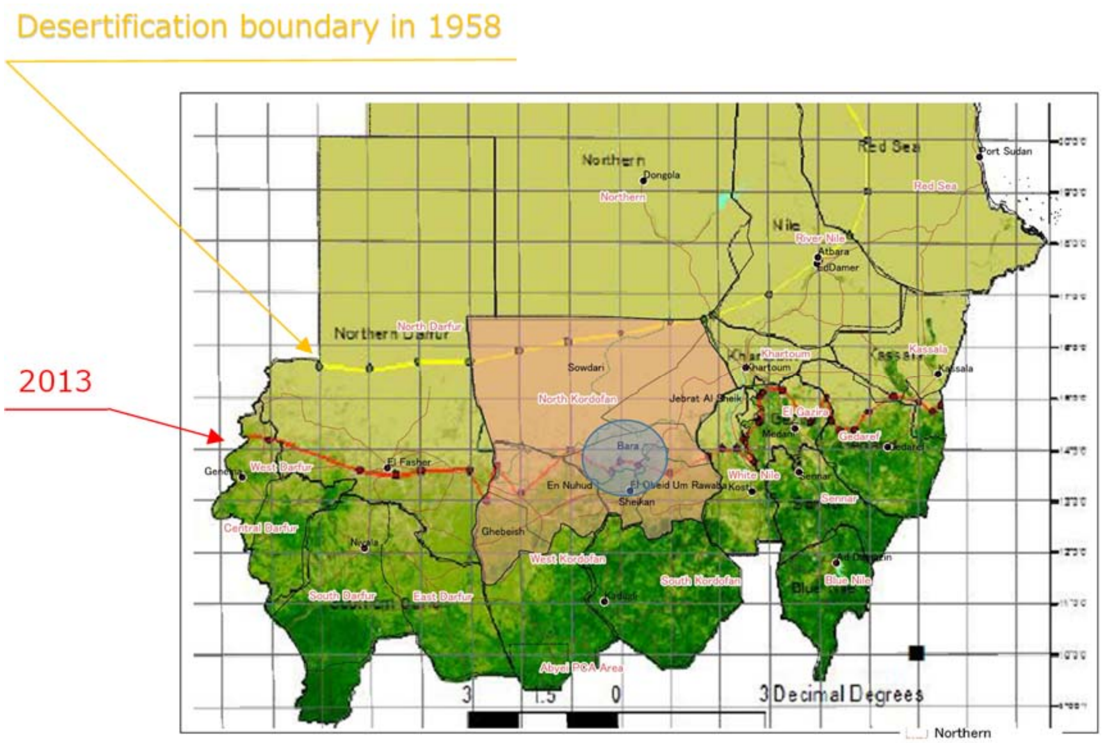


Figure 8.6-3 Desertification Boundary in Sudan

Source: JICA Project Team

8.6.3 Lack of Water

A problem analysis workshop was convened and involved members of the Higher Council of Environment in North Kordofan. They suggested two core problems namely water shortage and water pollution. The problem tree related to water shortage is shown in Figure 8.6-4.

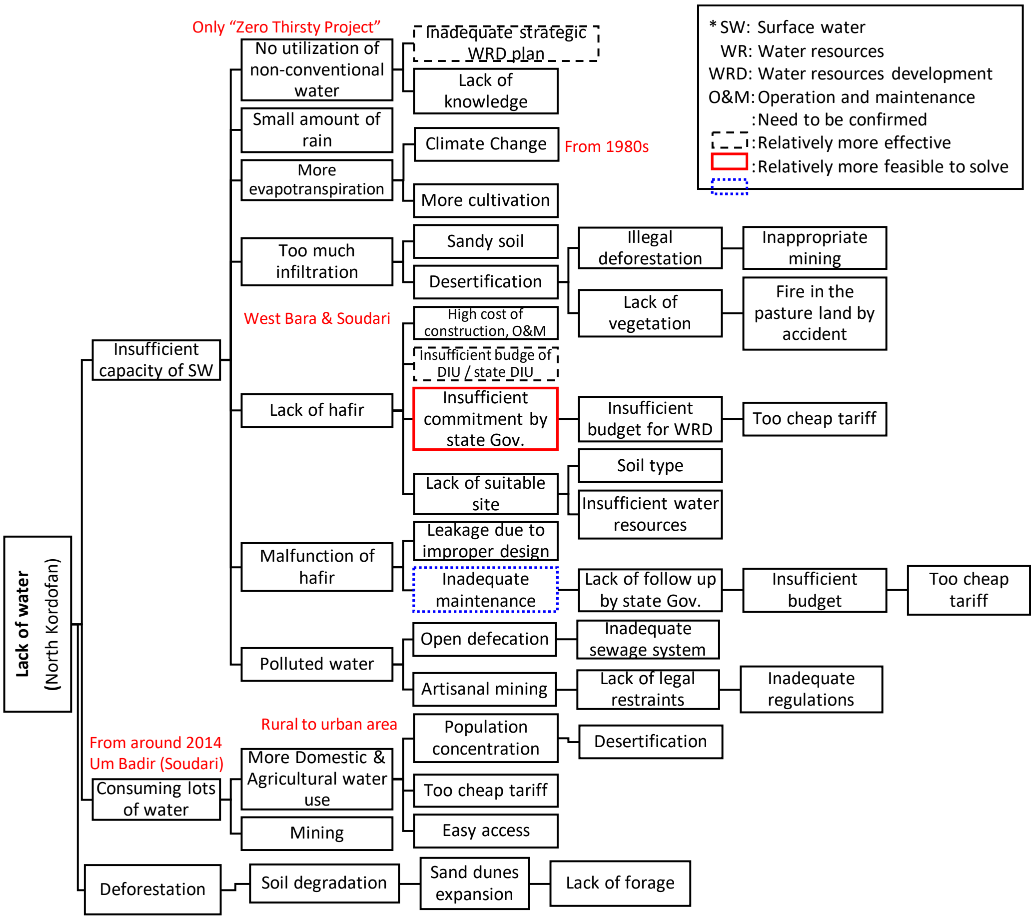


Figure 8.6-4 Water Shortage-Related Problem Tree Prepared in the Workshop

Source: JICA Project Team, based on the result of the problem analysis workshop

In order to solve these issues, the following points were suggested:

- ✓ Introduction of the drip irrigation system to minimize wasted water.
- ✓ Promotion of a common irrigation system
- ✓ Promotion of a diversified cultivated crops
- ✓ Promotion of financed projects related to the construction of water management facilities

8.6.4 Water Pollution

As described above, one of the core problems suggested in the workshop is water pollution. The problem tree is shown in Figure 8.6-5.

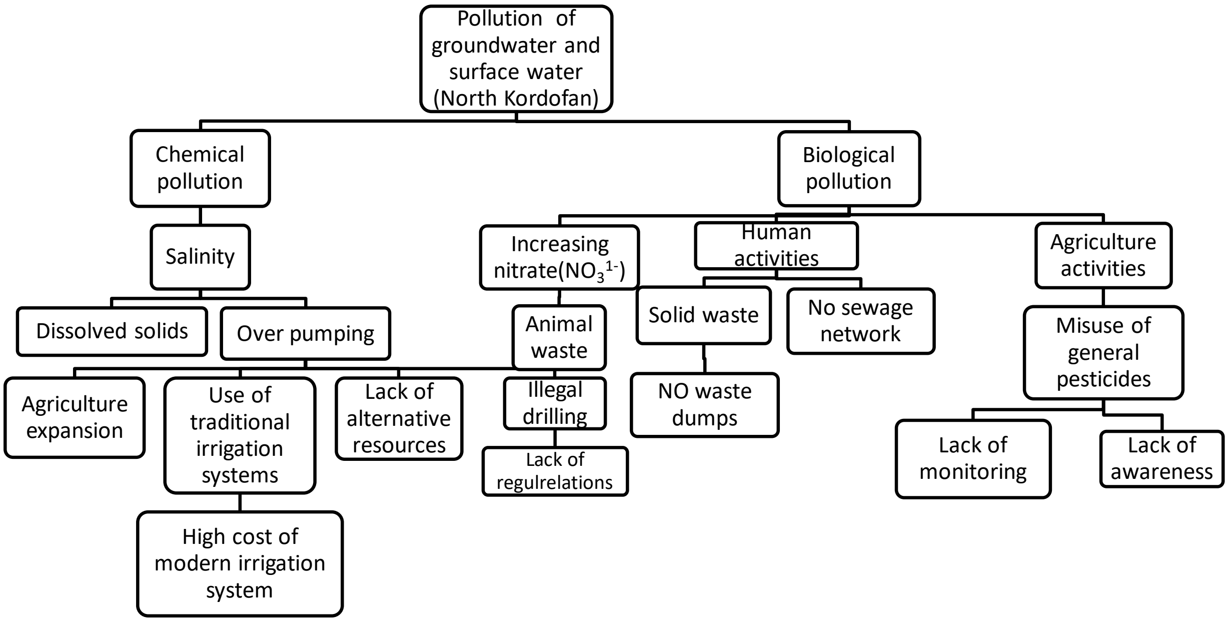


Figure 8.6-5 Water Pollution-Related Problem Tree Prepared in the Workshop

Source: JICA Project Team, based on the results of the problem analysis workshop

The participants suggested several solutions to these problems during the workshop:

- ✓ Reinforcement of laws and regulations by the Ministry of Water Resources in State Government to be used to stop unauthorized digging or drilling wells.
- ✓ Good sewage methods must be introduced.
- ✓ Digging in the range of GW should be prohibited by law.
- ✓ Construction of quarries or incinerators is encouraged.
- ✓ Construction of treatment stations for GW desalination is needed.
- ✓ Pasture near water resources should be prohibited by law.
- ✓ Free education and awareness campaigns by the Ministry of Agriculture in State Government should be implemented to support farmers in using fertilizers, herbicides, and pesticides.