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
SUMMARY

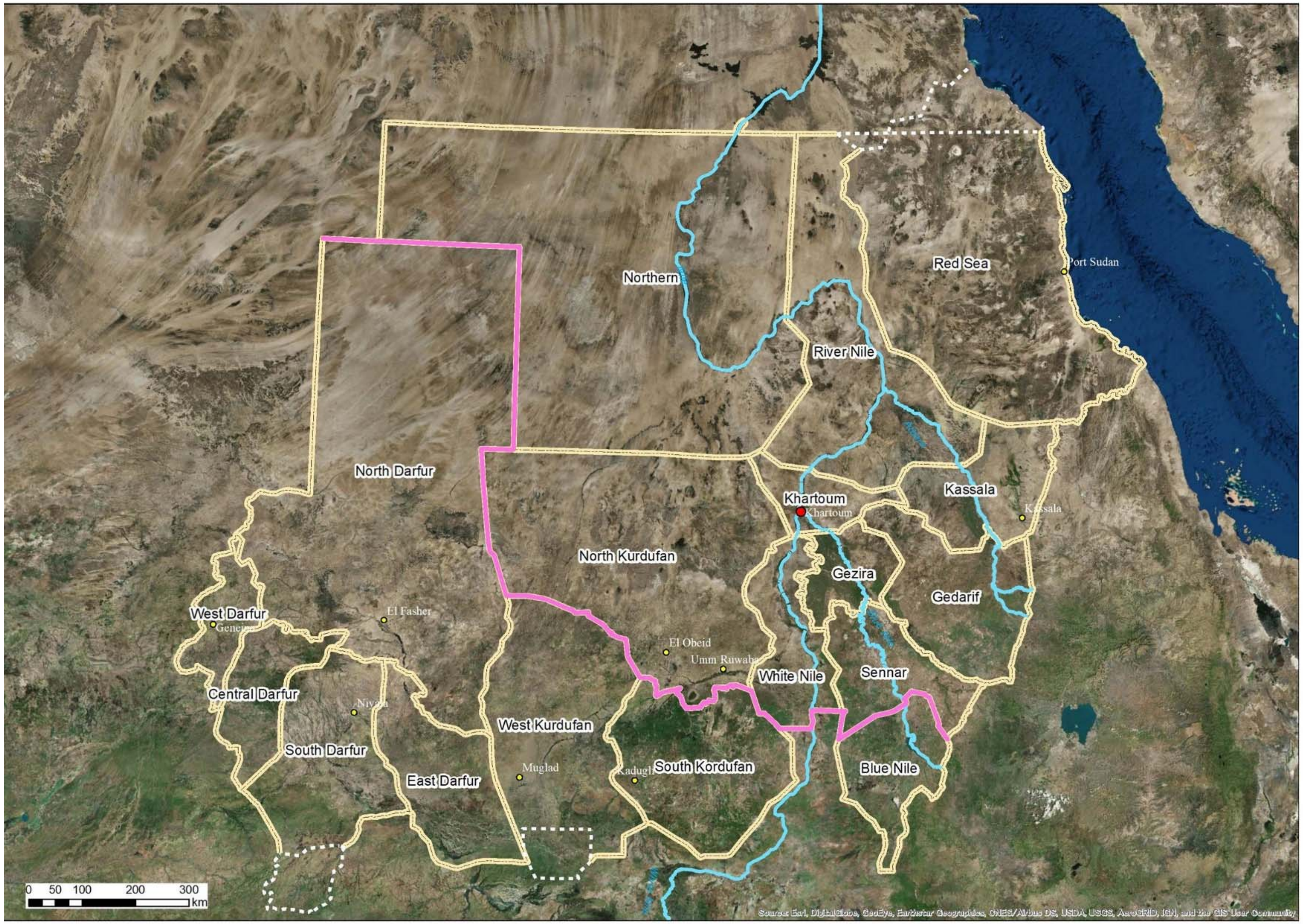
May 2023

JAPAN INTERNATIONAL COOPERATION AGENCY
(JICA)

YACHIYO ENGINEERING CO., LTD.
RECS INTERNATIONAL INC.

GE
JR
23-062

Map of the Sudan



THE REPUBLIC OF THE SUDAN
PROJECT FOR ENHANCEMENT OF
INTEGRATED WATER RESOURCES MANAGEMENT
FINAL REPORT SUMMARY

Table of Contents

*Disclaimer: Country borders or names do not necessarily reflect official endorsement or acceptance by JICA. These maps in this report are only for illustrative purposes and do not imply the expression of any opinion on the part of JICA, concerning the legal status of any country or territory or concerning the delimitation of frontiers or boundaries.

Chapter 1: Project Background, Objectives, and Structure

1.1 Project Background

Sudan has limited water resources, with less than 300 mm of precipitation per year over most of the country, limiting economic development and people's livelihoods. In addition, Sudan's water resources are unevenly distributed by region, with the non-Nile region in particular suffering from water shortages compared to the Nile region. In such a severe and serious water situation, Sudan needs to identify the water balance based on scientific data, consider measures to bridge the gap between water demand and supply based on the water balance, and update not only the water resources development plan but also the water use strategy at the national level. In the water resource management, it is also necessary to promote the Integrated Water Resources Management (IWRM), which improves coordination mechanisms among stakeholders, reduces conflicts over water allocation, and improves water use efficiency.

1.2 Project Summary

Project Objectives

The objective of this Project is to contribute to the improvement of IWRM policies, strategies, and plans, and to the improvement of related water resources-related projects by identifying recommendations on the related legal and institutional system through the practice of IWRM.

Expected Results

Output 1: Evaluation of water balance

Output 2: Analysis of issues related to water resources management

Output 3: Implementation of IWRM in selected areas (pilot activities)

Output 4: Recommendations on strategies, legal framework, and implementation arrangements

Major Related Government Agencies and Organizations

WRTO (Water Resources Techniqal Organ) of MIWR (Ministry of Irrigation and Water Resources), water resources related departments of MIWR (GD GW&W, General Directorate of Groundwater and Wadi, etc.), water resources related ministries (Ministry of Agriculture and Livestock, etc.), and relevant organizations of the state government (Ministry of Infrastructure and Urban Development, State Water Corporation, etc.).

Implementation Period

August 2016 through March 2023.

Basic Policy on Project Implementation

The final output of this Project is Outcome 4, the process of which is shown in Figure 1-1. By utilizing the results of science-based water balance analysis, water resources and water issues will be identified at the national level (Output 1 and 2), and IWRM will be piloted by promoting the establishment of a participatory consensus-building mechanism with a wide range of stakeholders regarding water resources (Output 3) to make recommendations based on lessons learned from these IWRM practices (Output 4).

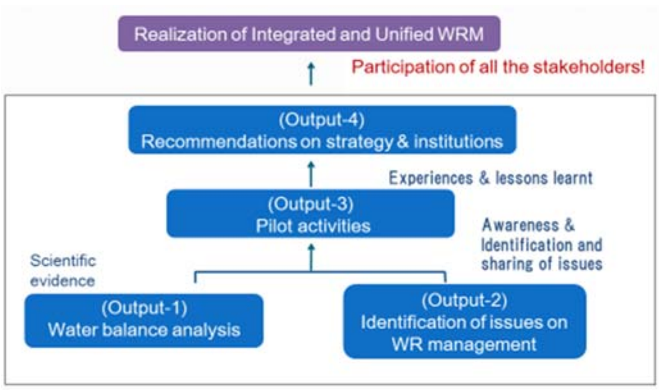


Figure 1-1 Project Outputs and Relationships

Chapter 2: Overview of Water Resources in Sudan

2.1 Overview of Water Resources

(1) Topography and Geology

Sudan is the third largest country in Africa. The terrain is generally flat, with elevations ranging from 200 to 600 meters. The geology of Sudan ranges from Precambrian crystalline basement rocks to Quaternary unconsolidated alluvium. During the Mesozoic, Nubian sandstone sediments formed and were deposited in basaltic and Palaeozoic sedimentary basins. During the Middle to Late Tertiary, tectonic basins formed extensively in Sudan. During the Pliocene and Pleistocene, thick sedimentary layers of the Um Ruwaba Formation were formed in these Tertiary basins.

(2) Climatic Conditions

Sudan is located between 8 and 23 degrees north latitude and 21 and 39 degrees east longitude, and most of the country is classified as having a "mild desert climate". Generally, the rainy season lasts about three months in the north (July to September) and six months in the south (June to November).

(3) Hydrological Conditions

The Nile, one of the world's great rivers, flows from south to north in Sudan, and its tributary, the Blue Nile, joins the White Nile at Khartoum. The flow of the Blue Nile during the rainy season is relatively low compared to the White Nile during the dry season, but is very high during the rainy season. The average monthly flow of the Nile is shown in Figure 2-1.

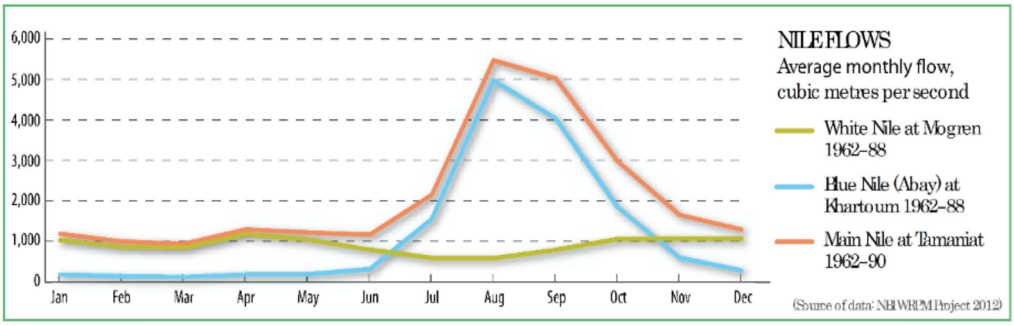


Figure 2- 1 Average Monthly Flow of the Nile River

(4) Hydrogeology

As shown in Figure 2-2, Sudan's major groundwater aquifers cover approximately 95% of the country's surface area. These aquifers can be classified into three main categories based on aquifer type and groundwater availability:

① Bedrock
② Nubian Sandstone aquifer
③ Tertiary sandstone aquifer

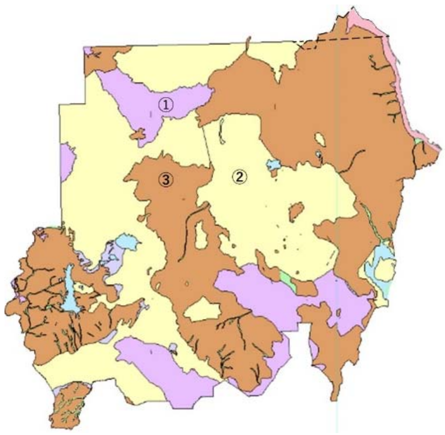


Figure 2- 2 Hydrogeological Map of Sudan
Source: Hydrogeology of Sudan, British Geological Survey

2.2 Organizational System

(1) Ministry of Irrigation and Water Resources

The ministry responsible for water resources was reorganized during the Project period and its new name is the Ministry of Irrigation and Water Resources (MIWR). The organizational chart is shown in the figure below.

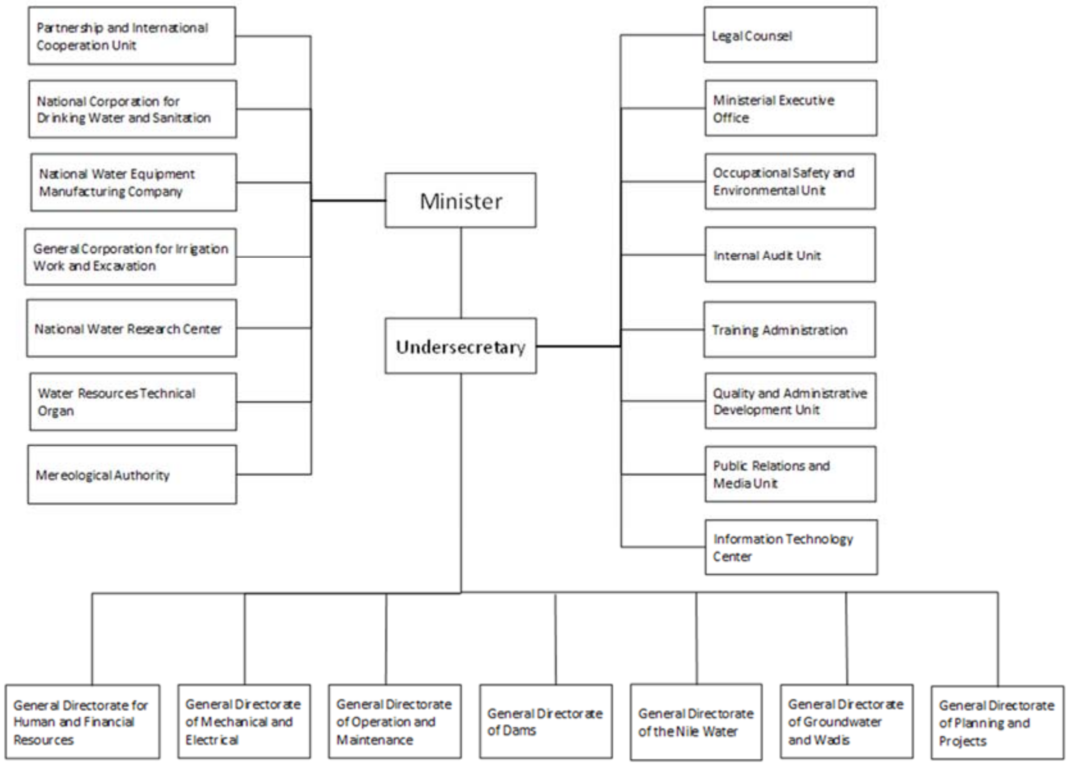


Figure 2-3 Organization Chart of Ministry of Irrigation and Water Resources

Source: Organizational Structure and Job Description, MIWR

(2) Laws and Regulations Concerning Water Resources

The major laws and regulations for water resources are summarized in the next table.

Table 2-1 Laws and Regulation for Water Resources in Sudan

Name	Year	Content
Water Resources Act	1995	This is the core law for water resources in Sudan and was amended in 2021. It stipulates the creation of National Water Resources Council and its functions and powers.
Environmental Protection Act	2001	It stipulates how to protect the environment including water resources.
Regulation for surface water	2016	This regulation is supplement to the Water Resources Act 1995. It stipulates the licensing system for surface water.
Regulation for ground water	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

(3) Water Resources Policy

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.The Country strategy 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. The transitional government prepared a strategy called the “Sudan Water Sector Strategy 2021-

2031 – the promise of the Ministry of Irrigation and Water Resources to Transform the Livelihoods of the People of Sudan (the Water Sector Strategy)" in 2021. The Water Sector Strategy will be operationalized by the following three transformative strategic plans. 1) The National Irrigation Transformation Plan (NITP), 2) The National Water Supply Transformation Plan (NWS-TP) and 3) The National Water Resources Management Transformation Plan (NWRM-TP).

2.3 Society and Culture

(1) Population Movement

The precise population is difficult to project for Sudan since there has been a significant movement of the population. Firstly, 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 Kordofan and Blue Nile states. As of November, 2022, Sudan hosts 1.1 million refugees from the neighboring counties and there are 3.7 million IDPs[1]. Secondly, 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.

One unique characteristic of Sudan is that the country has a significant nomadic population, comprising over 10% of those living in the Kordofan and Darfur States according to the census in 2008.

(2) Ethnicity

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). Each tribe has a traditional authority called the Native Administration (idarra ahliya), which was formally institutionalized by the British during the colonial era. 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

(3) Livelihood

Means of livelihood vary from area to area in Sudan. 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.

(4) Gender

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

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

rights as men. This is particularly true in rural areas in Sudan, although it largely varies between tribes and places.

(5) Participatory approach

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.

Chapter 3: Activities and Results of Phase-1

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 and was dedicated to implement IWRM in the federal government all over Sudan. This phase consisted of a "Water balance analysis" (Output 1) and a "Water issues' analysis" (Output 2) to analyze the current status of water resources in each basin in Sudan using both quantitative and qualitative information in order to understand the challenges. Through the activities in the federal government in Phase-1, a priority region and issues were selected as targets for Pilot activities to address existing issues with water problem solving practices. Activities mentioned below were implemented with C/Ps through technical transfer.

3.2 Water Balance Analysis

3.2.1 Methodology for Water Balance Analysis

Water balance analysis is evaluated by balancing three factors: i) water resource potential of surface water and groundwater, ii) facility capacity for water resource development and supply, and iii) water demand (see Figure 3-1).

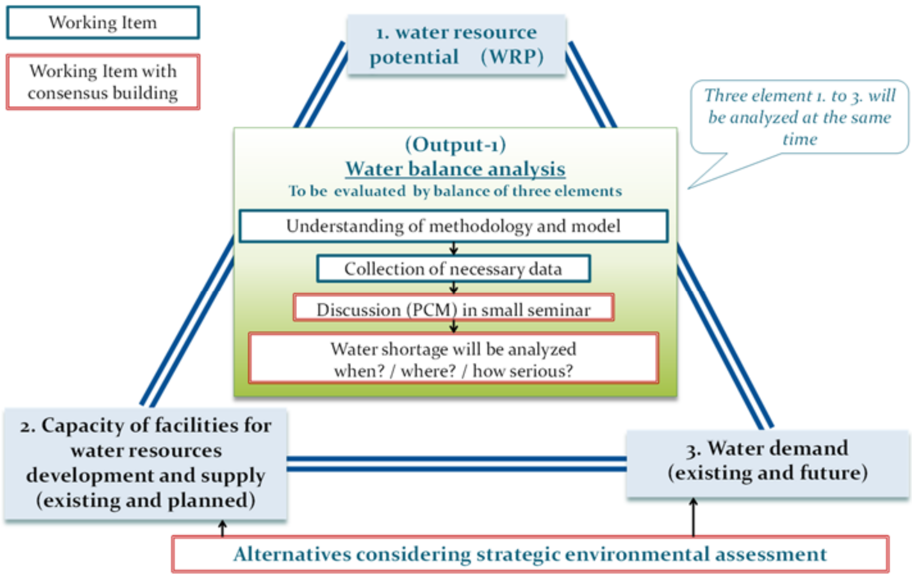


Figure 3-1 Three Components of Water Balance Analysis

3.2.2 Assessment of Water Resource Potential

(1) Assessment of Surface Water Resources Potential

River runoff represents the water resource potential of surface water. It is calculated using a rainfall-runoff analysis and is derived from three main items: input data, parameters (conditions), and computational model.

Definition of River Basin

River basins were delineated based on topographic data. River flow directions and accumulation were estimated using GIS. As a result, Sudan was divided into 177 sub-basins for water balance analysis. Furthermore, from the perspective of future water resources management and development in Sudan, these sub-basins were classified into 12 major sub basins. It is recommended that this classification would be applied for future water resources management and development.

Rainfall Analysis

Observation data from the Sudan Meteorological Agency was collected from about 30 stations and utilized in the calculations. On the other hand, several high-resolution satellite observation data which are available on the internet free of charge, including JAXA's GSMaP, covering the entirety of Sudan, were utilized.

Evapotranspiration Analysis

Potential evapotranspiration (PET) was analyzed using the Hamon equation. The situation regarding the data source for temperature was the same as for rainfall data, using both observatory and satellite data.

Rainfall-runoff Modeling

The rainfall-runoff calculation model used was SHETRAN. An image of the rainfall-runoff model is shown in Figure 3-2. The software was used for rainfall-runoff analysis for the entire Sudan.

Assessment of Surface Water Potential

SHETRAN was used to calculate surface water potential and long-term average annual runoff and runoff ratio. The results are shown in Figure 3-3. The river discharge ratio is less than 5% and less than 1% in most sub basins. The total annual discharge of surface water for the entire Sudan was estimated to be 4.05 BCM.

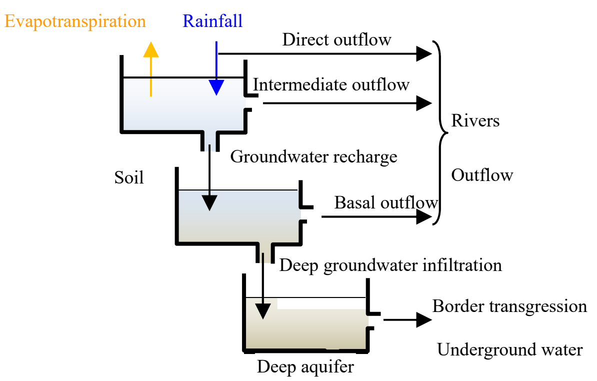


Figure 3- 2 Water resources Potential Assessment Model

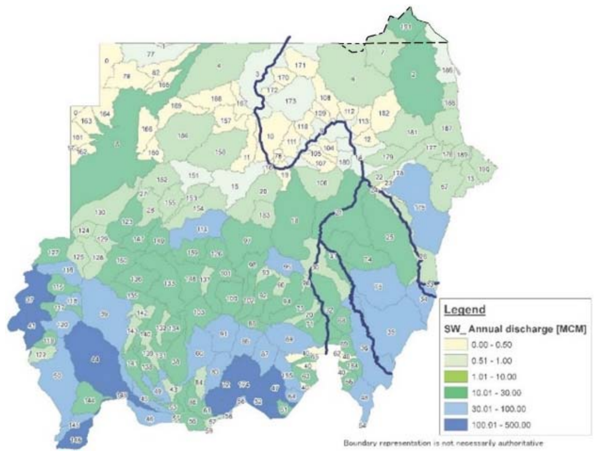


Figure 3-3 Water Resource Potential

(2) Assessment of Groundwater Potential

Aquifer Classification

The hydrogeological map of Sudan is shown in Figure 2-2 of Chapter 2 based on which Aquifer is classified into 3 different types. Following this classification, a groundwater development and management plan was formulated. Groundwater recharge was estimated using soil water balance. Soil water balance was analyzed using daily precipitation for 33 years (1980-2013).

Groundwater recharge was analyzed through long term rainfall runoff analysis. Formula for calculation is shown below.

$GR = 0.0005 \times P^{2.43}$ (see Figure 3-4)

GR: Groundwater recharge rate (mm/year)

P: Precipitation (mm/year)

The analysis shows that the average annual groundwater recharge rate for the entirety of Sudan is 25.7mm/year, equivalent to 12% of the average annual precipitation, and the groundwater recharge rate is estimated to be 24 BCM/year (see Figure 3-5).

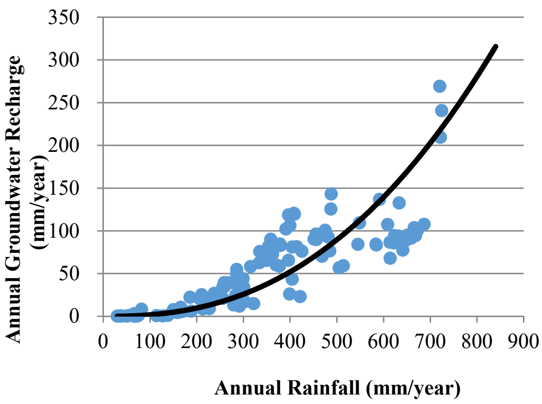


Figure 3-4 Rainfall and Groundwater Recharge

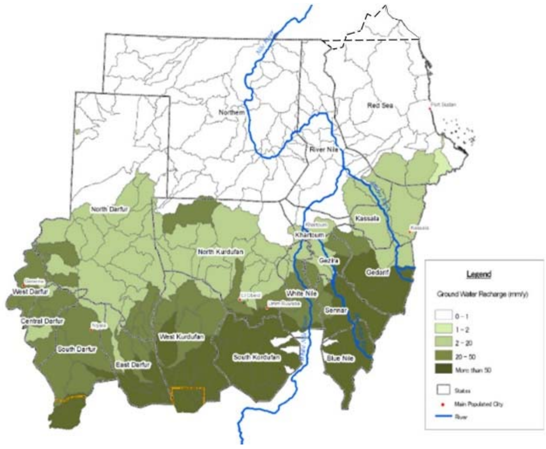


Figure 3-5 Groundwater recharge by Sub Basin

3.2.3 Water Resources Development and Supply Facilities

Regarding surface water, dams and hafirs (reservoirs) are typical facilities for water resource development and supply. For the Nile River, where there is a constant flow of water, a total of four large dams have been constructed on the Blue Nile and Atbara Rivers, and one large dam on the White Nile. In the non-Nile areas, small dams (rainwater harvesting dams) have been constructed across the wadis to store rainfall during the rainy season. Hafirs have also been constructed along the wadis. The water from the wadi is channeled through a short channel to the hafir. There are also hafirs that collect rainfall through catchment landforms. Both small dams and hafirs are designed to store rainfall during the rainy season and are not replenished during the dry season, so the sustainability of water storage is highly uncertain.

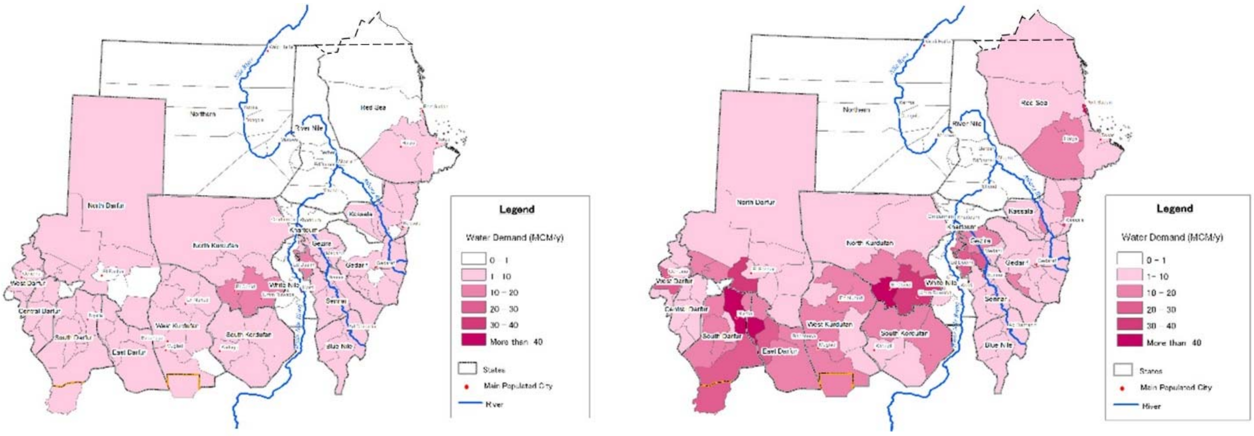
Groundwater is pumped through wells. There are two types of wells: shallow wells that draw water from shallow aquifers and deep wells that pump water from deep aquifers. Shallow wells are classified into shallow dug wells (hand dug to a depth of 20 m or less) and borehole wells (machine drilled to a depth of 300 m or less). Deep wells are generally drilled by machine to a depth of up to 300 meters. Water can be pumped from the wells throughout the year, both during the wet and dry seasons.

3.2.4 Estimation of Water Demand

(1) Domestic Water Supply

Domestic water use consists of drinking, cooking, bathing, flushing, washing water, and other forms of 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).

Water demand projections were calculated using population, classification of settlements based on water demand projections, water supply coverage, target population, and unit water use. The total water demand (urban, village, and nomadic) in 2015 was 223 MCM and estimated to reach 519 MCM in 2035 (see Figure 3-6).



a) 2015 b) 2035

Figure 3-6 Water Supply Demand in a) 2015 b) 2035

(2) Agriculture (Irrigation)

<u>Current Estimates of Irrigated Agricultural Water Demand (2015)</u>

Irrigation water demand is derived from the unit water demand of major crops and crop production. Water demand is the sum of the water requirements of each sub basin and crop group. Sudan was classified into four individual agro-climatic zones (ACZs) (see Figure 3-7). In this estimation of irrigation water requirements, water requirements for flood irrigation were not considered as irrigation water demand.

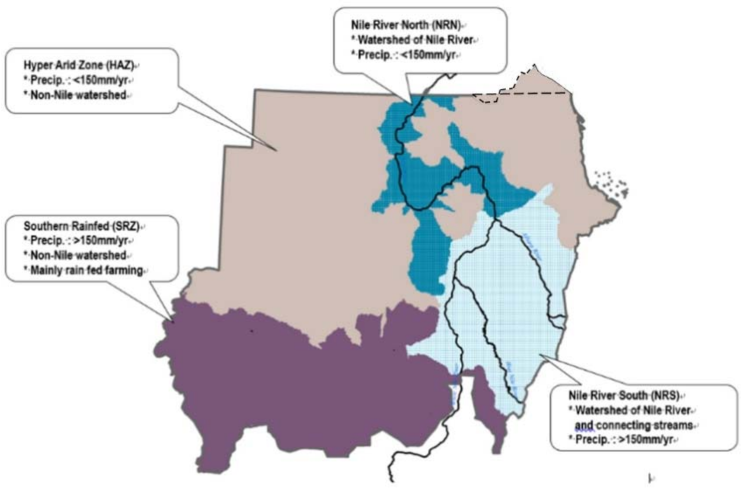


Figure 3-7 Agro-climatic Zones (ACZ)

<u>Current Irrigated Agricultural Water Demand Estimates (2015)</u>

Crop water requirements were calculated using soil type, temperature (minimum and maximum), precipitation, relative humidity, evaporation, wind speed, sunshine hours, cropping pattern and acreage in the sub basins, and soil type. The overall water demand estimate under current conditions in 2015 is 16,117 MCM per year (see Figures 3-8).

<u>Proposed (Future) Irrigated Agricultural Water Demand Estimates (2035)</u>

To estimate the future water demand for irrigated agriculture in 2035, various reports on irrigation development and rehabilitation plans and strategies in Sudan were consulted, plus the consideration of water demand reduction through promotion of IWRM. The overall water demand was estimated at 29,980 MCM per year (see Figures 3-9).

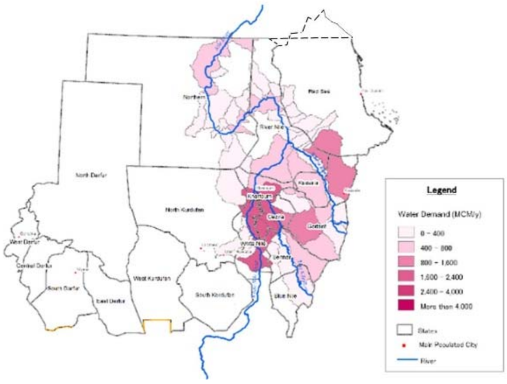


Figure 3-8 Water Demand of Irrigated Agriculture (2015)

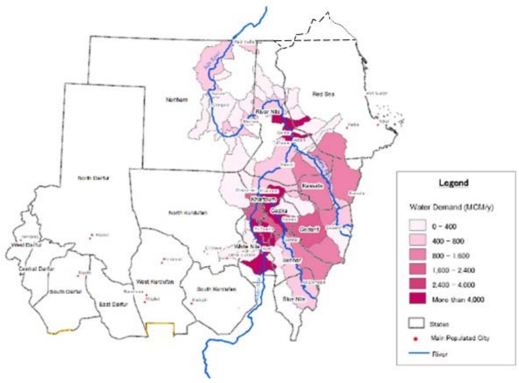


Figure 3-9 Water Demand of Irrigated Agriculture (2035)

(3) Livestock

Estimated Current (2015) and Future (2035) Water Demand for Livestock.

To estimate the water demand for livestock, the current and future number of livestock were estimated and multiplied by the FAO proposed standard water requirement per livestock in the tropics. The resulting livestock water demand is 338 MCM in 2015 and 381 MCM in 2035.

3.2.5 Water Balance Analysis

(1) Water Balance Analysis for 2015

A water balance analysis for the year 2015 was conducted to determine the current water supply capacity. First, information on the current existing hafirs, dams, and wells were collected. Then, the following steps were taken to analyze the water balance for that year.

a) Water balance analysis was conducted for 177 sub-basins that were delineated for long-term rainfall-runoff analysis.
b) Monthly wadi flow (m^3/month) and groundwater recharge (m^3/year) obtained from long-term rainfall-runoff analysis were assigned to the delineated sub basins. Urban, rural, nomadic and livestock water demands estimated for the year 2015 were assigned to the sub-basins.

Below are the results of the water balance analysis.

Total Water Resources

The overall water resources potential for surface water and groundwater combined is shown in Figure 3-10. The northern region of Sudan has lower water resource potential than its southern region.

Total Water Demand in 2015

Total water demand, including urban, rural, nomadic, and livestock water supply, is shown in Figure 3-11 for each sub-basin. The results highlighted an uneven distribution of water demand within Sudan with noticeably high values in Port Sudan, Kassala, Blue Nile, and South Darfur ranging from 10 to 20 MCM/year.

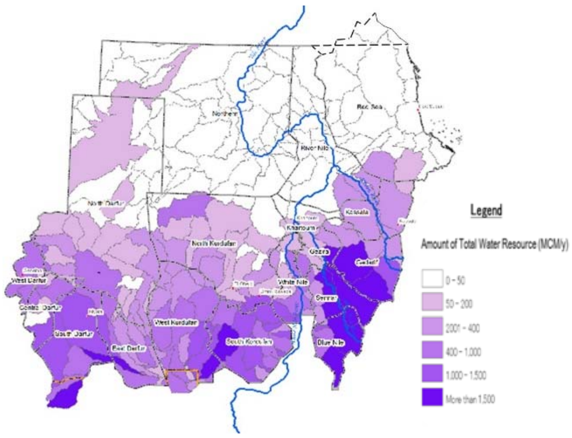


Figure 3-10 Total Water Resources

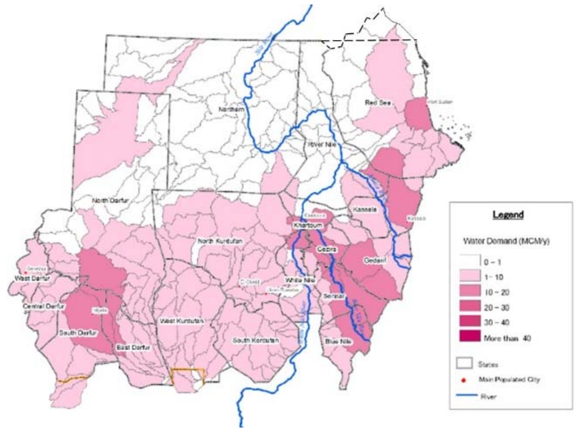


Figure 3-11 Total Water Demand in 2015

<u>Ratio of Water Demand/Water Resources (2015)</u>

Figure 3-12 shows the ratio of water demand to water resources by sub-basin in 2015. As observed, water demand distribution is more uneven than that of water resources. It is also noticed that regions with high ratios (1-50%) present high values of water demand. It is important to note in this context that, generally, that the higher the ratio of water demand to water resources, the higher the risk of water scarcity.

<u>Required Capacity of Surface Water Facilities (2015)</u>

The surface water supply capacity of hafirs, small dams, and other surface water supply facilities for 2015 water demand was estimated by sub-basin and shown in Figure 3-13. This parameter indicates the capacity of existing facilities and provides a baseline for estimating how much surface water supply facilities will be needed in the future to meet 2035 water demand.

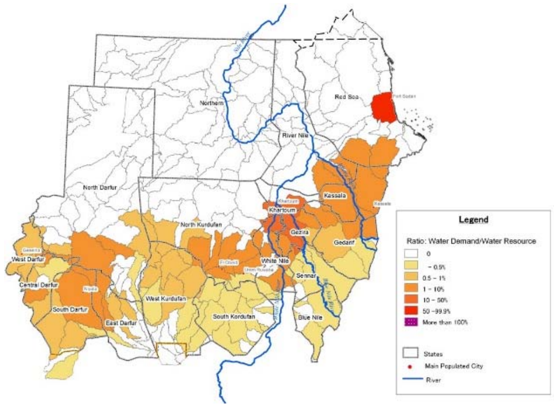


Figure 3-12 Water Demand/Water Resources Ratio (2015)

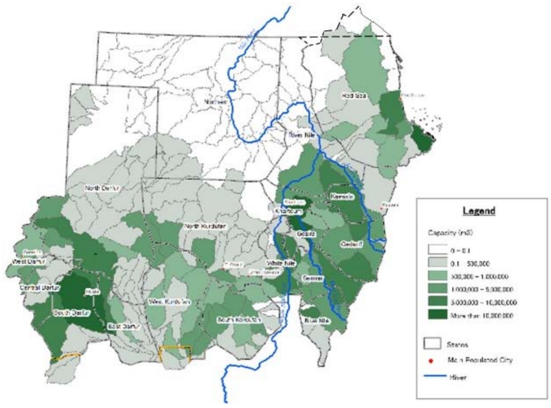


Figure 3-13 Requirements for Surface Water Facilities Capacity (2015)

(2) Water Balance Analysis for 2035

The water balance analysis for the year 2035 was conducted following the procedure described as follows; Water resource potential fluctuates between the wet and dry seasons. Therefore, there will be periods when water supply capacity is less than water demand (see Figure 3-14). Shortening this period is an important aspect in water supply facility planning.

Total Water Demand in 2035

Figure 3-15 shows total water demand in 2035, including urban, rural, nomadic, and livestock. It can be seen that the pattern of distribution of water resources is similar to that of today. However, the uneven distribution of water demand will be more accentuated.

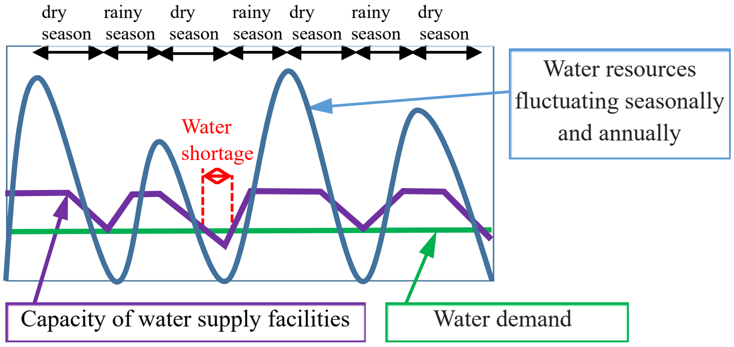


Figure 3-14 Important Points of Facilities Planning

Ratio of Water Demand/Water Resources (2035)

Figure 3-16 shows the water demand/water supply ratio in 2035 for each sub-basin. For the region as a whole, the ratios are considerably higher than in 2015 (Refer to Figure 3-15). In 2035, sub-basins with ratios above 30% are expected to experience severe water supply shortage.

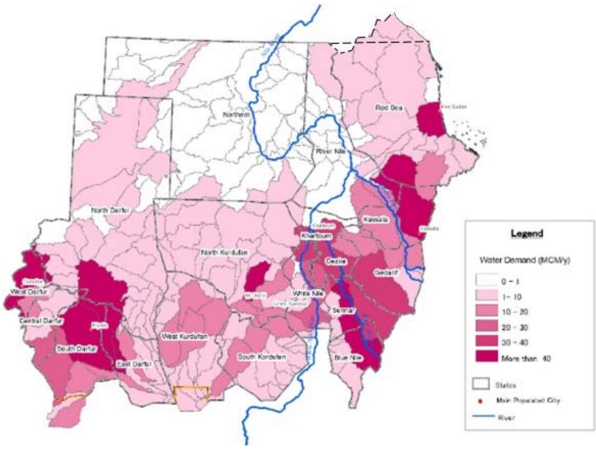


Figure 3-15 Total Water Demand in 2035

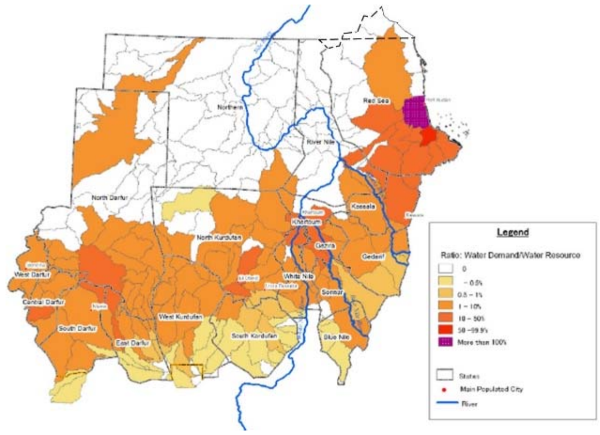


Figure 3-16 Water Demand/Water Resource Ratio (2035)

Required Capacity of Surface Water Facilities (2035)

The required capacity for surface water facilities in 2035 is shown in Figure 3-17. This figure shows the total storage capacity of hafirs and small dams including existing facilities in 2015 (m^3).

Required Pumping Rates from Wells (2035)

The required pumping rates from wells in 2035 are shown in Figure 3-18. In general, the number of wells required will be less in sedimentary rock areas where the pumping rate of individual wells is large, and conversely, the number of wells required will be more in basement rock areas where the pumping rate of individual well is small.

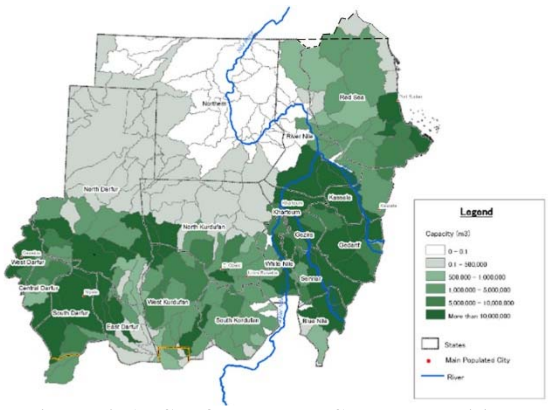


Figure 3-17 Surface Water Storage Facility Capacity Requirements (2035)

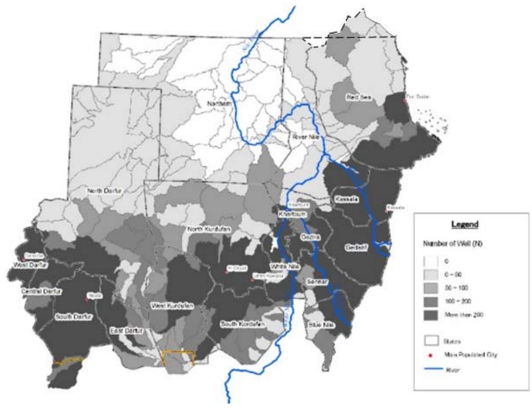
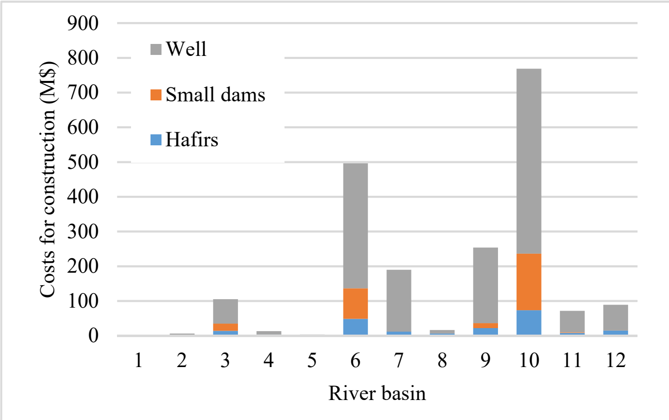


Figure 3-18 Well Pumping Requirements (2035)

(3) Construction Costs

The costs of constructing water development facilities to meet water demand in 2035 was estimated by basin. As can be seen from Figure 3-19, there is a large difference in construction costs for the different basins, with construction costs in basins No. 3, 6, 7, 9, and 10 being larger than those in other basins. In particular, costs are outstandingly high for basin No. 10.



River basis

Figure 3-19 Cost of Constructing for Water Resource Development Facility

3.2.6 Findings and lessons learned from water balance analysis

(1) Main Research Results

The water balance analysis yielded the following key findings.

<u>Characteristics of the Wadi Facilities</u>

Annual and seasonal variations in wadi flow are important which indicates that using average values in evaluating water resources is not appropriate in this case. For sustainable water supply, wadi flow should be discussed in terms of minimum annual and monthly flow values. The total water demand in Sudan is only 2% of the total water resources. However, there is a clear division between wet and dry seasons, with no rainfall during the eight months of the dry season. The amount of water resources available throughout the year is limited. Therefore, sustainable use of water requires the use of facilities to store rainfall during the rainy season. In Sudan, development of surface water has historically preceded development of groundwater. In recent years, however, the development of powerful well drilling machines has made it relatively easy to drill many wells. Ideally, surface water should be used during the rainy season and groundwater during the dry season. Such a conjunctive use of surface water and groundwater is the best combination.

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

As shown in Figure 3-19, the unit cost of developing surface water is lower than that of groundwater. In addition, pumping costs for water supply are generally higher for wells than for dams and hafirs. In other words, operating costs for surface water facilities are lower than costs for groundwater. Therefore, it is more efficient to develop surface water prior to groundwater in the non-Nile areas. In this case, groundwater should compensate for the lack of surface water in a coordinated manner. It should be noted, however, that surface water requires more water treatment than groundwater.

<u>Rainfall Characteristics</u>

Rainfall varies widely from year to year. Therefore, therefore water supply should not be planned based on average rainfall. The following points were recognized regarding the rainfall situation in Sudan

- The less precipitation an area receives, the greater the variability in precipitation.
- Areas with low precipitation also experience high variability in precipitation during droughts. Rainfall during droughts can sometimes be extremely low, almost zero.
- Thus, the less rainfall an area receives, the more difficult it becomes to manage water resources efficiently and the greater the risk of water shortage.

Due to low wadi flow values in 60% of Sudan's sub-basins, it won't be possible to meet 2035 water demands with surface water alone which emphasizes the need for implementing a strategy based on the conjunctive use of groundwater and surface water.

<u>Natural Conditions and Water Supply Patterns</u>

Precipitation and topography/geology factors are the most basic conditions governing water resources in Sudan. The above two factors create four combinations (2 × 2) that govern the nature of water resources development (see Figure 3-20). Water resources development must be undertaken with the following relationships in mind.

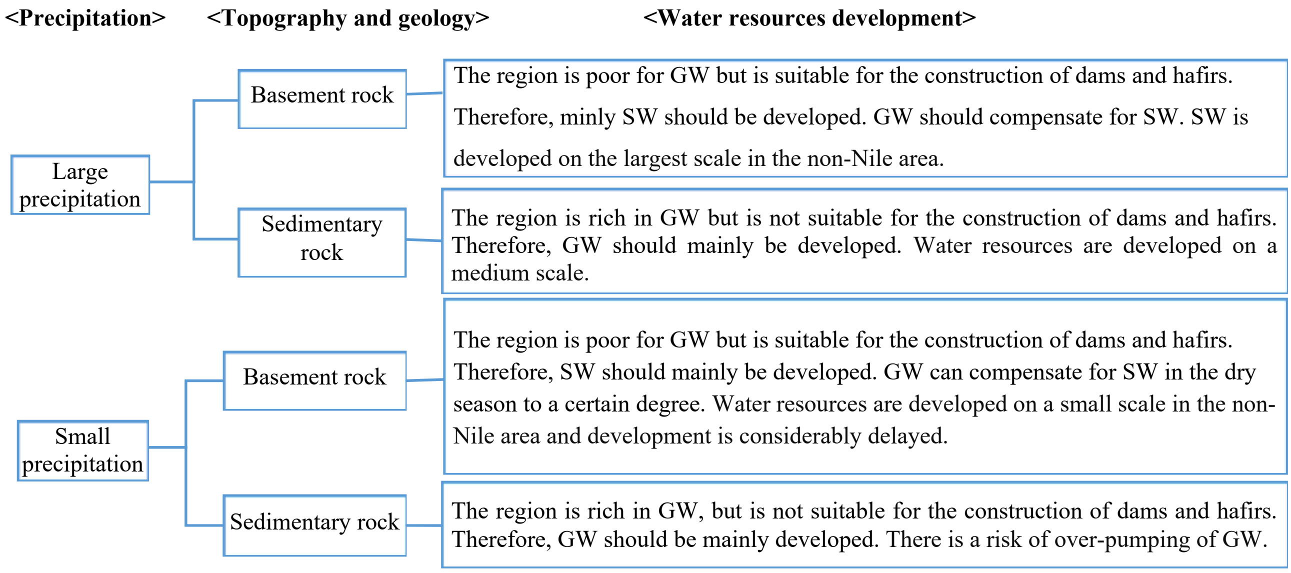


Figure 3-20 Typical Pattern of Water Resources Development in Sudan

(2) Lessons

The following lessons were learned from the water balance analysis.

<u>Technical Basis for Water Resources Potential Assessment</u>

Several water resource potentials for Sudan have been published in the existing literature. However, there is no information that provides the theoretical and technical basis. The present analysis presents the first attempt to conduct a systematic water resources potential analysis for the entire Sudan. When the engineers concerned use the analysis results in the future, they need to understand the theory and technical basis of the analysis from the Project report. The analysis results by SHETRAN should be considered as a first step, and the accuracy of the analysis should be improved by engineers who conduct similar analysis in the future.

Water Usage Rate during Drought

The water supply facilities planned in the water balance analysis were designed to be able to cope with droughts that occur in 10-year return period. However, in a country like Sudan, where the rainy and dry seasons are clearly separated, annual precipitation is low and highly variable, it may be impractical to apply such a criterion. It would be more realistic to set the unit consumption (ℓ/person/day) during the drought season below the normal value. The current standard is 90 ℓ/person/day in urban areas and 30 ℓ/person/day in rural areas, but a more realistic consumption intensity in drought years should be considered in the future.

Hydrological Features of Sudan

The hydrology of Sudan has special characteristics influenced by the arid and semi-arid climates and Sudan's unique topographic and geologic environment. There are still many unknowns regarding the mechanisms of wadi runoff in Sudan. In addition, the existing monitoring data on wadi runoff is not accurate, and the runoff analysis model is difficult to calibrate and unreliable. Therefore, it is highly desirable to strengthen research to clarify the mechanism of wadi runoff and groundwater recharge by rainfall in order to achieve a more reliable water balance analysis.

3.3 Problem Structure of Water Sector in Sudan

3.3.1 Overall Picture of Challenges in Sudan's Water Resources Sector

The findings through the water balance analysis in the first phase, the results of the problem analysis workshops for the various departments of the Ministry of Water Resources and related ministries, and the National Water Resources Survey through a re-commissioning study were integrated to identify the challenges facing the water resources sector in Sudan. Figure 3-21 shows the overall picture.

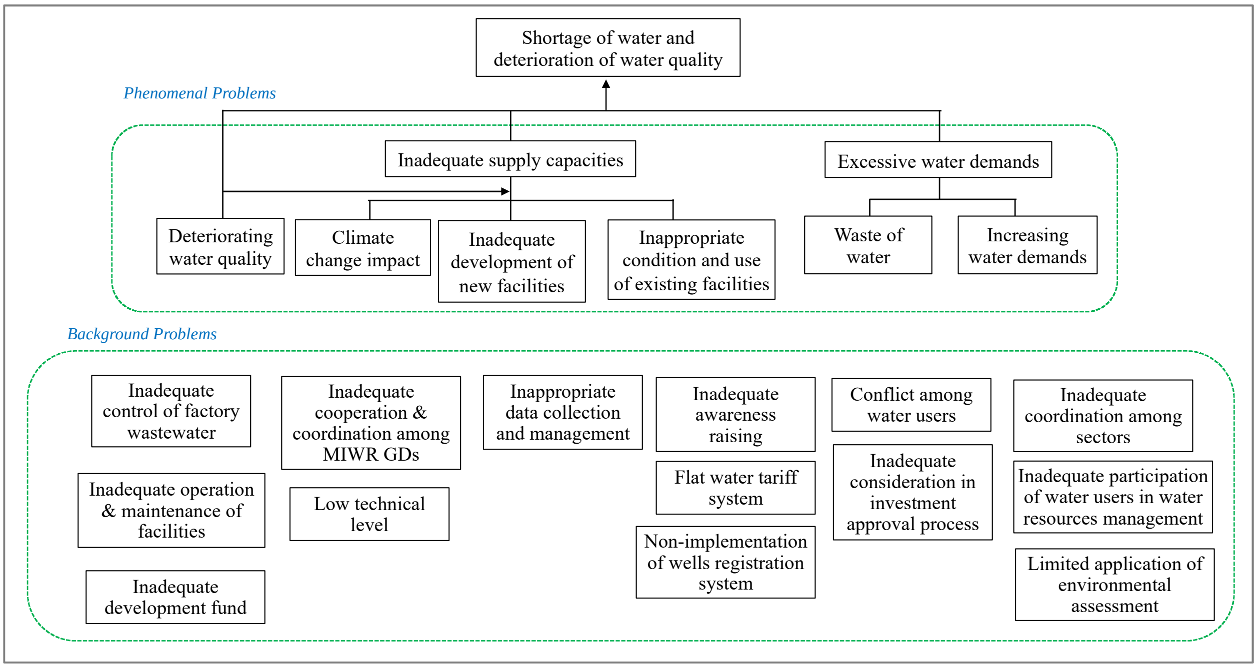


Figure 3-21 Overall Picture of Challenges in Sudan's Water Resources Sector

Sudan's water problems can be summarized as a shortage of water in terms of quantity and a deterioration of water quality in terms of quality. On the quantity side, supply-side factors such as climate change, inadequate development of new facilities, and inadequacy of existing facilities, and demand-side factors such as water wastage and increased demand are the causes. Deterioration in water quality is both a problem in itself, such as causing sanitation problems, and a supply-side factor, such as reducing the amount of safe water.

There are a variety of technical, institutional, social, financial, and other factors that contribute to the various water-related problems and phenomena.

3.3.2 Water-related Problem Phenomena and Background Factors

(1) Water-related Phenomenal Problems

On the supply side, the following phenomenal problems exist.

- Inadequate new facilities: Inadequate development of water supply facilities due to lack of development funds and technical capacity cannot keep up with increased demands.
- Inadequate or inappropriate use of existing facilities
  - ✓ Groundwater drawdown: Groundwater drawdown is occurring in shallow and deep aquifers across the country as a result of over-pumping. Over-pumping for irrigation is the main cause. In the case of shallow aquifers, over-pumping by self-irrigated farmers is seen, while in the case of deep aquifers, groundwater levels decline due to over-pumping caused by large-scale agricultural investments. In some cases, groundwater resources are depleted as a result of declining groundwater levels.
  - ✓ Water scarcity in the basement-rock areas: The basement-rock areas are poor in groundwater reserves, and with the inherently low rainfall, the rainfall during the 3-4 month rainy season is stored in dams and hafir to meet the demand during the remaining 8-9 months of the dry season. As the end of the dry season approaches, water becomes scarce, and in many cases, people are forced to purchase water from water vendors.
  - ✓ Flow path of Nile River: Existing water intake facilities cannot be used due to seasonal changes in the flow path of the Nile River. In addition, there are cases where water intake facilities cannot be used due to sedimentation.
  - ✓ Water supply systems in local cities are aging and not functioning adequately to keep up with increasing water demand.
  - ✓ The supply capacity of dams and hafirs has been reduced due to sedimentation, leaks, and other causes.
- Impacts of climate change: Climate change is causing decreased precipitation, more temporary heavy rains and increased flooding and drought, making a stable water supply difficult.
- Deterioration of water quality
  - ✓ Groundwater contamination is occurring due to natural factors such as salt in the aquifer, fluorine (F), and seawater intrusion in coastal areas. This is especially common in deep groundwater.
  - ✓ Untreated sewage from toilets and runoff of excess chemical fertilizers for crop cultivation contaminate shallow groundwater.
  - ✓ Pollution of surface water includes: (i) untreated wastewater from sugar factories flows into a reservoir and contaminates surface and groundwater from there; (ii) water from irrigation canals is withdrawn for domestic use and used untreated; (iii) nomads steal water from urban water pipes and contaminated water flows in through the broken parts and is supplied to downstream urban residents; and (iv) animals and humans use the same hafir, and animal waste, dumping of garbage,

and lack of water purification facilities have contributed to the deterioration of hafir water quality.

On the demand side, the following phenomenal problems exist.

- Many farmers lack correct knowledge about the proper amount of irrigation and are over-irrigating. Problems such as reduced crop yields due to over-irrigation and building collapses due to rising groundwater levels in Nile-side areas have occurred.
- Under the flat-rate tariff system, urban residents are less concerned about the amount of water they use and tend to waste water.
- Sudan's population growth rate of 3.0%/year from 2011 to 2021 was higher than Africa's overall rate of 2.6%/year. Rapid population growth coupled with water wastage is increasing water demand.

(2) Background Factors Causing Phenomenal Problems

The following technical, organizational, institutional, and social background factors are responsible for the phenomenal problems described above.

1) Supply-side background factors

- <u>Inappropriate information collection and management</u>
  - ✓ Monitoring of groundwater and surface water is limited. Monitoring is to be conducted for three purposes: to assess water resource potential, to ensure effective operation of water source facilities, and to ensure compliance with regulations. There are, however, only limited examples of monitoring conducted in Sudan for assessing water resource potential.

    In the case of groundwater, groundwater recharge is also small due to Sudan's low precipitation, so it is necessary to regulate pumping while monitoring groundwater levels, but this is rarely done. Groundwater in the Nubia sandstone area is used without monitoring, even though it is fossil water and has no recharge.

    Water source facility design with inadequate monitoring data often results in facility failures.
  - ✓ In addition to inadequate monitoring data, sharing of collected data, small in amount though, is very limited. A large amount of data is collected but not properly managed, which means that the data is not available after each project and cannot be used for other projects. Even when data is stored, it is not shared among the parties involved due to unnecessary confidentiality requirements. Data sharing is essential for building consensus among stakeholders in the early stages of water resource development. An example of the lack of information sharing has been seen in North Kordofan State, where an Africa Development Bank-supported water supply project was abandoned due to disagreement between the federal Ministry of Irrigation and Water Resources, the state government, and local communities.
- <u>Poor technical capability</u>:

  The problem is the low technical capability of the technical staff in charge. An organizational problem exists in which the lack of status and income commensurate with capability results in low motivation among technical staff. The General Directorate of Groundwater and Wadi, which is in charge of water resources development in non-Nile areas, lacks young engineers who should inherit the experience of senior engineers. Another problem is seen in that the General Directorate of Groundwater and Wadi has been functioning with the consultant status of the Dam Implementation Unit (DIU) and not fully executing its original mandates, although the situation has improved since 2019.

  Water resource development plans are not developed on a watershed basis, which can lead to the malfunctioning of facilities that have been constructed. A lack of scientific knowledge regarding safe pumping rates has led to unrestricted groundwater development and a lowering of the groundwater table.

Inadequate maintenance and management of facilities: Hafir is not adequately maintained due to low user fees. For urban and village water supply, facilities are inadequately maintained and function poorly due to a lack of spare parts. For rural water supply facilities, the VWSC (village water supply committee) does not function well, and water users are not fully involved in maintenance, resulting in inadequate maintenance. Insufficient maintenance of irrigation canals causes sedimentation and overgrowth of weeds, which reduces the water delivery capacity of the canals.

2) Demand-side, social, and institutional/organizational background factors

- Lack of water conservation awareness: A flat rate pricing regime is applied to general household water users of urban water supply, and water users only pay a fixed amount regardless of the amount of water they use. Combined with a lack of awareness-raising activities, this flat water tariff system has led to an increase in water demand. Irrigated farmers lack knowledge of the appropriate amount of irrigation water and tend to irrigate more frequently and with more water than necessary, raising irrigation water demands more than necessary.
- Social conflicts: Conflicts between nomads and farmers, especially in the southern region of Sudan, are limiting access to water sources. As farmers expand their agricultural lands, nomads are prevented from traditional nomadic routes and are forced to find detour routes, resulting in poor access to water. Ethnic conflicts and other major issues surrounding water are often the cause.
  In addition, there are many cases of conflict over water between urban water users, between upstream farmers and downstream urban residents, and between upstream and downstream residents.
- Inter-sectoral coordination: The lack of inter-sectoral coordination at the federal and state levels has led to problems in inter-sectoral water allocation, such as improper allocation of water between irrigation and hydropower. The National Water Resources Council, established in the 1990s, was created to address this situation, but after holding only a few meetings, it has fallen dormant and has not functioned to date. Coordination among sectors such as water resources, agriculture, livestock, and energy is of particular importance.
- Approval process for large-scale agricultural investment: In recent years, the number of large-scale agricultural investment projects by foreign investors has been increasing, and in many cases, groundwater is used as a water source. However, water resource aspects are not fully considered at the investment approval stage. The risk of depletion of groundwater resources exists because the investment is approved without the concept of safe pumping capacity.
- Lack of a groundwater licensing system: the Groundwater Law, which came into effect in 2016, requires registration of groundwater development and use, but has not been fully applied in the field. As a result, licenses are being granted and well drilling is proceeding unchecked, with a lack of judgment on appropriate groundwater development levels and pumping rates.
- Lack of regulation on factory effluent: In Sudan, regulations on factory effluent do not exist, resulting in the untreated discharge of sugar factory effluent in the White Nile and Blue Nile Rivers, degrading the water quality.
- Environmental Impact Assessment: Although the Environmental Protection Law of 2001 mandated that environmental impact assessments be conducted by project implementers, few assessments have been conducted due to a lack of understanding among implementers and government officials

regarding the content of the mandate and the process. Without proper environmental impact assessments, there is a risk that projects that may have serious environmental impacts will be implemented without any checks and balances.

- <u>Lack of coordination and cooperation among MIWR's departments</u>: MIWR's departments rarely cooperate or coordinate in the form of utilizing common databases, utilizing research results, etc. The lack of a common database has led to inefficiencies in collecting data again from scratch each time a new project is initiated. The scientific approach is inadequate, as decisions are made relying on readily available information and solutions without fully utilizing the results of research.

.

Chapter 4: Activities and Results of Phase-2

4.1 Activities in Phase-2

The second phase of the Project consisted of pilot activities and recommendations related to water resources. It was implemented from August 2019 to March 2023. The North Kordofan State was selected as a priority area to implement pilot activities through the Phase-II of the Project, and activities to put into IWRM's practice the solutions to the problems (Output 3) were carried out.

The pilot activities were conducted in a participatory manner with the participation of stakeholders, including administrative agencies and water users (farmers, residents, etc.) in the North Kordofan Region, and were intended to lead to the resolution of water issues and to be reflected in recommendations (Output 4) for legislation, planning, organizational structures, and methods for water resource management. Activities mentioned below were implemented with C/Ps through technical transfer.

4.2 Selection of Pilot Activities Area

(1) Selection Process for Pilot Activities Area

In selecting candidate region for the pilot activities, water problems currently occurring throughout Sudan were identified and narrowed down based on the following four selection criteria.

① Severity of the water problems
② Need for IWRM
③ Reproducibility in other regions
④ Possibility of efficient achievement through pilot activities

Figure 4-1 shows an overview of the water problems and the sub-basins where water problems were identified.

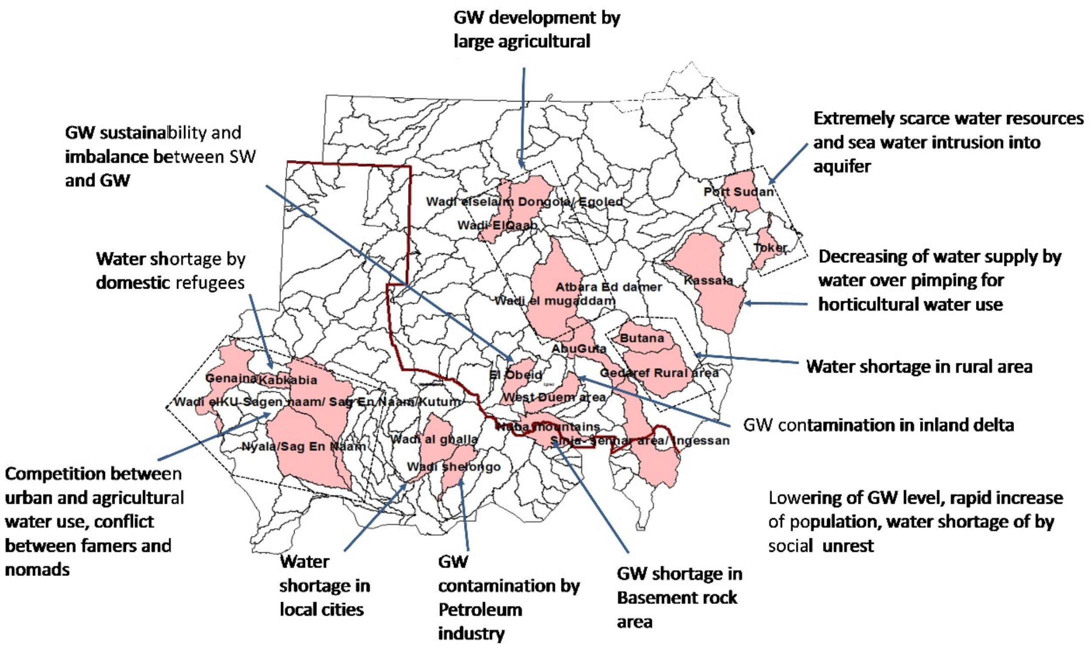


Figure 4-1 Water Problems and Sub-Basins Where Water Problems Were Identified

To identify water problems, the Project team and the University of Khartoum jointly conducted a listing of water problems in various regions of Sudan. As a result, water problems were identified in 23 regions.

(2) Selection of Pilot Activities Regions

To determine the target region for the pilot activities, the Project team reviewed 23 regions based on the selection criteria and narrowed down the selection. As a result, North Kordofan State was selected as the target area for the pilot activities. The selected state presents many similarities with other regions in Sudan in terms of IWRM such as, kind of water resources, purpose of water usage, number of water issue across the basins, variation of stakeholders. Within North Kordofan State, the area of the Bara Basin was selected as the target region for implementing the pilot activities. The region has cross-sectoral water issues that have a high priority for IRWM due to the large number of stakeholders in the region.

4.3 Current Status of Pilot Activities Area and Water Resources Challenges

(1) North Kordofan State and Bara Locality

There are eight localities in North Kordofan State and population by locality is as follows.

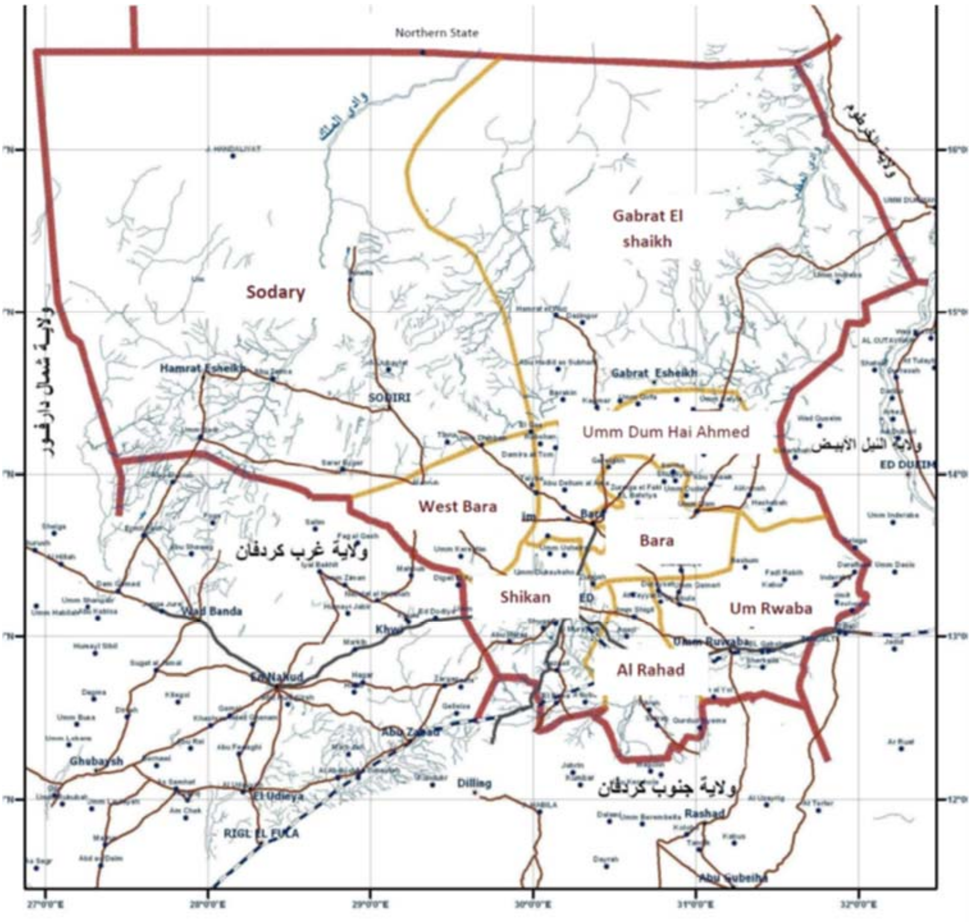


Figure 4-2 Map of North Kordofan State

Table 4-1 Population by Locality

	Locality	2018 (Estimate)
1	Shiekan	704,475
2	Um Rwaba	452,846
3	Um Dum Haj Ahmed	175,151
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 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 4-2 Population of Major Cities and Towns in North Kordofan

Cities and Towns	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

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 share of the agricultural sector is around 70%, the industry sector equates to 5-6% and the service sector, 22-23% from 2012-2016.

(2) Baseline Survey

The Project conducted a baseline survey in 2018 to understand the target areas and water use. The target area of the survey is Bara town and the Bara Rural Administrative Unit, which roughly corresponds to the Bara sub-basin (Al Bashiri sub-basin), as shown in the figure. This area includes Bara town and its vicinity. The target groups are irrigation farmers, rain-fed farmers, settled pastoralists, nomads passing through the target area, urban residents in Bara town and El Obeid city and rural residents in the target area (the Bara Rural Administrative Unit) utilizing GW from shallow wells.

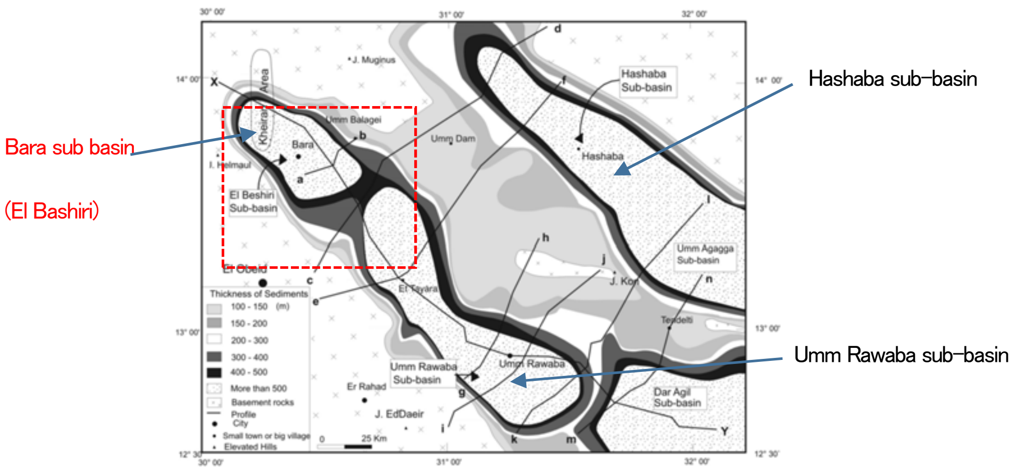


Figure 4-3 Target Area of Baseline Survey

Major findings are summarized below.

- El Obeid citizens are the group most dissatisfied with the current water supply. The dissatisfaction rate is as high as 47% in summer, however 100% are satisfied in other seasons. This is because urban water supply is insufficient in the summer and considerable sums of money have to be spent to purchase water.
- 93% of the irrigation farmers answered that they would expand their irrigated farms, 70% of rain-fed farmers would start irrigated farming, 65% of permanent pastoralists would increase the number of livestock, and all 40 villages

answered they wanted new wells. An increase in water demand is expected in the future.

- No major conflicts over water use were reported between nomads and settled farmers.
- 43.5% of the irrigation farmers and 8% of the villages answered that the groundwater level of the wells they use has decreased.
- 91% of Barra Town residents and 47% of El Obeid residents are concerned about future sustainability of water resources.
- The traditional leaders and the popular committees play important roles in water resource management.
- Women and youth are not able to participate in decision-making on water management

(3) State Ministry

The Ministry of Infrastructure and Urban Development (MIUD) is responsible for water resource in North Kordofan State and the organization chart is shown in the figure.

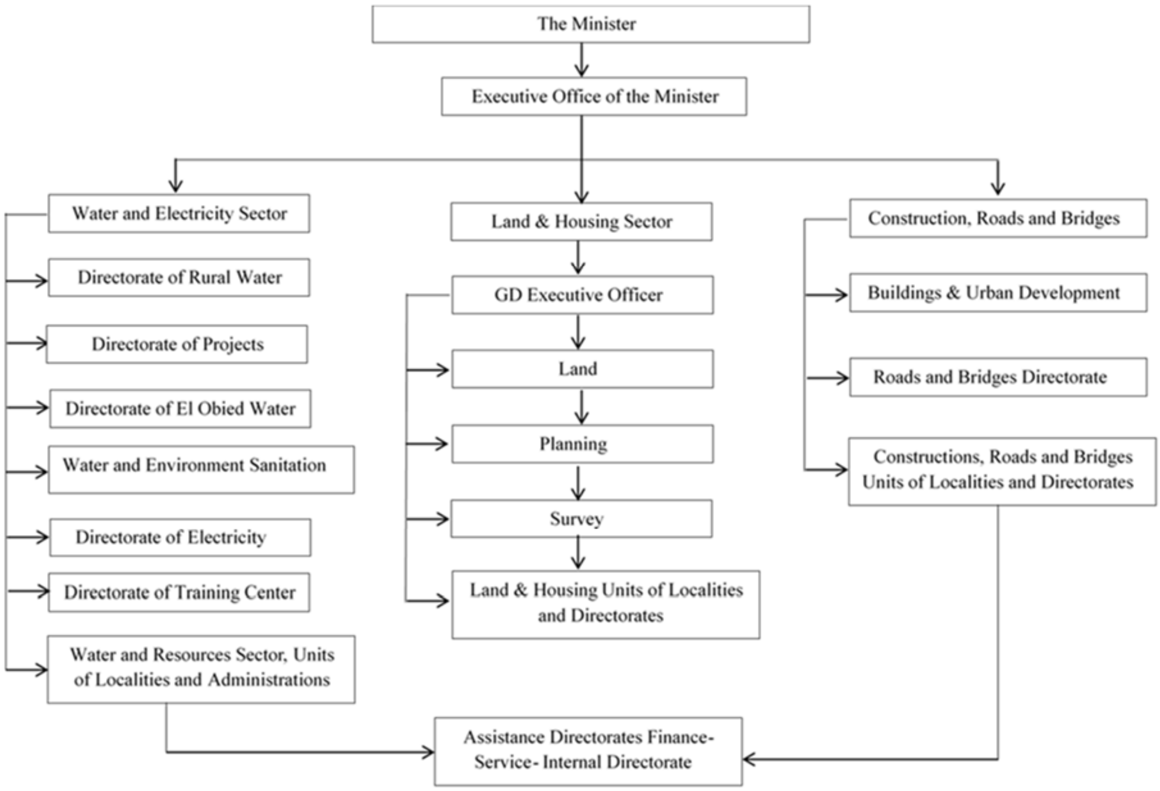


Figure 4-4: Organizational Chart of the Ministry of Infrastructure and Urban Development

(4) Water Problems in the North Kordofan Region

The analysis of water issues in North Kordofan State at the beginning of the pilot activities revealed that a huge amount of water resources are being used for various purposes, including domestic use and irrigation, without monitoring, and that the sustainable use of these resources in the future is threatened. The water resources of El Obeid, the capital of North Kordofan State, consists in groundwater in the northern region and surface water in the southern (see Figure 4-5). From 2001 to 2013, groundwater levels were observed by the Sudanese side (see Figure 4-6). Based on these observations, a decrease in the groundwater level was noted during this period. This means that the groundwater level has been decreasing at a rate of 1.5 m to 2.3 m per year. However, groundwater levels have not been monitored since 2014.

Bara Town, the capital city of Bara Locality, is located near the Al Sidir well-field, and a large amount of groundwater is pumped from shallow wells in Bara town for domestic use and irrigation. The decline in groundwater levels in the shallow wells is thought to be due in part to excessive pumping of water from the Al Sidir well-field. In general, when large amounts of groundwater are pumped from deep aquifers, groundwater in shallow aquifers moves into deep aquifers (see Figure 4-7). Therefore, pumping of groundwater from the deep aquifer in the Al Sidir well-field will cause groundwater levels in the shallow wells in Bara town to lower. Furthermore, the drawdown of the groundwater level in shallow wells in Bara town is mainly due to over-pumping of many shallow wells in and around Bara town, as shown in Figure 4-8. The results of the analysis of these water problems are shown in Figure 4-9.

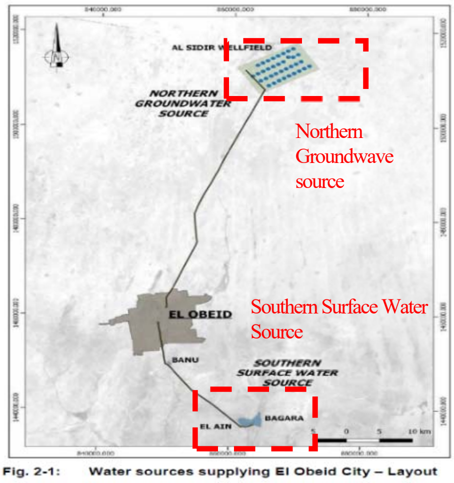


Figure 4-5 Two Water Sources in El Obeid

As a conclusion of the above analysis, the following three water problems in the area were identified.

- Decline in groundwater levels in deep aquifers
- Decline in groundwater levels in shallow aquifers
- Deterioration of water quality in shallow aquifers

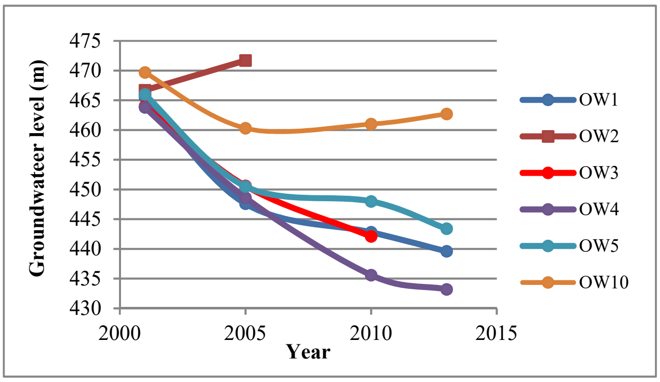


Figure 4-6 Monitoring Results of Al Sidir well Field

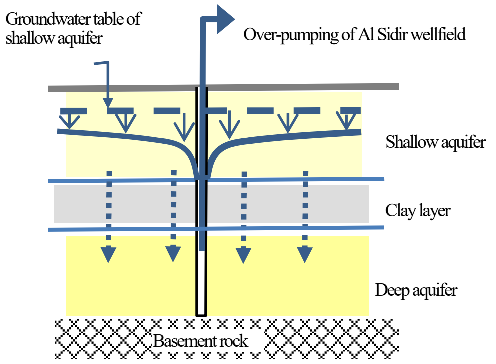


Figure 4-7 Relationship between Shallow and Deep Aquifers in Al Bara town

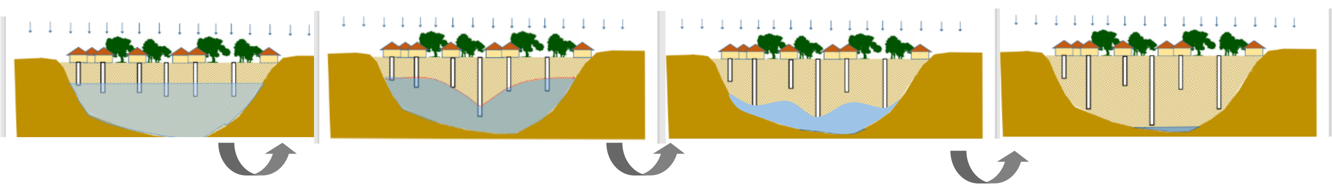


Figure 4-8 Well Interference in the Town of Bara

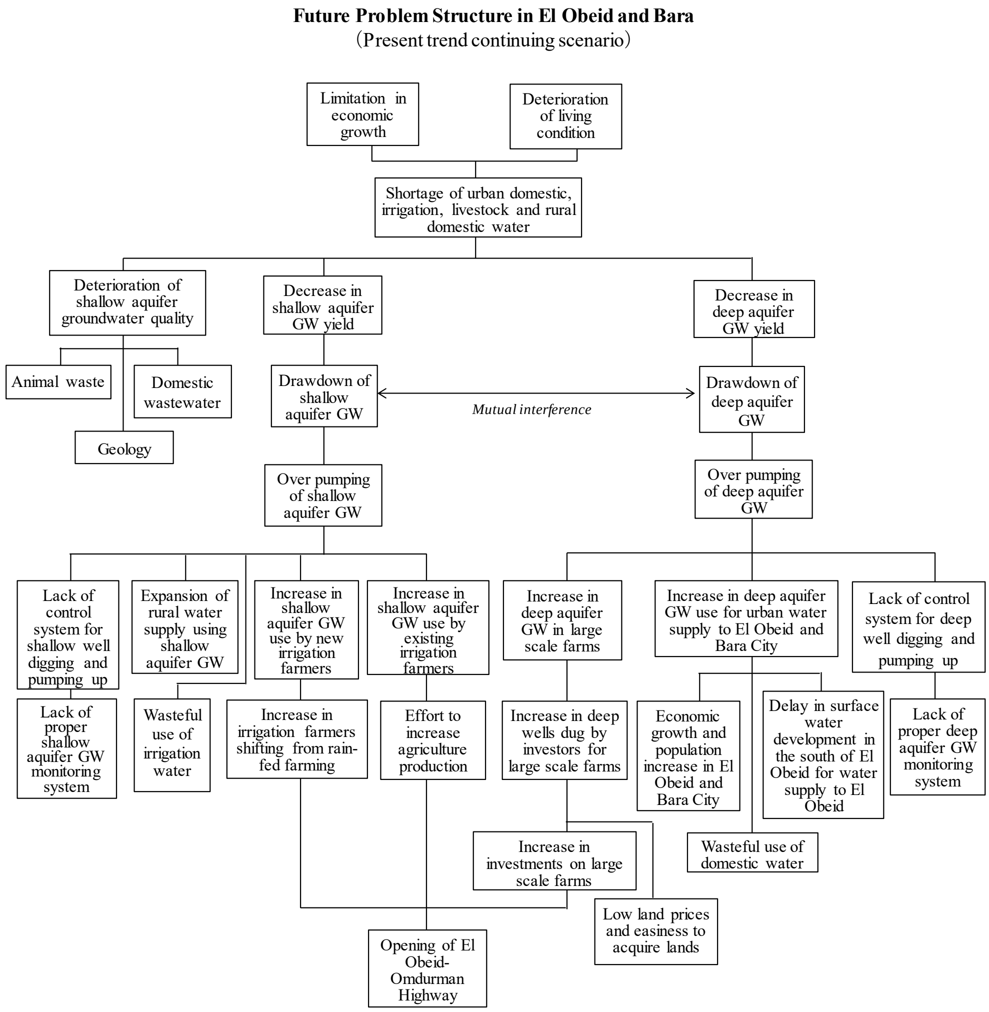


Figure 4-9: Analysis of Water Problems

4.4 Overview of Pilot Activities

Objectives of Pilot Activities

The objectives of the pilot activities are the following.

- to evaluate the risk of groundwater depletion of the Al Bashiri Sub Basin, identify required actions to minimize such a risk and implement them 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

Selection Process and Results of Pilot Activity Selection

Pilot activities in the Bara region were selected according to the following procedure.

Step (1): Listing of water-related activities planned 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, then assessment by the

C/Ps considering the actual situation in North Kordofan

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

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

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

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

First, the above work was done in cooperation with the State Government C/P. It was then discussed between JPT and the C/Ps. The pilot activities and budget finally approved are shown in Table 4-3.

The unique feature of this attempt is that, in selecting the above-mentioned pilot activities, the selection was made from the perspective of enhancing the effectiveness of water-related projects planned under the existing budget rather than devising and applying new IWRM activities. By positioning the activities as complementary to and enhancing the effectiveness of the originally planned activities, it was possible to smoothly gain the understanding of state officials.

Table 4-3 Description and Budget of Pilot Activities Approved by the SC

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

Subsequent discussions between JPT and the C/Ps resulted in the exclusion of items 2, 3.5, and 3.6 from the activity items, and the four themes of "1. Database establishment", "3. Monitoring", "4. Well registration system" and "5. Water-saving irrigation" were determined to be the pilot activities. Furthermore, following UNEP's subsequent withdrawal from support for the establishment of the State Water Resources Council (SWRC), it was decided to include this initiative in the pilot activities. Table 4-4 shows the relationship between each pilot activity and the three problems in the Bara area, namely, the "decline of shallow groundwater level," "decline of deep groundwater level," and "deterioration of shallow groundwater quality," and the pilot activities.

Table 4-4 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

The MIWR's C/Ps took the opportunity of the implementation of the 1995 Water Resources Amendment Act ("the Amendment" hereafter) in August 2021 to start considering concrete measures to reactivate the National Water Resources Council as stipulated in the Amendment, with the intention of promoting IWRM nationwide. JPT supported this initiative regarding it as equivalent to the pilot activities in North Kordofan State.

4.5 Implementation of Pilot Activities

4.5.1 Establishment of IWRM Promotion Structure

(1) Establishment of the State Water Resources Council (SWRC)

1) Objectives and Activities

In North Kordofan State, the SWRC was officially established in February 2022. The establishment of the SWRC was not included in the pilot activities initially because UNEP was supporting it when the pilot activities under the JICA IWRM Project were selected. However, since UNEP subsequently terminated its support, JPT and the North Kordofan C/Ps agreed to support the establishment of SWRC as a Pilot Activity.

The purpose of establishing the SWRC was to create a structure for cooperative water resource management between state governments and water users in coordination with relevant organizations and institutions. Activities included reviewing the UENP proposal, preparing a proposal to the state governor, preparation for the formal launch of the IWRM Unit, and enhancing the capability in managing meetings. The following is a chronological description of the activities undertaken.

The process from preparation to the establishment of SWRC can be divided into the following three phases.

- Support by UNEP (April 2018 - early 2020)

- Support by JPT (early 2020 - February 2022)
- Formal establishment and holding of SWRC meetings (February 2022 – March 2023)

Support by UNEP

After UNEP supported the establishment of an SWRC in Kassala state, it started to support the establishment of an SWRC in North Kordofan State with a similar concept. The purpose of the SWRC was proposed to be to provide advice for the proper management of natural resources, particularly water. Various functions were proposed, including awareness-raising and inter-sectoral coordination, many of which were taken over by the JPT for support.

A single-tier structure of the SWRC was envisioned, with a representative of the Environment Committee as Chair, a representative of MIUD as Vice Chair, and 16 other relevant government organizations and private sector representatives as proposed members, with a primary mandate to provide advice.

Support by JPT

Following UNEP's withdrawal in early 2020, JPT took over support for the establishment of the SWRC. The JICA project management structure included Steering Committee and Technical Committee (TC) designated by a North Kordofan State decree. This management structure was assumed to be transferred to new SWRC system once it is established because of the similarities of the functions.

Preparations for the establishment of the SWRC structure by JPT were based on the basic concept of realizing the consensus building cycle shown in Figure 4-10. Three organizational units were envisioned: a Water Users Committee (WUC) to represent water users, a Technical Committee (TC) to share and discuss water-related information at the technical level, and a Steering Committee (SC) to make decision. The proposal was prepared and submitted to the Governor of North Kordofan in December 2020. The following is a summary of the proposal.

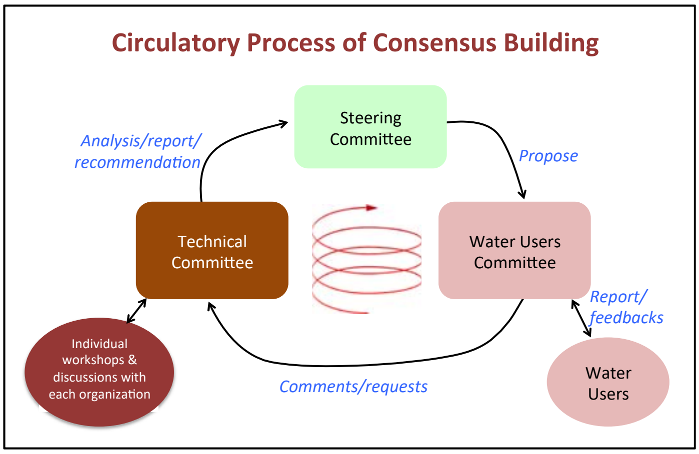


Figure 4-10 IWRM Consensus Building Cycle

- Objective: To share information and discuss among water-related stakeholders based on scientific judgment, and to cooperate in implementing solutions.
- Functions: Awareness-raising, inter-sectoral coordination, strategy development, capacity building, policy and legislation development, monitoring and evaluation of activities, coordination of issues related to watersheds and aquifers across states, advice on licensing, addressing all water issues
- Members: (SC) The governor of the state is the supervisor, the undersecretary of the state is the deputy supervisor, the minister of MIUD is the chairman, the minister of the Ministry of Economy and Production is the deputy chairman, and the following 5 members (Environmental Commission, Senior Legal Officer, Director General for Water and Energy of MIUD, Director General for Agriculture of Ministry of Economy and Production, Director General of General Directorate of Ground Water Wadi Kordofan Office) (TC) Chaired by the MIUD Director for Water and Energy, Vice-Chaired by the Director of the

Agriculture Department of the Ministry of Economy and Production, and 18 other relevant ministries and organizations, including WUC representatives

- Structure: As shown in Figure 4-11
- Frequency: Twice a year for SC and four times a year for TC

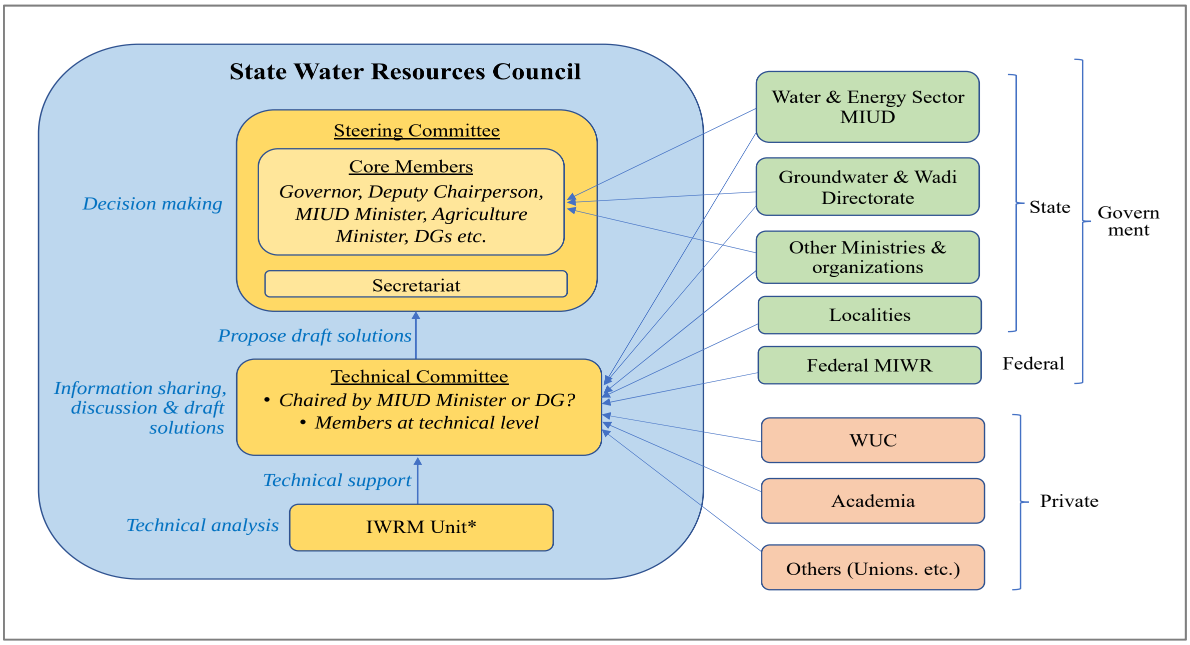


Figure 4-11 Configuration of the SWRC Proposed to the Governor in December 2022

The proposal has the following features

- During the preparation process, there was some discussion about the selection of the chairperson. There were two proposals: one was to have the governor of the state as chairperson to provide strong coordinating capacity, and the other was to have the MIUD minister, who could easily attend each meeting, serve as chairperson. A middle ground between the two was proposed as a result, with the state governor involved in a supervisory capacity and the MIUD minister serving as chairperson. The idea is that the governor's involvement would provide sufficient coordination capacity, while the MIUD chairperson, who is in charge of water issues, would preside over each meeting to enable regular meetings on behalf of the governor, who is too busy to deal with all the various issues facing the state.
- While UNEP proposed a single-tier structure for SWRC alone, the proposal proposed a multi-tier structure consisting of SC, TC, and IWRM units. It envisaged a division of roles in which the SC would make decisions after the analysis and coordination among sectors at the technical level by TC, rather than merely providing advice. If monitoring, water balance analysis, and cooperation with water users are already in place on an ongoing basis, then the SWRC could coordinate on top of this and a single-tier structure like the UNEP proposal would work. However, because such a basic foundation was lacking in North Korodafan, a multi-layered structure was proposed based on the judgment that it is necessary to build from the foundation up.
- The IWRM unit was proposed as a concept to develop the current North Kordofan State C/P team, consisting of working-level staff from the General Directorate of the Groundwater and Wadi Kordofan Office, MIUD, and the Agricultural Department of the Ministry of Economy and Production, into a permanent section to support the SWRC and TC. The C/P Team will perform key functions as the foundation of the IWRM process in North

Kordofan State, such as monitoring, technical analysis, and support to the WUC, reporting to the TC and SWRC, and continuing further activities based on the decisions made by the TC and SWRC.

- Only on the basis of continued activities related to water resources management on the ground, meaningful discussions and coordination at SCs and TCs become possible. Originally, the General Directorate of Groundwater and Wadi was in a position to conduct such continuous activities, but due to restrictions under the decentralized system, it has not been able to fulfill its functions, and there was no prospect for improvement in the future. Against this background, JPT and the C/P team proposed the establishment of an IWRM unit, which would include officials of the General Directorate of Groundwater and Wadi, MIUD, the Agricultural Department of the Ministry of Economic Production, and others. It would be managed from the state budget. The main role of the IWRM Unit is to continue technical and social activities related to water resources management, such as monitoring, water balance analysis, and support for the WUC, and to propose, prepare, and manage the holding of TC and SC meetings, provide materials, and lead discussions.

Formal Establishment of SWRC

SWRC and TC were formally established in February 2022. While in the 2020 proposal the overall structure consisting of SC, TC, and IWRM units was called "SWRC", the State Decree No. 13 refers to the decision-making unit as the "State Water Resources Council" rather than the "Steering Committee. After the formal establishment of the SWRC in February 2022, the first SWRC meeting was held in May 2022, and the second SWRC meeting was held in December 2022, followed by the third SWRC and TC n March 2023. A TC was sought to be held in August of the same year, but due to a number of problems, including a strike by state employees and flooding, the TC was not held.

The first SWRC meeting was held on May 26, 2022, as a joint meeting with the TC. Under the chairmanship of the State Undersecretary, the meeting lasted from 11:30 to 15:00. The main conclusions and confirmations were: approval of the JICA project activities until March 2023; continued information sharing on the AfDB-supported water supply project; the fact that the State Decree does not include the Director of the General Directorate of the Groundwater and Wadi Kordofan office as a member and he should be added as a member; to continue to consider the proposed budget of SDG 19.4 million shown in the 2020 proposal, and to approve the establishment of the IWRM Unit and to proceed with the formal procedures in the future.

The second SWRC meeting was held on December 15, 2022. The Governor chaired the meeting and the meeting lasted two and a half hours from 11:40 to 14:10. On the agenda were the message regarding the Bara region, "Let's cut groundwater pumping in half!", the results of the water balance analysis, the need to conserve irrigation water as a means of saving water and the progress of the water-saving irrigation experiment, attempts to introduce groundwater licensing, and the conjunctive use of groundwater and surface water. It was observed in the meeting that the SWRC meeting, chaired by the Governor, turned out to have a more top-down nature. It was originally intended that a resolution would be adopted at the end of the meeting, but it did not proceed that way. Instead, the Governor was to review the draft resolution prepared in advance after the meeting and make a decision.

The last TC and SWRC during the JICA IWRM Project period were held on March 7 and 9, 2023 respectively. TC confirmed the completion of the JICA project in March 2023. SWRC held on March 7 confirmed the following resolutions and requests submitted by TC: to continue the pilot activities in North Kordofan after the completion of the JICA project; to request the SWRC to officially launch the IWRM Unit, to work with the Ministry of Economy and

Production and the IWRM Unit for the second round of the water-saving irrigation experiment; to take budgetary measures for various activities; and to start considering the expansion of the SWRC activities to other areas in the state.

2) Findings, Lessons Learned and Challenges Related to the SWRC-TC-WUC System

2-1) Findings

Horizontal and Vertical Coordination Functions between the Parties

Figure 4-12 shows the status of vertical and horizontal linkages, which are key concepts in IWRM. The following are the main points

- Vertical coordination between the IWRM unit and the WUC is good, with support from the Bara Locality Office. Messages on the risk of future groundwater depletion and the need to reduce pumping were transmitted and understood by the WUC.
- The collaboration between WUC and general water users has also been good: WUC members shared the discussions at WUC meetings with general water users, and a community started to reduce the time for supplying water for domestic use to local residents. As a result of the pilot activities, general water users' awareness of the scarcity of groundwater and the need to conserve water has begun to increase.
- On the other hand, there is a unidirectional trend from bottom to top in terms of coordination from IWRN units upward; a TC resolution was submitted to the SWRC in December 2022 but no response was received; a resolution was submitted to the SWRC in March 2023 in the same manner, but is still waiting to be responded.
- At the level of IWRM units and locality offices, horizontal cooperation is good, with close cooperation between water and agricultural administrators.
- Interdepartmental cooperation in the TC and SWRC is weak; in the TC, members tend to make general statements in their own areas, and there are few discussions that converge on a resolution. The same tendency can be observed in the SWRC, but since the SWRC is a decision-making body, it would be less harmful as long as it leads to budgetary measures.

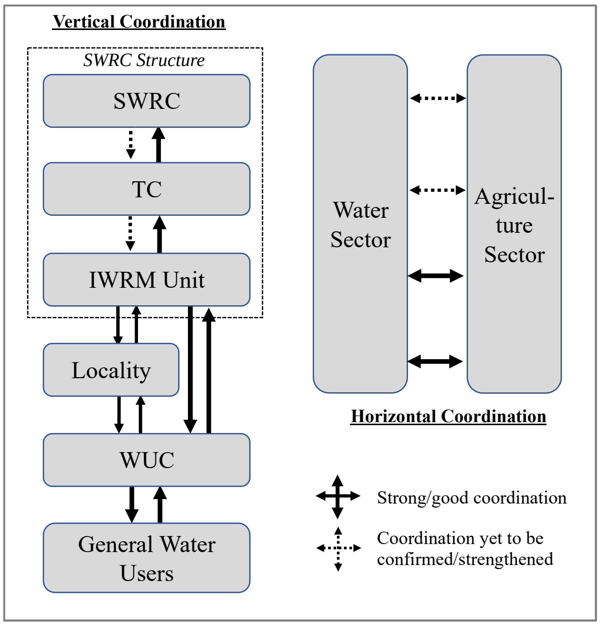


Figure 4-12.
Status of vertical and horizontal linkages in the Bala IWRM model

Overall, the fact that the SWRC-TC-WUC system raised the awareness of general water users and actually led to the movement of water conservation activities is a major achievement of the pilot activities. A cooperative relationship was successfully established between the government and water users, which was a major finding. It demonstrated the validity of the consensus-building mechanism proposed in the form of SWRC-TC-WUC system.

Need for Adequate Discussion by the Stakeholders

The establishment of the IWRM consensus-building system with the SWRC in North Kordofan State took about two years from early 2020, when JICA experts began supporting the SWRC establishment, to the official establishment of the SWRC in February 2022. During this period, remote guidance lasted for a long time due to social unrest caused by political upheaval and the ban on travel to Sudan by COVID-19. Under the facilitation of the JPT, the state C/Ps repeatedly discussed the SWRC's objectives, functions, structure, membership, frequency of meetings and so on. The result was the establishment of the SWRC and TC along the lines proposed by the state C/P. The proposal by the C/P s was convincing enough for the state decision-makers because it was prepared based on sufficient discussions among the C/Ps.

In the future, as the WRTO-IWRM Unit leads each state in supporting the establishment of SWRCs, it is important to take sufficient time for discussions by the stakeholders in each state, and to assist them to develop a proposal that is acceptable to decision-makers. It is quite possible that the desirable form of the IWRM consensus-building mechanism will differ depending on the situation in each state, so it is necessary to respect the ideas of the stakeholders in each state, rather than unconditionally following successful examples.

In the case of North Kordofan, progress was greatly influenced by the attitude of the governor, MIUD minister, and MIUD director at that time. In the first half of the Project, the Project remained stagnant due to the negative attitude of the minister and director general, but in the second half of the Project, a positive minister and director general took over, and progress was accelerated. Although the personnel changes of state officials are external conditions that cannot be controlled by C/P at the technical level, the importance of continuing discussions and efforts at the technical level, even in adverse conditions, was a discovery made through the JICA IWRM Project in North Kordofan.

<u>The Importance of the Technical Working Body</u>

Along with the creation of the SWRC, it is important to strengthen the working groups, because both the SWRC and the TC are time-limited committees, not permanent organizations. The existence and continued functioning of a technical working body is necessary to provide technical analysis and lead stakeholder discussions on various topics related to water resources management. In the case of the Project, the State C/P fulfilled this role and is now transitioning to the IWRM unit, which has been effective in establishing a cross-sectoral structure with members from several ministries, including MIUD and the Agricultural Department of the Ministry of Economy and Production. In the case of other states, there may be options depending on the situation in the state, whether to form a combined team such as the IWRM Unit or to have an existing government agency in charge of water, such as MIUD, take charge. In any case, what is needed is a permanent unit to support the activities of the SWRC.

<u>Importance of Water User Involvement</u>

A unique feature of the attempt in North Kordofan State is that the WUC was established and positioned as part of the IWRM consensus-building mechanism. A major water source in the Bara area, is shallow groundwater, and since water users are also water source managers, their participation was indispensable to achieving appropriate groundwater management. After sharing the results of the water balance analysis with the WUC, which showed that groundwater in the Bara area will be depleted in the future if the current pumping rate continues, water users began to understand the fact that groundwater resources are finite. Although more awareness-raising is needed, it was a great achievement as the first step. Although water users' involvement in water resource management may vary from region to region, the major finding of this project is that it is important to establish a mechanism for water users to participate in water resource management, especially in areas where groundwater is used.

<u>Importance of Scientific Explanation</u>

The results of the water balance analysis were explained frequently through the WUC, and water users have become more aware of the implications of water balance analysis. As a result of the raised awareness, a community started to reduce the time for supplying water to their neighborhoods. While there are still many water users who are concerned about the decline of the groundwater table but have the mistaken perception that groundwater sources are infinite, the fact that the

WUC was able to recognize the importance of sharing future risks based on scientific evidence and voluntarily spreading understanding among general water users is a major finding of the Project. An important principle of the IWRM was reaffirmed: water resources management must always be accompanied by a technical basis for consensus building among stakeholders.

2-2) Lessons

Meeting Management Methods

Entering the Project extension period from April 2022 to March 2023, JPT attempted to improve the way SWRC, TC, and WUC meetings are managed. This endeavor could have been implemented earlier. The technical details of the C/Ps' presentation materials resulted in longer presentation times, and as a result, TC meetings once lasted up to four hours and participants had to leave the meeting in the middle of the meeting. It was decided in April 2022 onward to set the maximum meeting time to 2 hours and to prepare brief presentation materials accordingly, which, together with other measures, resulted in more efficient meeting management. Had these attempts been realized earlier, it is possible that the C/P's ability to manage the meeting could have been further enhanced.

Understanding of Social and Cultural Context

The Sudanese officials, especially those involved in decision-making at the state level, tended to think in a top-down manner, to speak on matters of their own interest rather than on the agenda set for the meeting, and to adjourn without clearly confirming the meeting's conclusions. These phenomena could reflect Sudan's unique culture and way of thinking, which is different from Japan's. This tendency became particularly noticeable after the SWRC and TC were officially established and the meetings were held purely as the Sudanese side initiative. Had JPT been able to understand this cultural background at an earlier stage, it is possible that JPT's guidance for meeting management could have been more effective.

2-3) Challenges

Need for Awareness Raising of State Decision-makers

The fact that the SWRC and TC were officially established shows the high level of awareness of the North Kordofan government decision-makers regarding the need for such a new framework. Further awareness, however, is needed in terms of management, including consensus-building based on a bottom-up approach. In order to appropriately respond to the ever-changing situation of water resources, it is necessary for the IWRM Unit to play a central role in continuously monitoring the situation of water resources and water uses, proposing measures after technical review, and putting them into practice after approval by the SWRC. For such a mechanism to function, it is essential that the state decision-makers who preside over the SWRC understand the importance of the bottom-up approach and are always ready to communicate with technical staff such as IWRM Unit and make needed decisions swiftly. Guidance by MIWR in relation to NWRC revitalization and continued inputting from IWRM Unit would be needed.

Promoting IWRM with Water Users as the Driving Force

The experience of the JICA IWRM Project showed that water users are the greatest driving force behind IWRM. The IWRM Unit should take this point as the basis for future IWRM promotion activities in the entire state. Engineers tend to be satisfied with technical analysis such as monitoring and water balance calculations, but what is important in IWRM is the message to water users. If the technical explanation is sufficiently given to the water users, they will be convinced and will take action.

(2) Establishment and Operation of WUC

1) Background and Objectives

The top-down approach was taken for a long time in Sudan and the government made important decisions while voices of water users were not heard and they were not considered as an important player in water resource management. However, in order to organize water users, listen to their voices, and cooperate with them in the future management of water resources and facilities, the government has established a committee called "Water Users' Committee (WUC)" in the Project. The Project aimed to hold regular meetings to connect governments and water users and create an environment in which they could work together for water resources.

2) Activities

The WUC was established in November 2020, connecting the government and water users at the state level, and building an institutional framework that allows water users to participate in water resource management together with the government. Activities included support for the establishment of WUC, provision of information on water resources, and support for strengthening the independent operation of WUC after the completion of this project. Six WUC meetings were held by March 2023 as shown in Table 4-5 below.

Table 4-5 Agenda for WUC Meeting

	Time	Agenda
1st Meeting	November 2020	- Quizzes and presentation on the basic knowledge of groundwater - Purpose of shallow well monitoring (groundwater) - JICA project - Why we need the WUC - Shallow well monitoring (water quality) - Irrigation agriculture
2nd Meeting	July 2021	- Monitoring results of participatory shallow well monitoring and water quality - Changes in the participatory monitoring (introduction of self-registered water meters and participatory monitoring of water use) - Method of disinfection of drinking water using solar energy - Selection of WUC representatives to attend the SWRC and their roles.
3rd Meeting	May 2022	- Progress of monitoring - Irrigation agriculture: the concept of proper irrigation water amount, possibility of over-water use in the current traditional irrigation method - Trail ground water license in Bara - Progress of AfDB project - Better memberships, functions and activities of WUC
4th Meeting	August 2022	- Report on the last SWRC by the representatives of WUC - Structure, roles and activities of WUC - Saving-irrigation water experiment
5th Meeting	December 2022	- WUC's role and structure - Proposal from North Kordofan State government ～Let's reduce the water use by half! ～ - How can we control groundwater use? How to reduce irrigation water use 1. Irrigation water saving experiment 2. Groundwater licensing - 3. Conjunctive use of GW and surface water
6th Meeting	February 2023	- Confirmation of the structure and role of WUC - Results of irrigation experiment - Updated safe yield - Results water quality test - After the Project

The WUC started by providing information to help people understand the basics of groundwater, and then conducted activities that actually involved WUC members, such as the participatory groundwater monitoring and water-saving irrigation experiment. The Project team endeavoured to produce concise and easy-to-understand presentations throughout the meetings to provide information on groundwater and the progress of project activities. The Project team found out from the responses and reactions of WUC members to these presentations that the general public, including WUC members, did not know the basics of groundwater.

The Project team and the participants of the 1st WUC meeting selected the 20 members for WUC listed in the table below. They consisted of representatives of irrigation farmers, including women's groups, representatives of private well operators, omdas (traditional leaders), and representatives from the FFC. For the smooth operation of the WUC, it was decided by the C/Ps and participants to include six government officials in the WUC. There were geographical constraints in the selection of members. There are 63 villages in the Bara aquifer, but there are no paved roads, and access to Bara town is not easy from many villages. In addition, including representatives from each village would increase the size of the WUC. This is why the Project team decided that members would be selected from the two major water using areas, Bara town and Al Kheiran.

A chair, vice chair, secretary, and treasurer were selected as the core members of the WUC in 2023, with two of them also serving as WUC representatives to the TC. The activities of the WUC after the completion of the Project were discussed and decided at the last WUC meeting led by the core members.

Table 4-6 Members of the WUC

Non-government members	Government members
Fourteen water users (eight from Bara town and six from Al Kheiran) <u>Bara</u> ● Forces of Freedom and Change (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) <u>Al Kheiran</u> • Irrigation farmers (6) Note: One member is an *Omda* (traditional leader in Sudan)	Six governmental officials from Bara locality 1. Executive officer[2] 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

3) Findings, Lessons and Challenges

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 the Project period. Information sharing on water resources, collection of concerns and requests of water users, discussion on actions to be taken by water users and the governments were realized in the six WUC meetings. A platform was created to directly interact with water users for government offices. For the WUC members, it was a good opportunity to learn about the current status and future prospects of water resources, and they recognized the significance and usefulness of the WUC.

[2] 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.

WUC is expected to be a suitable place for both sides to discuss how to manage water resources. Discussions on water conservation methods has started by the both sides since December 2022.

Raised Awareness and Actions Taken on Water Resources Through Information Sharing of the WUC

WUC members gained a better understanding of the mechanism, current status, and future analysis of groundwater in Bara as indicated by the responses of WUC members during the phone interviews and WUC meetings. It has changed their mindset, as they stated that they thought groundwater was unlimited, but now understand that it is a finite resource and that they need to manage it for the future. Actual behavioral changes have also emerged. A member who is a caretaker of a public well has learned the importance of water conservation and has started shortening the time to provide water to users and WUC members have formed a Natural Resources Management Committee (NRMC) to manage natural resources in the area they live, including water.

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

Two representatives of the WUC began participating in the SWRC(TC) in July 2021. Water users' participation in SWRC could lead to transparency in decision-makings of the government and build trust between both sides. The government and water users also can work together to consider and implement countermeasures.

3-2) Lessons Learned

Need for Intensive Discussion at an Earlier Stage

Discussions about the WUC's organizational structure were hampered, as WUC members believed that the WUC was a government-initiated establishment and that they were merely guests. The Project should have spent more time to discuss this issue with WUC members at an early stage.

Low Attendance of WUC Members

WUC members' participation in the meetings was low because the Project failed to announce them of the meeting dates well in advance. However, the WUC chairperson personally contacted other members to request their attendance at the 6th WUC meeting, which improved the attendance rate. The situation is likely to improve in the future as WUC members have begun to take ownership.

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

It is important to work with government officials who know the local water users and the area concerned such as the Bara Water Manager and the Director of Agriculture of Bara.

3-3) Challenges

Absence of Organizations and Persons Representing Water Users

The Project was implemented during a period of political and social change in Sudan. Therefore, it was difficult to select representatives and organizations to participate in the Project due to dismantling of organizations at the community level. It was not possible to involve women, youth, and nomads. Efforts should be made by the government and WUC members to consider and add representatives to make WUC a better organization.

Limited Representatives in Terms of Areas

The WUC started with only representatives from Bara town and Al Kheiran, but it is necessary to consider adding representatives from other villages in the Al-Bashiri sub-aquifer in the future.

(3) National Water Resources Council (NWRC) Revitalization

1) Background and Activities

With the enactment of the Amendment in August 2021, JPT and the federal C/Ps of MIWR began to study specific measures to reactivate the National Water Resources Council (NWRC) as provided for in the Amendment, with the intention of promoting IWRM nationwide.

2) Activities

The NWRC was established under the Water Resources Act of 1995. After three NWRC meetings were held, it went dormant and no meeting has been held as of March 2023. After the commencement of the JICA IWRM Project in 2016, a movement to restart the NWRC was initiated led by the then first Project Director (Advisor to the Ministry of Water Resources), and as a result, the Amendment was issued in August 2021. The Amendment changed the membership structure of the NWRC and clarified the new roles of the WRTO. The following is a summary of the changes.

- Members: Ministry of Irrigation and Water Resources, Ministry of Defense, Ministry of Foreign Affairs, Ministry of Justice, Supreme Court, Ministry of Agriculture and Forestry, Ministry of Energy and Petroleum, Ministry of Interior, Ministry of Environment
- Functions: approve water-related policies, approve long-term programs, manage relations with other countries sharing water resources, encourage scientific research, and establish committees as needed
- Involvement: supervision of water use, establishment of the basis for permits and licenses related to water use, proper water allocation, regulation of water use, and recording of irrigation water use.
- Frequency: Twice a year
- Functions of WRTO: Formulate water-related policies and make recommendations to the NWRC, advise on maintenance of water facilities, formulate long-term programs, conduct surveys and research, oversee relations with other countries, forecast future water demand and recommend necessary management, represent the Nile River at international conferences, make recommendations on revisions to laws, international cooperation, etc.

A weakness of the Amendment is that its members do not include state representatives. The MIWR C/Ps and JPT proposed the establishment of a committee called “the Federal-State IWRM Partnership Committee” to overcome this weakness. The Partnership Committee will function as a means of sharing information and discussion relating to the water resources’ situation in each state with the WRTO and the state representatives. On 15 March 2023, the first Partnership Committee meeting was held sponsored by the JPT.

In addition, a number of important new tasks have been assigned to WRTOs, which are difficult to handle under the current WRTO structure. A proposal was prepared by MIWR C/P team and JTP to relocate the IWRM Unit established in 2012 in the General Directorate of Groundwater and Wadi to WRTO and name it “the WRTO IWRM Unit” as a means to strengthen the organizational capacity of WRTO.

3) Findings, lessons learned, and challenges related to the NWRC

The following are issues to be addressed in the future.

- Establishment of a WRTO-IWRM unit with the MIWR C/P at its core and strengthening of WRTO's organizational capacity
- Making the Federal-State IWRM Partnership Committee permanent
- First NWRC meeting after revitalization

4.5.2 Enhancement of Monitoring Activities

(1) Surface Water and Groundwater Monitoring

1) Objective and background

Objective of the monitoring is to establish a surface water and groundwater monitoring system and sustainably manage the monitoring data in a database. The monitoring results obtained will be used in the consensus building and policy making system led by SWRC and WUC for discussions and policy making for sustainable use of the Bara aquifer. Monitoring was conducted to solve the water problems of Bara aquifer and solutions were proposed to the SWRC and WUC. The following are the details.

2) Outline of the Monitoring

Groundwater and surface water monitoring was conducted. The details are shown in Table 4-7.

Table 4-7 Outline of Each Monitoring

Subject of monitoring	Type of well		Monitoring Location
Groundwater	shallow groundwater	Participatory monitoring	60
		Automatic groundwater level recorders	10
	deep groundwater	Measured manually	4
	water quality	Water sampling	several
Surface Water	river discharge		3

3) Surface Water Monitoring

Wadi monitoring was conducted throughout the four seasons from the 2019 rainy season to the 2023 rainy season (see Figure 4-13) at four sites along the Shikeran wadi. In addition, bathymetric surveys were conducted in El Ain and Bagara reservoirs.

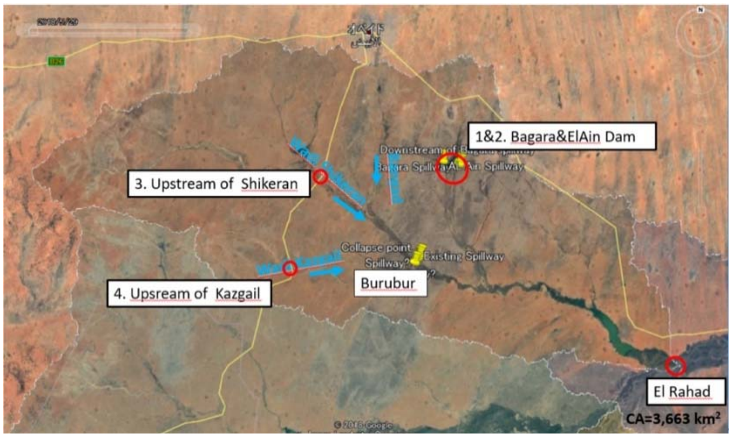


Figure 4-13 Location of Surface Water Monitoring

4) Groundwater Monitoring

4-1) Shallow Groundwater Monitoring

<u>Overview of Participatory Monitoring of Shallow Groundwater</u>

The purpose of the participatory monitoring is to assess groundwater potential and to help water users recognize the importance of water conservation by monitoring groundwater levels themselves. From 2020 to 2021, the participatory monitoring, in which well users observe groundwater levels themselves, was implemented. However, starting October 2021, monitoring using automatic water level recorders replaced participatory monitoring.

The site of shallow groundwater monitoring is shown in Figure 4-14.

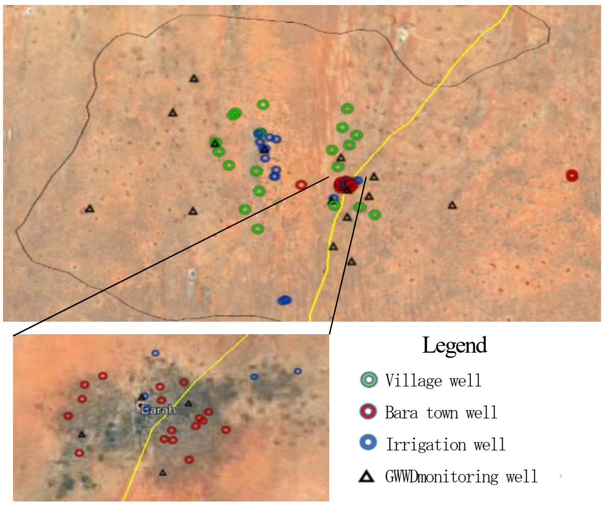


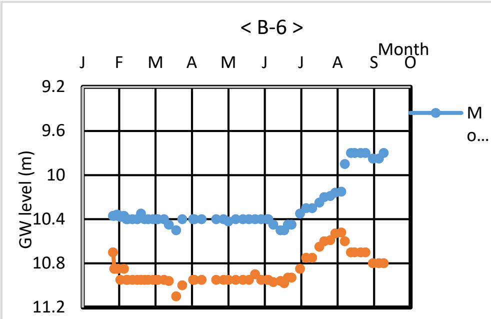
Figure 4-14 Location of Monitoring

<u>Results and Findings of Participatory Monitoring</u>

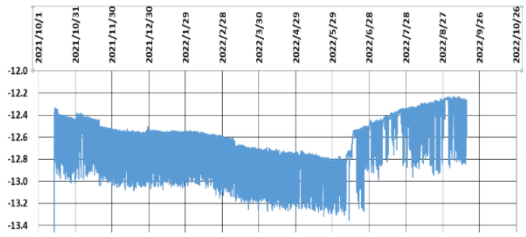
As a result of participatory monitoring, groundwater recharge in Bara town was estimated to be 10-60 mm/year and the safe yield was estimated to be 38 m^3 /day/well. The current average pumping rate of the wells, 80 m^3 /day/well in Bara town, is almost double the estimated safe yield. During the monitoring period, an average well level drawdown of 0.37 m/year was observed. If current pumping rates continue, groundwater levels in Bara town will continue to decrease.

Improvement of Monitoring Results

Figure 4-15 shows the results of i) participatory monitoring and ii) monitoring with automatic recorder.



a) Participatory Monitoring



b) Automatic Groundwater Level Recorder

Figure 4-15 Monitoring Result for Each Method

As the pattern of groundwater level changes show in Figure 4-15, the results from the automatic recorders is more reliable Based on these results, the monitoring method was changed from participatory monitoring to automatic recording monitoring. The participatory monitoring was conducted for about one year, and through this experience, the objective of making well users aware of the importance of groundwater resources and the need to conserve these resources was achieved.

Lessons Learned from Participatory Monitoring

Monitoring frequency varies from well to well and reflects the willingness of well users. It is not easy to get well users to accurately observe water levels daily. The following are suggested ways to improve monitoring.

Water users are not specially trained for monitoring nor have sufficient knowledge to assess the validity of the obtained results. Therefore, technology transfer to well users is necessary. If the diameter of the well is large, or if the diameter of wells is reduced in two or three steps downward within the well, it is difficult for water users to safely measure the groundwater level; therefore, small wells with a diameter of 1.5 m or less or wells with a single well diameter should be selected. It is important to select water users who are willing to conduct the monitoring. It is also important for the State CPs to visit the monitored wells regularly to interact with water users and motivate them to continue the monitoring work.

4-2) Deep Groundwater Monitoring

Monitoring wells in the Al Sidir well-field were completed in March 2020. Four deep boreholes were drilled by MIUD to a depth of 300 m as monitoring wells. The locations of these wells are shown in Figure 4-16.

The results of groundwater level monitoring for the Al Sidir well-field from February 2020 to April 2021 are shown in Figure 4-17. Overall, there is no clear trend of decrease in groundwater levels. One possible reason for this is that many of the wells in the well-field during the observation period had ceased operation due to well pump's failures.

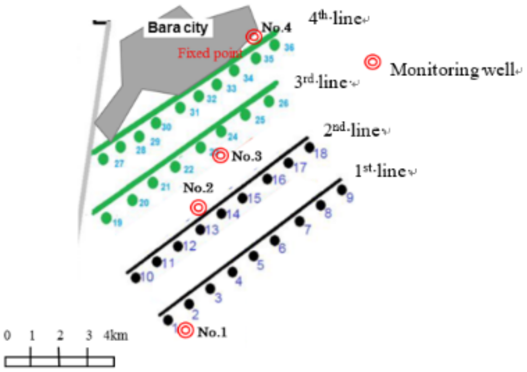


Figure 4-16 Monitoring Wells Installed at the Al Sidir Well

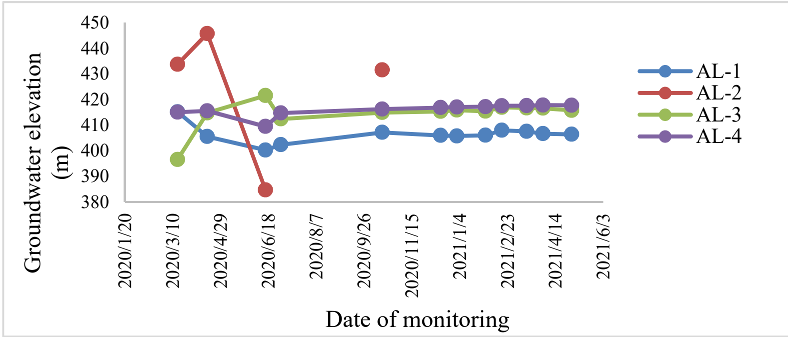


Figure 4-17 February 2020 to April 2021 Monitoring Results for the Al Sidir Well Field

4-3) Groundwater Quality

In the TCs during the 2019, issues with groundwater quality in private wells in Bara town were discussed. Groundwater in shallow aquifers is susceptible to contamination by coliforms and organic matter. It was important to confirm the water quality of Bara town wells. Therefore, water quality analysis was conducted on groundwater from these wells. The C/Ps team analysed water quality in shallow wells in Bara town that were targets of o groundwater level monitoring. The water quality analysis revealed that NO_3 concentrations exceeded WHO guidelines in more than half of the targeted wells. In many of the wells, NO_3 caused by organic matter is affecting the drinking water. The results of water quality analysis for coliforms showed a correlation between coliforms and NO_3. Therefore, the cause of high concentrations of NO_3 may be attributed to domestic wastewater. This was made clear for the first time by the monitoring of the pilot activity.

5) Technical Analysis Using Monitoring Results

5-1) Current Water Balance in North Kordofan State

Based on the monitoring results, the State C/P, with the assistance of JICA experts, conducted an analysis of the current status of the water balance as a long-term solution to the water problems in the target area, particularly the drawdown of the groundwater level. The water balance were identified and solutions were proposed. The plan presents a reduction target for groundwater pumping to control excessive pumping, which represents the main cause of the drawdown. Planning based on technical findings is an important aspect of IWRM practice. It was expected that through the establishment of groundwater reduction targets, C/Ps would recognize the importance of IWRM practices and that this plan would serve as a model for other state planning efforts.

<Analysis of Current Water Balance>

The current and future water demand in the subject area were calculated as well as the current water balance.

<u>Current and Future Water Demand</u>

The Bara Groundwater Basin, the subject of this analysis, is shown in Figure 4-18. Sub-basins (No. 88, 93, and 102) were selected that include the El Obeid, Bara, and Al Sidir well filed, where water problems have been identified.

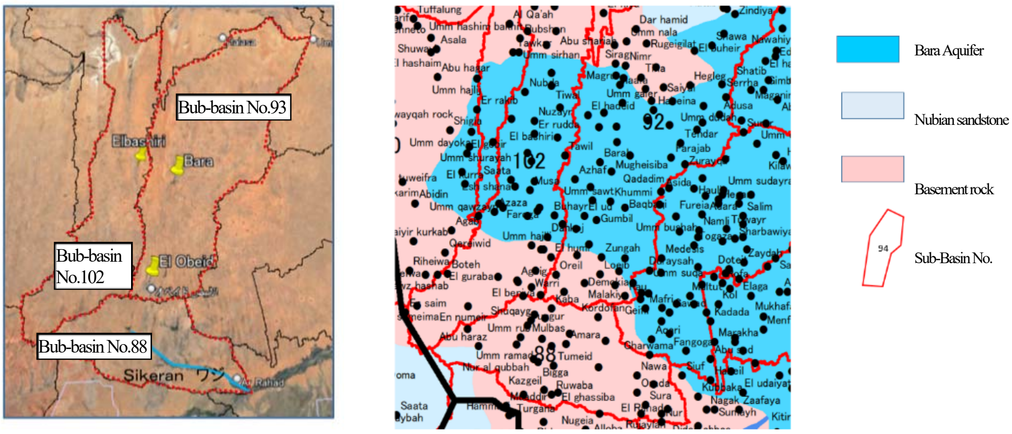


Figure 4-18 Basins which Undergone Water Balance

Conclusion of Water Demand Analysis

The results of the above water demand analysis are summarized in Table 4-8.

Table 4-8 Water Demand in Target Areas

Watershed No.	Number of villages	Rural Water Supply (m^3 /day)		Livestock water consumption (m^3 /day)		Irrigation water consumption (m^3 /day)	
		2016	Year 2035	2016	2035	2016	2035
88	32	2,880	10,368	2,784	5,024	0	0
93	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
whole	150	13,500	48,600	13,050	23,490	29,800	53,640

Groundwater Balance Analysis

A groundwater model was developed to analyze the groundwater balance in the Bara Basin. The purpose of the model is to predict how the groundwater level will decline under current water use. The analysis was based on a groundwater recharge rate of 14 mm/year for the Bara Basin.

Analysis Results

As shown in Figure 4-19, groundwater levels in the center of the Al Sidir well field are predicted to deplete over a 60-year period. The decline would be at a rate of approximately 32 m over 20 years, or 1.6 m/year. Some deep wells may be depleted earlier than predicted rate.

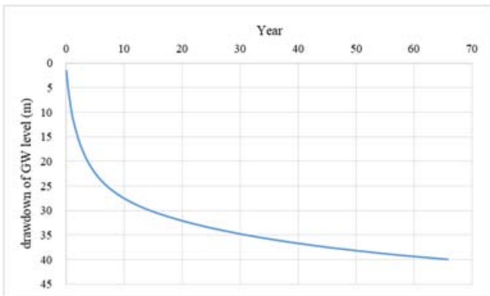


Figure 4-19 Al Sidir wells. Groundwater Level Decline Status

Surface Water Balance Analysis

There are three reservoirs in the Sikeran wadi basin: i) Bagara, ii) Al Ain, and iii) Burubur dam. The above three reservoirs supply water to El Obeid. Water balance of the three dams was analyzed.

Analysis Results

The current water demand in El Obeid is 50,000m^3 /day including which 30,000m^3 /day is supplied from the Al Sidir well field. Therefore, the remaining 20,000m^3 /day needs to be supplied from the three reservoirs. The optimal allocation ratio of water withdrawal from the three reservoirs was determined by simulation. As shown in Figure 4-20 and Table 4-9, the effective operation of the three reservoirs can provide El Obeid with a sustained and stable supply of 20,000 m^3 /day water.

Table 4-9 Optimization Results

Reservoir Name	Daily water supply (m^3 /day)	Average number of months of water supply available per year (months)
Burubur.	10,700	11.5
Al Ain	4,200	11.4
Bagara	5,100	11.6
total amount	20,000	11.5

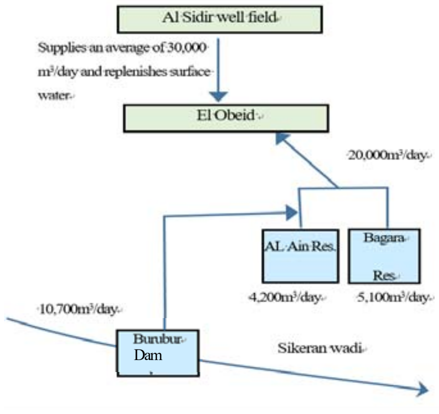


Figure 4-20 Optimal Water Allocation

5-2) Current Water Problems in the Target Area

Based on the results of the water balance analysis analyzed above, the two current water problems in the subject area are explained below.

a) Water issue-1: Excess groundwater pumping in Bara town and Al Bashiri area

Excessive irrigation water in the Barat own and Al Bashiri areas is causing groundwater levels in shallow aquifers to lower rapidly and threaten to deplete wells. To prevent this, groundwater pumping for irrigation should be regulated.

b) Water issue-2: Excess groundwater pumping from the Sidir well field

Groundwater levels in the Al Sidir well field have been declining for a long period of time, creating problems for the sustainability of the water supply to El Obeid. In the future, as the population of El Obeid increases, the groundwater level in the Al Sidir wells will decline further. 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 well field should be reduced.

Water issue-1: Groundwater over-pumping problem in Bara town and Al Bashiri

The amount of water that can be safely pumped from the shallow aquifer in the Bara town and Al Bashiri area for irrigation was calculated. This amount of water pumped is called safe pumping rate, and it suppresses the drawdown of the groundwater level. Two methods were used to calculate the safe pumping yield.

(i) Simplified Method

As shown in Figure 4-21, the distribution of wells within Bara town was modelled to estimate the safe pumping yield of wells within that area. The model was used to calculate the amount of groundwater level drawdown.

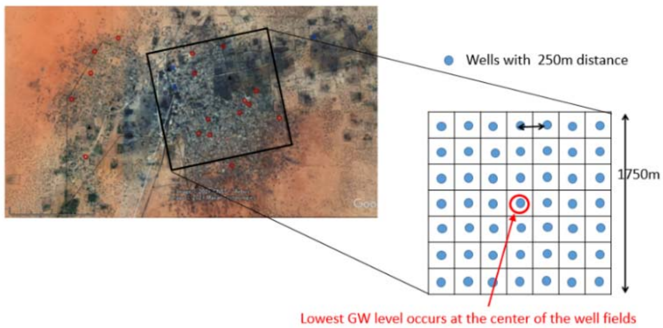


Figure 4-21 Model of Well Distribution in Bara Town

Analysis Results

The results of the monitoring with the automatic recorders showed that the safe pumping yield of the wells in Bara town was estimated to be an average of 37 m^3 /day. Information from participatory monitoring also revealed that the current average pumping rate of the wells in Bara town is 84.4 m^3 /day. This means that the current pumping rate of the wells is almost twice the safe pumping rate.

(ii) Detailed Method

A groundwater simulation model was used to predict future groundwater levels. The following two cases were calculated and the results were obtained.

Case 1: if the current pumping rate continue in the irrigation wells in Bara town and Al Bashiri, the groundwater drawdown in the Bara and Al Bashiri areas is up to 22 meters, and a number of wells may dry-up in 20 years.

Case 2: if the current irrigation wells in Bara town and Al Bashiri area continue to be pumped at half the current pumping rate, the groundwater drawdown in Bara town and Al Bashiri area is within 8 m in 20 year and the current pumping can be managed to continue

Based on these results, it can be concluded that reducing irrigation groundwater pumping to half the current level is necessary for sustainable groundwater use.

Water issue-2: Excessive groundwater pumping from the Al Sidir well-filed

To address excessive groundwater pumping from the Al Sidir well field, there is a need to increase withdrawals from the Sikeran wadi and decrease pumping of the Al Sidir well-field. To do this, withdrawals from the three surface water sources in the Sikeran wadi (Burubur dam, Al Ain reservoir, and Bagara reservoir) should be maximized and pumping from the Al Sidir well field should be minimized.

Analysis Results

The results of the analysis are shown in Figure 4-22. It is possible to send 50,000 (m^3 /day) from the three reservoirs of the Sikeran wadi to El Obeid during the rainy season, but not at the end of the dry season. Therefore, groundwater from the Al Sidir well field will be used during that period.

Effect of Reduced Pumping from the Al Sidir Well Field on Groundwater Level Recovery in the Bara Aquifer

Figure 4-23 shows the amount of groundwater level recovery when the water supply from the Al Sidir well field is reduced from 30,000 (m^3 day: 100%) to 11,500 (m^3/day: 40%). As shown in Figure 4-23, it is proposed that groundwater from the Al Sidir well can be used sustainably up to 40% to 50% of the current pumping rate.

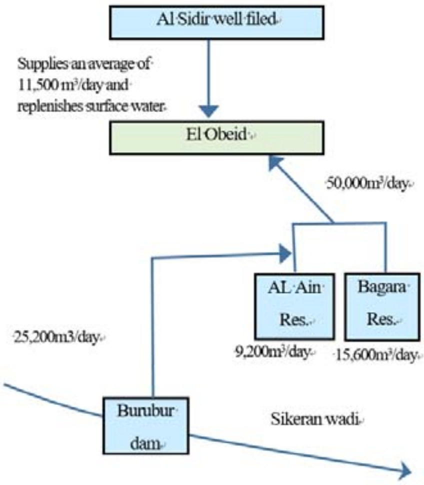


Figure 4-22: Model of Well Distribution

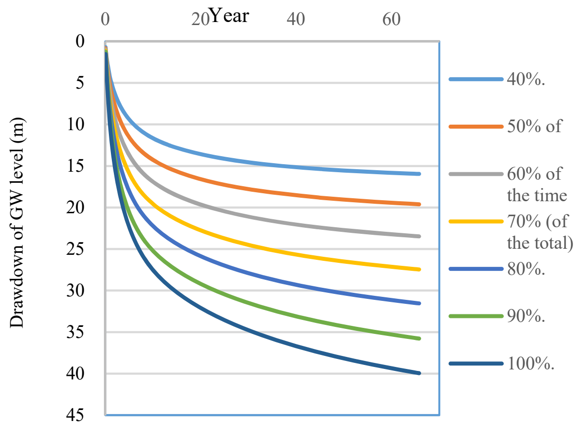


Figure 4-23 Long-term Reduction in Groundwater Level due to Reduced Pumping (%) in the Al Sidir Well Field

5-3) Water Problems in the Target Area in 2035

The current (2022) water problems in the subject area have been discussed in the previous section. In this section, the following points can be examined with respect to water issues in 2035.

In 2035, the population of El Obeid is projected to grow and water demand to increase from 50,000m^3 /day to 65,500m^3 /day. In this case, the optimal water withdrawal was calculated assuming that pumping from the Al Sidir wells would be the same as the 2022 level and that water withdrawals from the three reservoirs in the Sikeran wadi would be increased.

Figure 4-24 shows the optimization results.

As a result of the above, as shown in Figure 4-24, it is not possible to supply 65,500 m^3 /day from Sikeran wadi to El Obeid all year round, and the shortfall is replenished from the Al Sidir well-field. In this case, the average water supply would be 21,300 m^3 /day, 70% of the current 30,000 m^3 /day. In order to secure the water supply to El Obeid without increasing the pumping from the Al Sidir well field, the following measures are necessary:

- Reducing water use by conserving urban water and reducing leakage in El Obeid
- Conveying water from El Rahad lake downstream of Sikeran wadi to El Obeid.

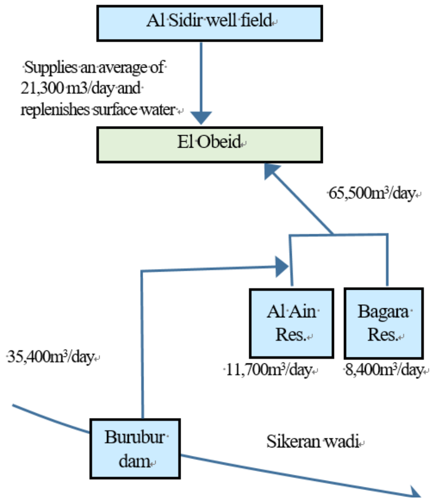


Figure 4-24 Water Supply to El Obeid through the Conjunctive Use of Surface Water and Groundwater

6) Effect of Deep Aquifers on Groundwater Levels in Shallow Aquifers

Since the shallow and deep aquifers are contiguous across the clay layer, pumping from the Al Sidir well-field could lower groundwater levels in irrigation wells in the shallow aquifer in Bara town. Based on the results calculated by the simulation model, the two conditions for sustainable use of groundwater in irrigation of Bara town and Al Bashiri and in urban water supply by the Al Sidir well-field are concluded as below.

- Pumping for irrigation in Bara town and Al Bashiri should be half from the current level (12,000 m^3 /day).
- Increase water withdrawal from Sikeran wadi and reduce pumping in Al Sidir well-field from 30,000 m^3/day to 12,000 m^3/day.

In conclusion, a 50% reduction in the amount of water used for irrigation in bara town and Al Bashiri area and water supply from the Al Sidiri well field is necessary for the sustainable use of the Bara Aquifer. This proposal should be shared with stakeholders through future discussions in the SWRC.

7) Findings, Lessons Learned, and Challenges

The findings, lessons learned, and issues that have been identified through the implementation of the technical analysis using the monitoring results are described below.

<u>**Relationship Between Monitoring and Technical Analysis**</u>

- It was found that there is little water resource monitoring in the pilot activity area. Large volumes of deep groundwater are pumped from the Al Sidir well-field and pumped to El Obeid, but no groundwater level monitoring is conducted. In the Sikeran wadi in the southern part of El Obeid, large scale surface water development was progressing despite the lack of wadi monitoring and its sustainability was being questioned. In the Bara area, shallow groundwater was pumped and used for irrigation of horticultural crops. Groundwater level monitoring had not been conducted, but a decline in the groundwater level has been reported.
- Monitoring is a basic requirement for water resources management prior to IWRM, and its absence prevents scientific judgment, one of the principles of IWRM. With this in mind, monitoring of the Bara shallow groundwater and Sikeran wadi was conducted in this case. As for the deep groundwater in the Al Sidir well-field, discussions with MIUD regarding the risk of future groundwater resource depletion resulted in MIUD's decision to newly drill four observation wells.

- While budgetary difficulties are often cited as a reason for the lack of monitoring, a lack of technical understanding may also be a factor. There appears to be a lack of understanding of the technical basis that the limit of the sustainable groundwater pumping is the groundwater recharge rate. As the SWRC continues to promote IWRM in North Kordofan State, it is necessary to expand the monitoring system, since monitoring is a basic requirement for consensus building based on scientific evidence.

First Step for Consensus Building Referring to Water Balance Analysis

- Water balance analysis of surface water is relatively easy to perform through long-term rainfall and river runoff analysis, but has not been done in Sudan. In this project, water balance analysis were conducted for the Burubur dam during its construction period to calculate the exact amount of water supply available for El Obeid from this dam. As a result, it was determined that the actual supply capacity was smaller than the state government believed and was not enough to cover the entire year-round water demand of El Obeid. Based on the results, a conjunctive use plan of surface water and groundwater was developed and proposed to the state government, in which the Burubur Dam would supply water for 6.5 months/year, including the rainy season, and deep groundwater from the Al Sidir wells would cover the remaining 5.5 months/year to meet El Obeid's annual water demand. The analysis based on the monitoring results led to this scientific solution, and for the first time, the exchanging opinions between JICA experts and state government were ready to reach a consensus. The Project has created a stir by presenting a model for a technical approach to the situation in North Kordofan State, Sudan, where decisions have been made for a long period time based on political considerations and customs without scientific or technical support.

Government Agencies Need to be Aware and Educated

- Awareness-raising to state engineers proved to be important. After sharing the results of the pilot activity monitoring and water balance simulation with MIUD and discussing the risk of depletion of groundwater in the Al Sidir well-field, MIUD's sense of urgency was heightened. As a result, MIUD decided to drill four observation wells and reduce the amount of water delivered to El Obeid. When JPT proposed to MIUD the conjunctive use of groundwater from the Al Sidir well-field and surface water from Sikeran wadi mentioned above, they countered that Sikeran wadi water can be delivered to El Obeid throughout the year even without groundwater from the Al Sidir well-field. After discussion, it was agreed that surface water monitoring in the Sikeran wadi would be conducted and that discussions would continue. Thus, along with the possibility that the technical basis could lead to action by government agencies, it was found that further awareness - raising is needed as a current situation.
- As part of the pilot activities, participatory monitoring was conducted by 60 shallow groundwater users in the Bara area with the cooperation of WUC. Although there was a temporary drop in motivation due to the time-consuming nature of the Project, the new groundwater development project by African Development Bank (mentioned below) raised their awareness of the crisis, and their motivation for participatory monitoring increased again. Facing the new risk factor of transporting water outside of their own water use, it is thought that the Project had a shock therapy-like educational effect.

Conflicts over Water

- In the case of North Kordofan State, the wadi is mostly a seasonal river, and upstream/downstream problems are not seen as they would be if river water existed year-round. Upstream/downstream problems occur only between upstream and downstream areas within the water supply system, or when upstream rural residents steal water from downstream water pipes.

- A different form of conflict between water users can be seen in the conflict between areas with abundant groundwater resources and areas with scarce water resources, such as base rock areas. In the pilot activity area, this structure of conflict was brought to light in the wake of the African Development Bank-supported water supply project to the El-Mazroub area. El Mazroub is located in a Basement rock area 100 km northwest of El-Bashiri, where chronic water shortages are severe. With the support of the African Development Bank, a water supply project for El Mazroub was planned using groundwater from El Bashiri as the source of water supply, but the Project is currently on hold because of opposition to the Project, which was attempted without any explanation to the local people. The residents of El Bashiri are becoming increasingly aware of the scarcity of their own groundwater resources as the groundwater level has begun to decline, and the presentation of a plan to send groundwater to other areas without any prior explanation has intensified their opposition.
- In view of the natural situation that groundwater is essentially flowing within aquifer from one place to the other place in the water cycle, groundwater in the Bara town and El Bashiri should be accessible not only to the residents living above it, but also to residents in other areas. The same logic applies to the water of the Nile River being pumped to remote areas far from the Nile River, not just to those living along the Nile River. However, in the case of the above-mentioned case, in addition to a lack of awareness of the public nature of groundwater, the Project was attempted to proceed without sufficient explanation, leading to opposition. The results of the technical analysis on the impact by the Project of African Development Bank performed by the Sudanese consultant were also not shared.
- Although the state CPs supported by JPT refrained from expressing our views on this case because they were not in a position to give a direct answer to this issue, it is the understanding of the state CPs that this is a topic that should have taken time and careful consensus building based on sufficient technical studies. It also demonstrated the need for IWRM, which is the goal of this project.

Role of the Groundwater Wadi Authority

- The Kordofan Office of the Groundwater and Wadi Directorate is a branch of the Federal Ministry of Water Resources' Groundwater Wadi Directorate. Although the SWRC is originally responsible for water resource management in the non-Nile areas, it has not been able to fulfill its original duties due to various constraints such as budget difficulties, lack of recruitment of young engineers, low salary level, and unclear division of roles with the state government.
  Regarding the budget for monitoring, the director of the Groundwater Wadi Directorate contributed greatly to the establishment of the SWRC. Budget for the monitoring of the pilot activities was mainly prepared by state government, though the federal government is in charge of preparing budget for monitoring. The reality was that federal government, i.e. Groundwater Wadi Directorate, did not afford to prepare the budget due to financial crisis. If monitoring is to be expanded in other states in the future, it is expected that a debate will arise as to whether the Groundwater Wadi Directorate should be in charge or whether the state government should be in charge for the monitoring. This is a matter that should be decided based on the principle and the reality of each state.

(2) Water Saving Irrigation

1) Background and Objectives

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.

In addition, it is expected that irrigation water use increases in the future according to the baseline survey. Therefore, the promotion of water-saving irrigation was chosen as one of the pilot activities.

Based on interviews with farmers, the farmers in Bara and Al Kheiran generally use more than 50L/m² 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

2-1) Shifting from Conventional Irrigation Methods to Modern Irrigation Methods

The water use efficiency of drip irrigation is very high and the water saving effect is also high. Drip irrigation, on the other hand, drips water gradually, making it suitable for crops planted with spaces, such as fruits trees, but not for densely planted crops such as leafy vegetables and root crops. In addition, the high initial investment cost makes it difficult for ordinary irrigation farmers to adopt drip irrigation technology. Interviews with irrigation farmers in and around Bara town revealed that the initial investment cost is equivalent to one to two years' gross income for a typical irrigation farmer. Bank loans are required, but the loan conditions are strict and only wealthy farmers have used the loan. Besides the initial cost, maintenance costs such as tube replacement were also required, which proved to be a hurdle for the average farmers to introduce drip irrigation.

2-2) Improving Efficiency of Conventional Irrigation Methods

Since it is not easy to introduce drip irrigation, the Project attempted to reduce the amount of irrigation water by improving the irrigation method traditionally practiced by farmers in the target area. The Project conducted an interview survey targeting farmers on the amount of irrigation water in advance, and obtained figures that could be judged as excessive irrigation in crop production during the dry season. The Project conducted an experiment to improve the conventional irrigation method and explore the possibility of saving water from November 2022 to February 2023 (winter and dry season), with the cooperation of four irrigation farmers.

Conventional and traditional irrigation is a method in which water is run through the channels between the furrows, and the water is irrigated from the channels to each plot with the size about 1m x 1m. The experiment was carried out in four farms in total, two farms each in Bara and Al Kheiran. A zone with normal irrigation frequency and zones with reduced irrigation frequency than usual were prepared to compare the growth status of crops (radish, arugula, carrot, and okra). A test was also conducted to confirm the water retention capacity of the soil in order to judge whether the current irrigation amount is appropriate.

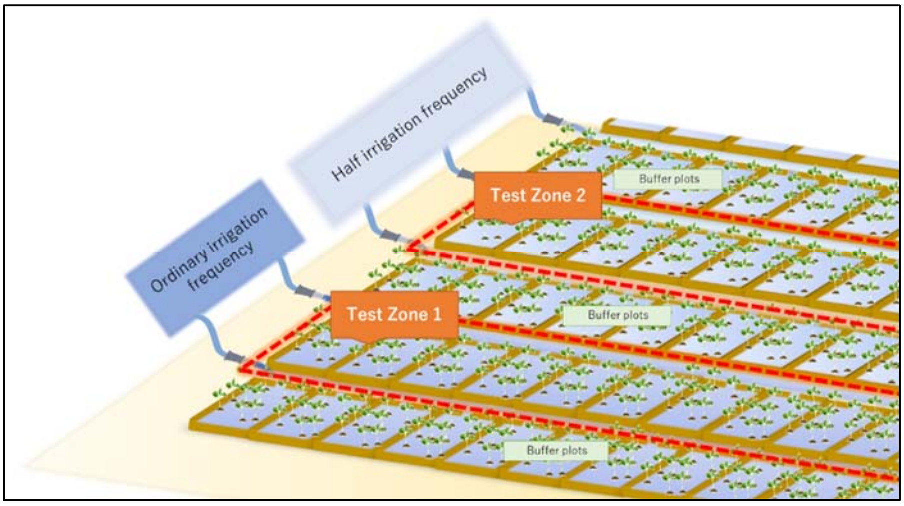


Figure 4-25 Field Configuration of Water-saving Irrigation Experiment

The experimental results and analysis obtained are as follows.

- As for arugula, in the zones where the frequency of irrigation was reduced, the yield decreased and the growth of the crop was poor. This is probably because the roots in the early stage of growth was in shallow soil where water evaporates, and thus the plants could not take in sufficient water. However, in one farm, a zone with regular irrigation was found to have plants having elongation symptom of weak and long leaves, which are signs of over-irrigation. In this case, a cultivation method that reduces the amount of water at one time rather than reducing the frequency of irrigation is suitable.
- For radishes, the yield decreased in zones where the frequency of irrigation was reduced. On the other hand, the occurrence of elongation was observed in the zone irrigated with regular frequency and the growth conditions such as length and thickness of root parts were better in the zone with less frequent irrigation than in the zone with normal irrigation. This may be due to the fact that when the radishes faced with mild drought, the plants adapted to the water shortage by extending their roots to search for water and accumulate more water in the roots. There is room to reduce both the amount and frequency of irrigation for radishes.
- As for okra, a high mortality rate was confirmed in zones where the frequency of irrigation was less than noraml. On the other hand, when comparing the growth of the individual plant that survived the withering among the zones, there was no significant difference in plant height, and that the reduced irrigation frequency did not result in inferior growth. The reduced irrigation frequency increased the mortality rate because the plants dried out before their roots extended to deeper soil area in the early growth stage, but the individual plant that escaped mortality were able to grow sufficiently by extending their roots to the deeper soil area. Therefore, it is considered possible to reduce the irrigation frequency in the late growth stage rather than in the early growth stage.
- Experimental results could not be obtained for carrots due to insect damage happened at the early stage. However, the farmer voluntarily conducted an experiment to reduce the irrigation frequency for onions. The onion bulbs become larger when the irrigation frequency was set lower. It can be said that this was due to the plants adapted to mild drought and stored water in the bulb part, as in the case of radish.

Based on the results of the experiment, recommendations for continuing similar irrigation experiments in the future were compiled along with the experimental results and shared with the General Directorate of Agriculture and SWRC.

3) Findings, Lessons Learned, and Challenges

3-1) Findings

Feasibility of drip irrigation

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 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 for the traditional method

The experiment has revealed that traditional method can save irrigation water. Although drip irrigation system has been introduced by some donors, it was a new attempt to save water with traditional irrigation method. The General Directorate of Agriculture and farmers were only interested in drip irrigation before the Project 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

Through pilot activities and presentations of TC, SC, SWRC, the awareness of the staff of the General Directorate of Agriculture regarding irrigation and water use in irrigated agriculture was raised, but not sufficient enough. It is expected that the two CPs of the General Directorate of Agriculture who participated in this experiment will share their experience and knowledge with other officials.

3-2) Lessons Learned

Simple plan

Although the experiment was designed to be very simple, it was not easy for the state C/Ps and farmers to understand how to conduct the experiment. As a result, the experimental plots were not prepared as planned, monitoring by the C/Ps was not properly conducted, and records by the farmers could not be kept. To continue this kind of experiment, the plan must be very simple, and only a basic level of data should be collected.

3-3) Challenges

Lack of knowledge and extension activities on irrigation agriculture by the General Directorate of Agriculture

It became clear that the General Directorate of Agriculture in North Kordofan State does not conduct research or extension activities on irrigation agriculture, nor does it have the knowledge or experience in providing guidance to farmers as regards irrigation agriculture through interviews and conducting the experiment. The branch office of the Federal Agricultural Research Centre in North Kordofan also does not conduct research on irrigation. Supporting irrigation agriculture in North Kordofan State is not easy.

Lack of statistics on irrigation

Limited data is available as certain farmers have registered their irrigation land with the General Directorate of Agriculture, but overall data such as the location and size of irrigated land, crops cultivated, and the amount of irrigation water used have not been collected. Because of the lack of statistics, it is difficult to estimate the amount of water used by irrigation and to manage irrigation water use. It is necessary for the water and agriculture sectors to work together to determine what kind of data to be collected and managed in the future.

(3) Groundwater License

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. 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. 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. 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.

Since the Groundwater Regulation does not clarify the details as to who is in charge of what and who grants licenses, the Project members planned to pilot this regulation in North Kordofan State to establish the flow of procedures to implement it. The objective was also to identify what is needed to implement the regulation, what gaps exists, and to learn lessons for better institutional arrangements at the federal and state levels.

2) Activities

The activities were led by the Federal Ministry of Irrigation and Water Resources, and the JICA team supported the Federal Ministry and the North Kordofan State government, taking the stance of supporting them to the extent possible. The following activities were carried out.

(a) Process of Application

The application process was discussed and agreed upon. 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 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.

(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.

Table 4-10 Aquifer classification for Ground water licence

Aquifer classification		Responsible Organization for Licence
Transboundary aquifer	• Bara Aquifer • Nubian sandstone	Federal government
Local aquifer	Basement rock	State government

(c) Revision of Application Format

MIWR prepared a format for the application, but this format was difficult to understand due to the use of many difficult technical terms, and in addition, there were two different applications on one format, one for new wells and one for existing wells. Therefore,

- Project members agreed to divide the format into two types: 1) existing wells and 2) new wells to be drilled. For new wells, the applicant must first obtain a permit to drill the well and then apply for a groundwater use.
- There is a section in the application form that describes the technical information of wells, but it needs to be revised in the future. This technical information is intended for deep wells drilled by drilling rigs, and only drillers have information to fill out. Therefore, the information is not suitable for hand-dug shallow wells and the form cannot be completed by the well owner. This is because the ministry had an intention to use the current format to control illegal drillers.

(d) Pilot Licensing

The Project team started trial licensing activity in the Bara Aquifer where many wells are concentrated, targeting the wells selected by the Project for participatory monitoring in December 2022. Through this activity, the Project aimed to accumulate administrative experience and promote understanding among well users. The CP explained to WUC members and other well owners how to fill out the application format and required documents to be attached, and handed over the application format to about 20 well owners and operators. Water users are now preparing application format and land title documents. After receiving the application along with the required documents, the state GWWD will issue the license. Collected comments on the format and application process from state government officials and water users should be fed back to the federal ministry, who should improve the format and the flow of procedure as necessary.

(e) Licensing Based on Evaluation and Justification of Future Safe Pumping Rates

Monitoring of groundwater levels and well pumping rates (m^3 /day) is effective in enforcing well control laws. The issuance of a well license should be determined in relation to the safe pumping rate of wells in the area (see Figure 4-26).

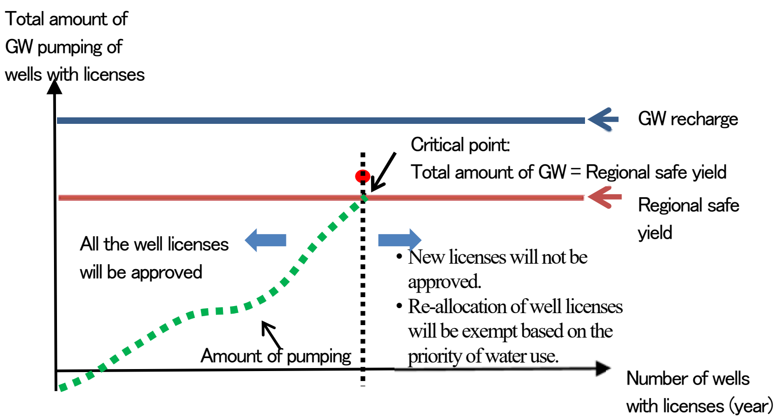


Figure 4-26 Relationship between safe pumping rate and issuance of well permit

If the total pumping rate from the well is less than or equal to the safe pumping yield for the area, a license for well use is issued without restrictions. However, if the total pumping exceeds the regional safe pumping yield, the issuance of license should be restricted. The safe pumping yield of a well is an important determinant in the issuance of well license. This parameter is estimated from the results of groundwater level and pumping monitoring.

A well licensing system shall be used to control the total pumping rate so that the total pumping rate does not exceed the well safe pumping yield for the area. If the total registered pumping rate exceeds the regional well safe pumping yield, the issuance of license for new wells shall be suspended and license should be redistributed according to the priority of groundwater use, with priorities to be discussed among the stakeholders in the SWRC.

-(f) Input to database

Information on licensed and registered wells will be entered into a database created by the Project, as described below, and will be managed centrally in this database.

3) Findings, Lessons Learned, and Challenges

3-1) Findings

Enforcement of the Groundwater Regulation

The groundwater regulation was approved in 2016 but had not been enforced for more than five years. CP began taking actions by convincing the Undersecretary and GWWD of the importance of the regulation. This was an important step for GWWD, which did not know where to start.

Preparation of the Application Format and Application Process

The application format was revised by the Project team and the application process was agreed upon. However, both the application format and the application process need to be improved based on the experience of the pilot activities before expanding the implementation of the groundwater regulation.

Prioritization of Areas

Through the pilot activities, it was found that the MIWR is trying to apply the groundwater licensing system uniformly throughout the country. The situation differs from region to region in terms of groundwater use, availability and risk of groundwater depletion. Therefore, it is desirable to prepare and apply a licensing system that matches the groundwater situation in each region. In addition, rather than applying the system uniformly to all regions, it is necessary to apply them by focusing on high-risk regions of depletion of groundwater resources.

3-2) Lessons

Difficulty of Enforcing the Groundwater Regulation

If local governments develop and implement groundwater regulations on their own, as in Japan, they can operate in accordance with local conditions. However, the MIWR has developed the regulation to implement it nationally. Therefore, the groundwater license for pilot activity was proceeded while discussing with state government and federal GWWD, but it took time to coordinate. The federal GWWD's leadership makes it difficult for the state government to determine the format and evaluation criteria for license applications at the state level according to local circumstances. The MIWR should reconsider future developments, including giving more discretionary authority to the states.

The Public Nature of Groundwater and the Significance of Licensing

Although groundwater is defined as public water in Sudan, some people are heard to consider groundwater as private water. Therefore, it is possible that residents distrust the well licensing system, which has no scientific basis. In the future, it will be necessary to persistently explain the benefits of the licensing system to well users and gain their understanding.

3-3) Challenges

Involvement of the Locality Officers

Although the application procedure established the roles of the locality's water manager and executive officer, the federal and state GWWD C/Ps went directly to the water users and communicated with them, and 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 individually. Therefore, there is a need to increase the involvement of locality officers.

Insufficient Data and Knowledge to Evaluate Applications

The state government has insufficient data on groundwater to evaluate applications for licenses. The federal government does not have the necessary knowledge and data to guide the states governments to evaluate them. Therefore, groundwater monitoring and analysis should continue in the future to accumulate sufficient scientific data to evaluate the application.

Registration of Well Drilling Companies

The Groundwater Regulation requires the registration of drilling companies. However, this could not be covered by the Project. There are many cases of well construction failures due to limited capacity of well drilling campiness, therefore, the registration of companies with the appropriate technical knowledge and skills is very important.

Licensing for New Wells

The pilot activities targeted only the existing 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 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. As the financial and human resources of the GWWD are limited, the GWWD should coordinate with the WES and the rural water supply unit.

(4) Database

1) Purpose and Background

The construction of a water resources database was selected as a pilot activity to cover information of water resources monitoring data and well inventory. The database is intended to be accessed and used by government organizations for water resource management as needed. The information in the database will also be used for consultation and policy making for sustainable use of the Bara aquifer in the consensus building and policy making system of SWRC and WUC.

The database to be developed under this Project will provide basic information to implement the water resource development and management of the Bara aquifers. The database will also record and store the results of the water resource monitoring conducted during the pilot activities, and will be used to evaluate the potential of the water resources.

As a result of discussions with C/Ps and North Kordofan State officers, it was decided that the database would consist of the following three types of information.

Table 4-11 Database Configuration

Database Type	Contents
1. Information on registered wells	Enter and maintain information on registered wells in accordance with the Groundwater Regulations Act (2016).
2. Inventory of existing wells	Information from the existing well registers (approximately 1,000 wells from GWWD, 3,000 wells from WES, and 300 wells from MIUD), are recorded. While the purpose of the existing well registers is to manage the region water supply, this well register is to share information among stakeholders for the purpose of groundwater conservation and management in the Bara aquifer.
3. Water Resources Monitoring Results	Groundwater, surface water, and water quality monitoring data conducted during this activity are being recorded. The results of future monitoring activities will be entered sequentially.

2) Activities

a) Database Construction and Planning of Operation Methods

Three databases were established by the Project team: 1. Information on registered wells, 2. Inventory of existing wells, and 3. Water resources monitoring results, as shown in Table 4-11.

In addition to this, discussions were held with C/Ps and state officers on how to operate the databases (e.g., managers, information sharing, operational budget, etc.), and the following plans were made.

- The database will be operated and maintained by the IWRM Unit of the SWRC and shared with stakeholders in water resources management and development in the North Kordofan State; since the IWRM Unit of the SWRC is composed of GWWD and MIUD officers, the database will effectively jointly operated and maintained by GWWD and MIUD. The budget for database operation, management and maintenance (data input, updating, and modification), and information sharing will be budgeted annually for the SWRC. Thus, the database operation and maintenance will receive personnel and financial support from GWWD and MIUD.
- Training materials on the database have been made by the Project as technology transfer from JICA experts to C/Ps on data input, modification, and data management. Based on this knowledge, the State C/Ps will be responsible for operation and maintenance of the database as the IWRM Unit.
- The data is stored on Excel sheets and linked to GIS software. This link will facilitate access to the monitoring data and display basic information and time-series graphs of groundwater level for each well on various analysis software. The database does not require advanced operation techniques and can be easily operated and maintained by the State C/Ps in the future.
- The key point of the plan is that the IWRM Unit of the SWRC of North Kordofan State will operate and maintain the database. This will create an environment in which the database can be directly used for policy making in water resources management. In addition, since the databases will be used by state-level engineers and advanced operating knowledge is not expected, emphasis was placed on the ease of operation of the databases. At this time, all relevant data has already been collected and entered into the databases.

b) Future Use of the Database

<u>Relationship between the database and well license system</u>

Until now, there has been no requirement to submit data on wells in North Kordofan state, resulting in a situation where well data is scattered; the Groundwater Regulations enacted in 2016 require well owners to register their wells, and the submission of basic information on existing and newly drilled wells to the federal government is a well registration requirement. Through this system, it is hoped that in the future all well information will be entered into a database without being scattered. The database will also be used in the Bara Aquifer for information to determine the issuance of well license as part of the over-pumping measures.

<u>Reference for drilling new wells</u>

Well information recorded in a well inventory will be effectively used, for example, to search for hydrogeological information on existing wells in the vicinity of a planned when drilling a new well and to use it as a reference in order to increase the success rate of well drilling.

3) Findings, Lessons Learned, and Issues

<u>Current status of water resource data</u>

Much information on existing wells exists in North Kordofan State. However, information on existing wells is described in different formats and scattered, and is not recorded, collected, and managed in a uniform manner. Until now it was not possible to construct a database of GW and surface water monitoring and a database of wells. As a result, administrative organizations were not able to access and utilize the database for water resource management as needed. This situation should be improved by using the database established through this pilot activity, and the database should be developed for consultation and policy making for sustainable use of the Bara Aquifer in the consensus building/policy making system of SWRC and WUC.

Data collection and management issues

The actual situation of lack of technical data on water resources development and management, which is widely observed not only in North Kordofan State but also in Sudan, is as follows.

① There is a lack of data both quantitatively and qualitatively

② There is much data, but it is not stored after use. As a result, data cannot be used in other projects.

③ Data is collected and stored, but not shared with others in terms of data ownership and confidentiality.

All of these problems are serious, but ③ is an institutional problem, a situation in which the right to use existing data is restricted. To solve this problem, it is highly desirable to remove unnecessary restrictions and share data among the parties concerned based on their agreement. Although confidentiality is important, there is a tendency to adhere to the principle of confidentiality without objectively comparing the advantages and disadvantages of data sharing, which should be reconsidered in the future.

Through discussions on the creation of the database and its operation and utilization in this pilot activity, the importance of data collection and sharing was recognized by the C/Ps and other government officers, leading to the provision of data possessed by each organization. However, the above-mentioned problems can still be seen, and the importance of continuing data collection and sharing should be spread through the parties involved in this pilot activity in the future.

Chapter 5: Achievements of Project Activities

5.1 Methodology

The achievements of the JICA IWRM project were evaluated from the following two points

- Assessment of the achievements of the pilot activity in contributing to solving the water resources management issue in the Al Bashiri Area and promoting IWRM in Sudan, 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.
- Detailed assessment of the achievements of each Pilot Activity by applying the indicators established by JICA

5.2 Overall Assessment of the Achievements of the JICA IWRM Project

(1) Assessment of the Pilot Activities in North Kordofan

In order to assess the achievements of the pilot activities in North Kordofan State under the JICA IWRM Project, the five pilot activities are positioned in a larger conceptual framework with goals, objectives and outcomes as shown in Figure 5-1. Five types of pilot activities are implemented in a mutually complementing manner, leading to the achievement of five outputs and further contributing to the achievement of the objective and goal. The objective was set as: *the depletion of groundwater is prevented and water use efficiency is enhanced in Bara.*

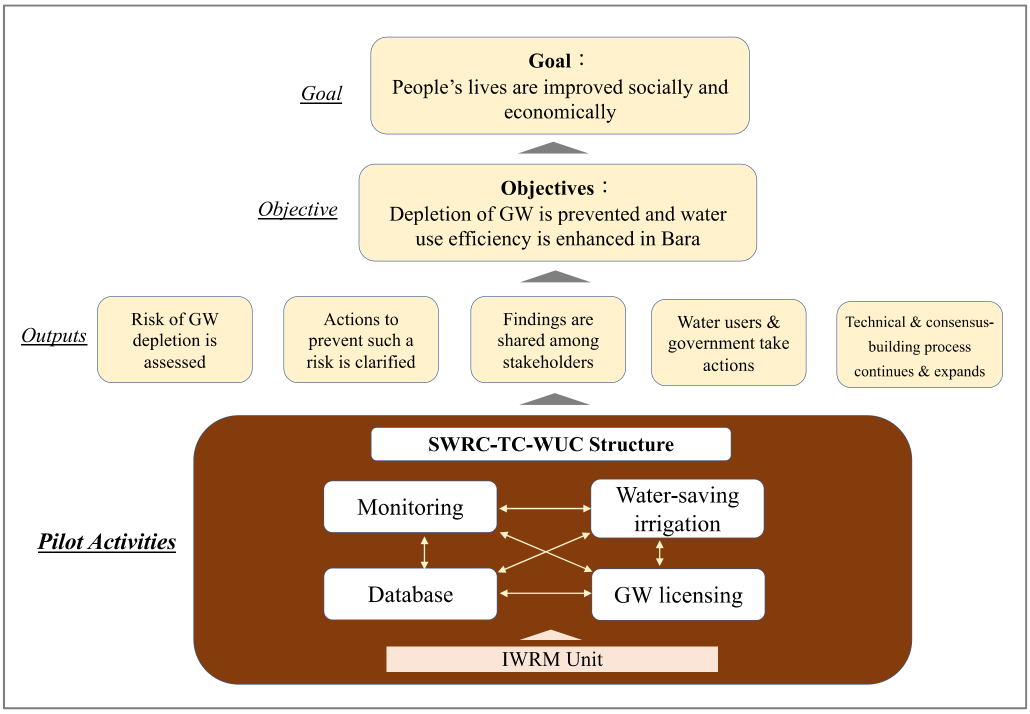


Figure 5-1 Pilot Activities and Outcomes, Objectives, and Goals in North Kordofan State

It is important that 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. After the establishment of SWRC and TC in February 2022, the pilot activities were implemented based on the above concept.

Table 5-1 provides an overview of the degree of achievements by comparing the outputs with the activities under the JICA IWRM Project. The first part, "*assessment of the risk of depletion of groundwater resources,*" "*clarification of* *actions to minimize such a risk," and "sharing of findings among stakeholders*," were achieved in the JICA IWRM Project. The next part, "*actions taken by water users and the government,*" can be evaluated as a partial achievement. Although some actions were taken, further development of activities is needed to achieve the goal of disseminating the action and reducing the water use by half in the entire Bara district. When this is achieved, the IWRM can be said to have taken root.

Table 5-1 Achievement of This Pilot Activity in North Kordofan State

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

In order to achieve the goal of "preventing the depletion of groundwater resources in the Bara area and enhancing water use efficiency," it is necessary to sustainably develop the pilot activities that were confirmed to be effective through the JICA IWRM Project and expand them to the entire Bara area. Based on the experience gained from the JICA IWRM Project, it is expected that the North Kordofan officials will take the lead in developing and intensifying activities to achieve the objective and goals.

(2) Assessment of the JICA IWRM Project Regarding the Federal Initiative to Disseminate IWRM in Sudan

The activities related to the revitalization of the NWRC in the JICA IWRM Project are placed in a larger conceptual framework of disseminating IWRM throughout Sudan as shown in Figure 5-2. The objective was set as "*IWRM is widely practiced in Sudan*". The various activities will lead to the achievement of the four outputs, "*creation of IWRM models," "establishment of a mechanism to share the IWRM models," "state governments sharing the IWRM models," and "each state applying IWRM to water resources management,*" and will further contribute to achieving the objective and goal.

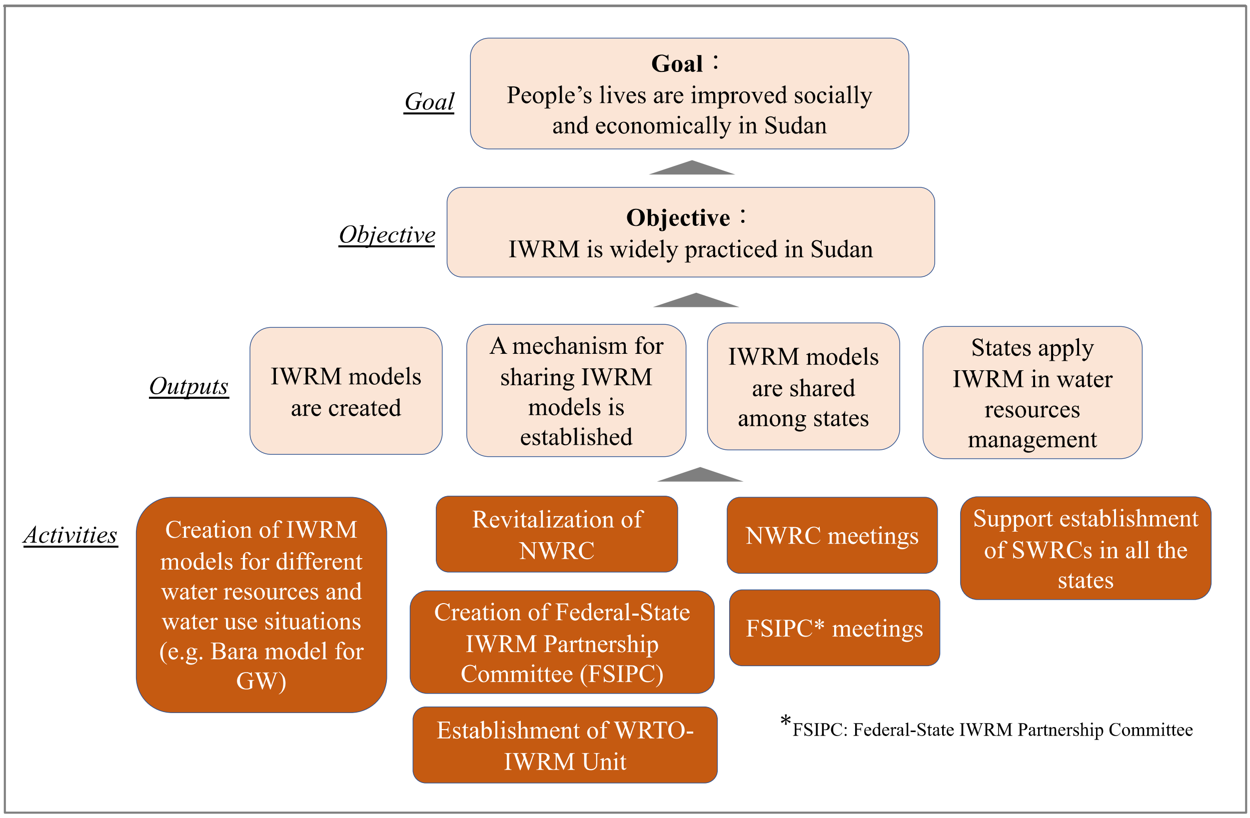


Figure 5-2. Activities Related to the Dissemination of IWRM in Sudan and Support for the Revitalization of the NWRC in the JICA IWRM Project

Table 5-2 evaluates the level of achievements of the activities involved in supporting the revitalization of the NWRC in the JICA IWRM Project in light of the four outputs in Figure 5-2

Table 5-2. Contribution of the Case to the Dissemination of 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

Regarding "*creation of IWRM models*," the Bara IWRM model in North Kordofan State falls under this category and can be evaluated as "achieved". As for "*the establishment of a mechanism to share the IWRM models*," JPT held discussions with the MIWR C/Ps and prepared a proposal on a path to revitalize the NWRC including the establishment of a Federal-

State IWRM Partnership Committee, and strengthen the WRTO by transferring the IWRM Unit to the WRTO. The proposal was submitted to the MIWR Minister with the approval of the WRTO chairperson. This output is, therefore, considered "partially achieved". If these proposals are realized, it will be an "achievement. As for " *state governments sharing the IWRM models* ", the sharing of the Bara IWRM model and the West Darfur experience at the Federal-State IWRM Partnership Committee meeting held on March 15, 2023, were realized. Because the sharing of experience was limited to an introductory level, however, the achievement is assessed as “partially achieved. It will be considered as "achieved" if more detailed information is shared more closely, and if this leads to the replication of the model in other states. Continued efforts on the part of Sudan will be necessary for states to adopt IWRM as a result of these developments.

5.3 Assessment of the Achievements of the Pilot Activities by the Indicators Established by JICA

JICA set evaluation indicators for the pilot activities conducted in the JICA IWRM Project. The level of achievement for each indicator is shown in the Main Report. Table 5-3 below shows the status of achievement of the objectives set by JICA for each pilot activity.

Table 5-3 Summary of Achievements and Challenges Related to the Thematic Pilot Activity Indicators Established by JICA (1/2)

SWRC	Objective	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
	Outputs/challenges	The SWRC and TC were officially established in February 2022. The North Kordofan State is highly motivated, so securing a budget is the key to sustainability. 1 million SDG per month will be allocated for the next fiscal year 2022.
		The capacity of the State CPs has been significantly improved as a result of participating in the JICA IWRM project. However, continued support from the Federal Ministry of Water Resources, both technical and operational, is needed in conjunction with the NWRC revitalization efforts in Khartoum.
WUC	Objective	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
	Outputs/challenges	The WUC was established and has been operating for two years. The core positions and roles of the WUC were defined and the foundation of WUC was laid.
		Scientific explanations by the IWRM unit have helped WUC members better understand the finite nature of water resources and recognize the need to use water more efficiently.
		Although the water saving irrigation experiment was conducted in the final stage of this project, it is necessary for WUC members to study the promotion of water saving irrigation and improvement of water use efficiency for domestic use, and report the results to SWRC to request supports.
		In order for the IWRM unit to continue to support the WUC, the state government needs to secure the necessary budget.
NWRC	Objective	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
	Outputs/challenges	Revitalization of NWRC has not yet been achieved. The first is to make NWRC member ministries to select a representative for their organization to represent in NWRC.
		The Water Act Amendment in 2021 newly defined the functions of the NWRC and the WRTO. Although technical support of the NWRC was defined as a function of the WRTO, the current structure of the WRTO is inadequate and its organizational capacity needs to be strengthened. The JICA IWRM Project proposed the transfer of the IWRM unit from the General Directorate of Groundwater and Wadi to WRTO as a means to strengthen WRTO. It is assumed that the MIWR CPs will be the core of the WRTO IWRM Unit.
		Budgetary measures are needed to revitalize the NWRC and strengthen WRTO.
		The WRTO fully understands the need for the above measures and has explained them to the MIWR Minister. Formal approval and action are awaited.

Table 5-3 Summary of Achievements and Challenges Related to the Thematic Pilot Activity Indicators Established by JICA (2/2)

Monitoring	**Objective.**	Establishment of water resources monitoring system, data management, discussion and consensus building on policies and measures for Bara aquifer management in SWRC and WUC
	Outputs/challenges	A monitoring (groundwater and surface water) implementation system (locations and methods, staffing, budget allocation, etc.) was established. Using the results of the monitoring, a water balance analysis was conducted, and a conjunctive use for the northern groundwater and southern surface water, which are the sources of El Obeid's water, was developed. Also, with this as the core, a plan to reduce excess pumping was developed for the sustainable operation of El Obeid's urban water supply and the irrigation and rural water supply in the Bara area. The capacity of the CPs was strengthened with respect to the methodology for the above series of activities and analysis, which can be implemented independently by the CPs in the future. The challenge is to implement the above proposals and to verify their effectiveness through monitoring in the future.
Water-saving irrigation	Objective.	Farmers implement water saving irrigation and share the results through discussion and agreement at SWRC and WUC
	Outputs/challenges	The farmers were able to gain a better understanding of the current state of groundwater and the Project conducted the water saving irrigation experiment with the help of farmers. The results were shared at SWRC and WUC. Since the experiment was conducted only once, similar experiments should be conducted further.
Groundwater Licenses	Objective.	Establishment of the groundwater licensing system and groundwater management through the licensing system
	Outputs/challenges	An application procedure, application format, and database templates for the ground water license, which are not stipulated in the Groundwater Regulation, have been prepared, but further improvements are necessary. The GWWD, which is responsible for the licensing system, needs to be strengthened. The data that serve as the criteria for granting licenses have not been developed, therefore control of groundwater use based on licenses is a challenge.
Database	Objective.	Creation and operation of water resources database, utilization by government agencies, consultation and consensus building on policies and measures in SWRC and WUC
	Outputs/challenges	Three databases were created for the purpose of policy making for water resources management in the pilot project areas; the IWRM Unit of the SWRC will operate and maintain the databases, share information, and obtain budgets. This has created an environment where the databases can be used for policy making for water resources management in the Bara Aquifer. At this time, all relevant data has been included in the database. The database is based on Excel and can be searched, added to, and modified easily by state government CPs. Continuous collection of water resource data is a future challenge.

Chapter 6: Recommendations on IWRM Promotion

6.1 Bara IWRM Model and Definition of IWRM

In this Chapter 6, a set of recommendations for the dissemination of IWRM in North Kordofan State and Sudan are presented, referring to the widely accepted definitions of IWRM proposed by various international organizations and the "Bara IWRM Model" developed through the JICA IWRM Project. Figure 6-1 shows the concept of the Bara IWRM model.

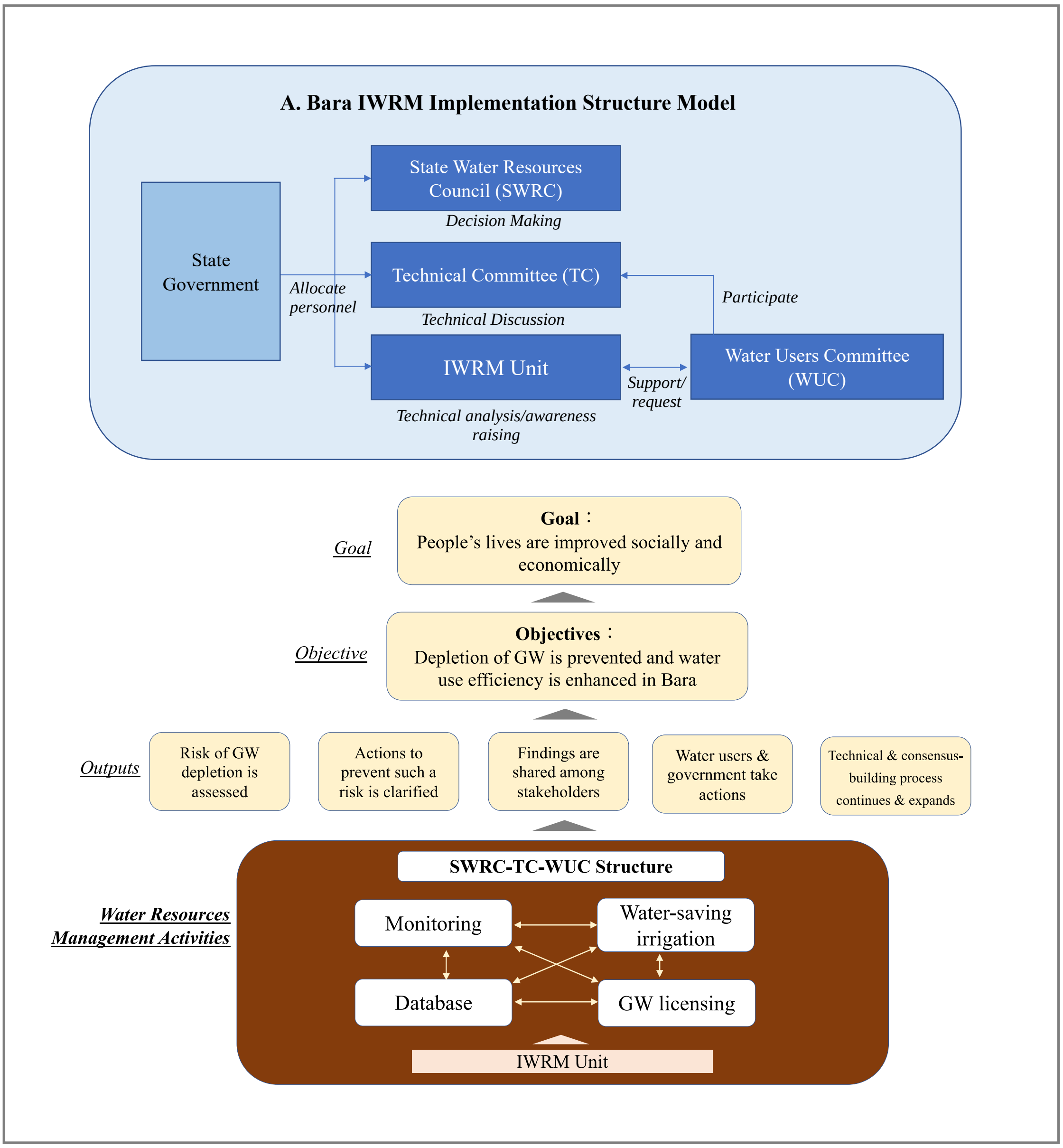


Figure 6-1. Bara IWRM Model

The following are the characteristics of the Bara IWRM model.

- The organizational structure shown in the upper part of Figure 6-1 is assumed to facilitate vertical and horizontal coordination and cooperation among the stakeholders involved.
- As shown in the lower part of Figure 6-1, specific activities related to water resources management such as the establishment of an organizational structure and operation, monitoring, database creation, water-saving irrigation, and groundwater licensing are carried out to achieve the objectives of preventing groundwater resource depletion and rationalizing water use.

- Activities are undertaken based on the aquifer boundary and are managed by the administrative offices including locality and state government.
- Engineering approaches are integrated with social, organizational, and legal aspects.
- Since the subject is water resources, a natural resource, an emphasis is placed on scientific evidence based on technical analysis.
- Emphasis will be placed on monitoring and databases to collect and accumulate information that will serve as the basis for all activities.
- Demand-side management with the cooperation of water users is emphasized.
- Groundwater development and management of its use through legal and regulatory measures is emphasized.
- Continuation and repetition of these activities will address the ever-changing water resource situation.

6.2 Recommendations IWRM Promotion in North Kordofan State

6.2.1 Overall Recommendations for the Bara IWRM Model Application

The following three points are proposed from the overall perspective: (i) flexible application of the Bara IWRM model, (ii) standard process of applying the Bara IWRM model and (iii) step-wise dissemination of the Bara IWRM model.

<u>Flexible Operation of the Bara IWRM Model</u>

In applying the Bara IWRM model, flexibility should be sought in adapting it to the natural conditions of the target area, the water resource situation, and the nature of the water problem. As shown in Figure 6-2, an appropriate approach that fits the regional conditions should be found and adopted between the two ends of the spectrum of demand management-oriented and supply-oriented approaches. In any case, scientific judgment and inter-sectoral coordination and participation of water users should be the basis.

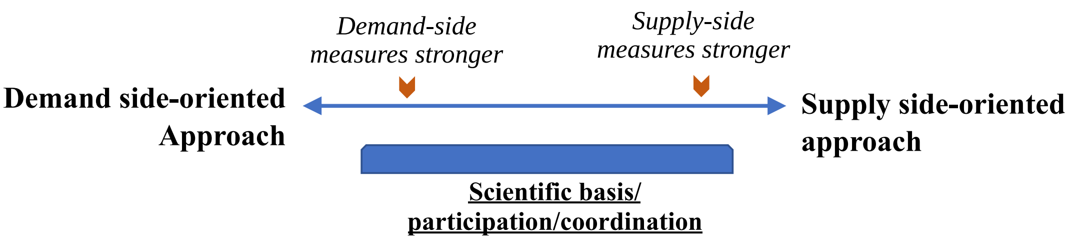


Figure 6-2 Demand Management Oriented and Supply Oriented Approaches

<u>Standard Process of the IWRM Application</u>

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 6-3 should always constitute the basis throughout the three steps. Since it is difficult to develop activities in all areas at once, it is advisable to select pilot areas and then gradually expand the activities.

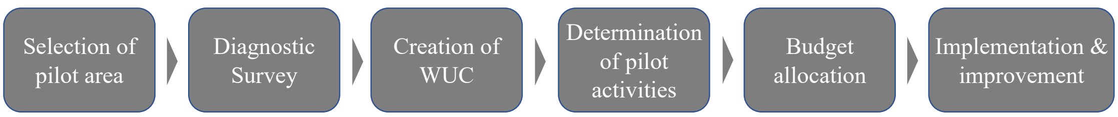


Figure 6-3 IWRM Methodology Provision Standard Type

<u>Step-wise Application of the Bara IWRM Model</u>

As shown in Figure 6-4, the application of the Bara IWRM model should be phased into three stages: first pilot target area and other parts of the El Bashiri sub-basin with similar water resource conditions, then to other Bara aquifer areas, and finally to other areas of North Kordofan State with different water resources conditions.

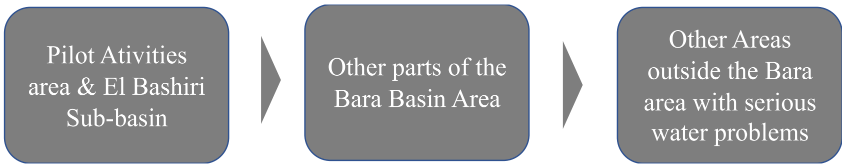


Figure 6-4 Stepwise Application of the Rose IWRM Model

Table 6-1 shows the thematic approach for each phase. After establishing the Bara IWRM model in the El-Bashiri area in Step1, activities in Step 2 will focus on the dissemination of the Bara IWRM model throughout the Bara region. In Step 2, the Bara IWRM model will have limited, if any, improvements since groundwater is the main source of water and the problems are similar to those in Step 1. In the third step, the model will be extended to other areas, mainly in the basement rock area and Nubian sandstone areas, where the main source of water is surface water and water source facilities such as hafirs and dams play an important role. Since the water sources and water use patterns are different from those in the first and second steps, the way of cooperation between water users and the government will be different, and the way how WUC functions would change accordingly. A new IWRM model different from the Bara IWRM model may have to be created. The integration of this new IWRM model with the Bara IWRM model will allow the North Kordofan State government to present a general IWRM model that can be applied nationwide.

Table 6-1 Stage-wise IWRM Dissemination in North Kordofan State

Subject	Target Area of IWRM Promotion		
	(1st Step) El Bashiri Sub-Basin	(2nd Step) Bara Basin	(3rd Step) Other Areas
SWRC/TC	Maintain the existing structure	Add new localities to TC	
		Modify Bara IWRM Model, if needed	Select an appropriate IWRM Model
WUC	Strengthen the self-management capability of Bara WUC	Support establishing new WUCs	
		Modify Bara IWRM Model, if needed	Find out an appropriate government-water users cooperation form and design WUCs accordingly
Monitoring	Maintain the existing monitoring and technical analysis	Install automatic recorders and undertake monitoring of water quantity and quality where GW is available	
		Undertake surface water monitoring where surface water is available	
Database	Expand the existing database by integrating scattered data and monitoring results	Expand the database by integrating the data additionally collected	Expand the database by integrating data additionally collected including surface water
Water-saving irrigation	Conduct second-round water-saving irrigation experiment	Conduct water-saving irrigation experiment to find an appropriate water-saving method matched to the local natural condition	Same as the 2nd stage, if there are irrigation farmers
	Disseminate the experiment results to irrigation farmers		
GW licensing	Complete the pilot introduction and move on to full application	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	

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

Table 6-2 shows measures to continue and strengthen the Bala IWRM model application in the El-Bashiri area where the pilot activities were conducted.

Table 6-2 Recommendations on the Continuation and Strengthening of the Bara Application in the Al-Bashiri Area (Pilot Activity Area)

SWRC and WUC	Raise awareness of state government decision-makers on the Bara IWRM model, especially the bottom-up approach
	Continued support (technical and operational) of IWRM dissemination activities in North Kordofan State by the Federal Ministry of Water Resources in conjunction with the NWRC revitalization initiative
	Emphasis on creating impact on the ground, recognizing that water users' participation is the driving force behind IWRM promotion
	Early formal establishment of IWRM Unit and strengthening of technical and operational functions
	Strengthening the WUC through increasing WUC membership in a way that represents a broad range of positions, strengthening support for the WUC by the IWRM Unit in a way that encourages WUC initiative
	Encourage the active participation of water users by undertaking practical activities that are relevant to them, such as promoting water-saving irrigation and piloting groundwater licensing schemes
	Use the WUC as a platform to expand the network and strengthen cooperation with water users in other regions, including outside the target watersheds.
	Extensive information sharing with water users in general through workshops, events, radio, SNS, etc.
Monitoring and technical analysis	Routinization of monitoring activities conducted in the pilot activities and formulation and operation of a flexible monitoring plan taking into account budget constraints
	Refinement of technical analysis through active and continuous use of automatic water level recorders installed for shallow groundwater and deep groundwater
	Promotion and realization of conjunctive use of northern groundwater and southern surface water
Water-saving irrigation	Continuation of water-saving irrigation experiments (two themes: irrigation volume reduction experiment for all crops and irrigation frequency reduction experiment focused on root and fruit vegetables)
	Improvement of the organizational structure of the Agricultural Directorate of the Ministry of Economy and Production (in terms of human resources and budget) to enable support for irrigated farmers, including implementation of experiments on water-saving irrigation and sharing of experimental results
	Supported by IWRM Unit, Natural Resources Management Commission (NRMC) and WUC collaboration to promote water-saving irrigation
	Establishment of a system for collecting agricultural statistics, including actual conditions of irrigated agriculture, and continuous collection of statistical data
Groundwater Licenses	Strengthen the organizational capacity of the General Directorate of Groundwater and Wadi Kordofan office (staffing, budget, computers and other equipment, etc.) so that it has sufficient capacity to take charge of groundwater licensing-related works.
	Simplification of the groundwater license application form by the federal MIWR based on input from state and locality governments responsible for application works and water users
	Examine the processes involved in groundwater licensing and how the relevant departments are involved in order to develop an implementation structure that can handle the huge volume of work that will arise with the statewide rollout of the groundwater licensing system
	Initiate the portion of the groundwater licensing system that involves drilling new wells, and campaign through well drilling companies.

Database	Expansion and validation of the database in North Kordofan, verification of its effectiveness, improvement and dissemination to other states.
	Expansion of the database, periodic review of groundwater availability using accumulated data, and updating of groundwater extraction reduction targets

6.2.3 Bara IWRM Model Application in the Bara Aquifer Area (2nd Step)

In the second step, the Bara IWRM model will be applied throughout the Bara area. Since shallow groundwater is the main source of water, the applicability of the Bara IWRM model would be high. It will be applied with minor adjustments as necessary after confirming the local conditions.

6.2.4 IWRM Promotion in Other Areas of North Kordofan State (3rd Step)

The third step will be the dissemination of the Bara IWRM model in other area of North Kordofan State. Since the main target areas are the basement rock and Nubian sandstone formations areas where surface water is the main source of water, an appropriate IWRM approach should be pursued. A new IWRM model may have to be established, using the Bara IWRM model as a reference.

6.3 Recommendations on IWRM Promotion in Sudan

6.3.1 IWRM Promotion Plan in Sudan

(1) Strengthening of the IWRM Promotion Structure at the Federal Level

Existing policy and legal frameworks should be used in the dissemination of IWRM in Sudan. As shown in Figure 6-5, in terms of policy, the Sudan Water Sector Strategy 2021-2031, publicized in October 2021, states the importance of IWRM as the third of three pillars. On the legal front, the "1995 Water Resources Act Amendment (the Amendment)" promulgated in August 2021 clearly stipulates the national-level policy and program planning functions of the National Water Resources Council (NWRC) and the Water Resources Technical Organ (WRTO) in relation to water resources management. NWRC and WRTO are, thus, responsible for water resources policy and program planning at the national level. The dissemination of IWRM in Sudan should be promoted in line with these policy and legal frameworks.

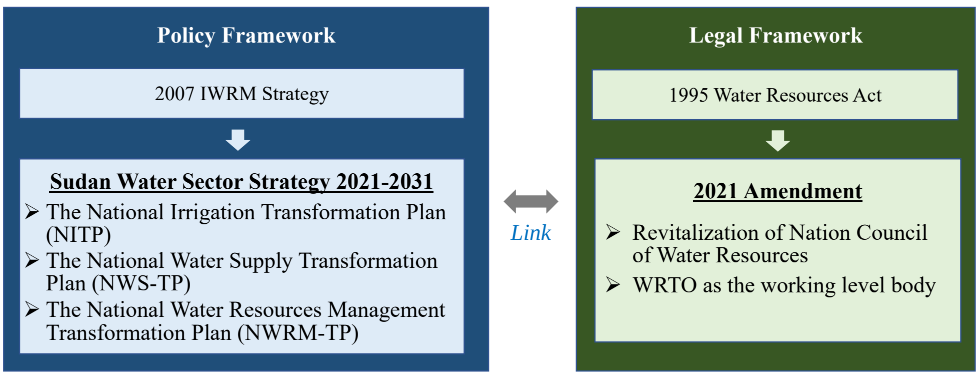


Figure 6-5. Policy and Legal Frameworks for IWRM Promotion in Sudan

A weakness of the Amendment is that the NWRC does not include state representatives as members. The original 1995 act included them, but for some reason they were excluded in the Amendment. A new mechanism to complement the NWRC is needed to compensate for this weakness. Since there is a provision in the Amendment that allows for the establishment of subcommittees as needed, it is proposed to establish a "Federal-State IWRM Partnership Committee" under this provision. Figure 6-6 illustrates the mechanism.

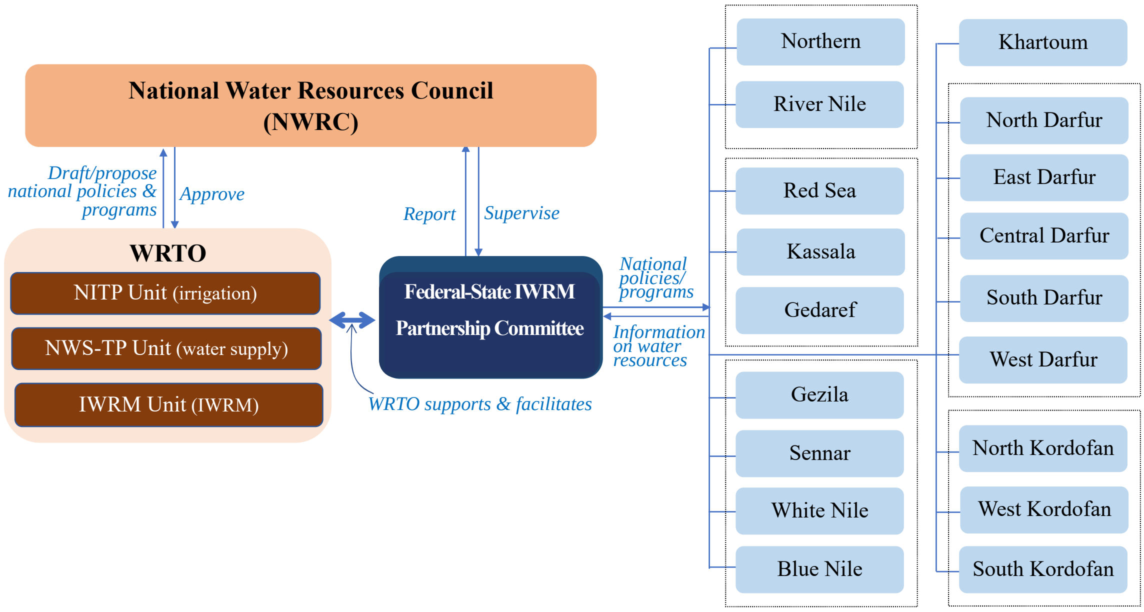


Figure 6-6. Organizational Structure to Strengthen the Federal-state Cooperative Relationship

According to the-Amendment, WRTO is to serve as a technical body to support NWRC. In order for WRTO to be able to fully perform its required functions, it is proposed that the WRTO-IWRM unit be relocated. The reason for the relocation rather than establishment is that a unit of the same name already exists within the General Directorate of Groundwater and Wadi, albeit dormant. With the Federal C/P that participated in this project as the core, the C/Ps will play a leading role in the dissemination of IWRM throughout Sudan, utilizing the knowledge that they have accumulated through their participation in the JICA IWRM Project.

The Federal-State IWRM Partnership Committee will include representatives from 18 Sudanese states. The purpose of the committee is to strengthen ties between the federal government and the states. The federal government will provide information on policies and projects at the national level, while the states will report on the current status of water issues on the ground and the solutions that are required. This will enable two-way information provision and sharing, which is expected to increase federal-state collaboration and enhance the effectiveness of water resource management.

The first meeting of the Federal-State IWRM Partnership Committee was held on March 15, 2023, utilizing the JPT budget. The meeting successfully achieved its initial objectives, and many of the state participants expressed their hope that the meeting would be made permanent. It is expected that the committee will be formalized as part of the NWRC in the future.

(2) **Need for Stage-wise Approach and Action Plan Preparation for IWRM Promotion in Sudan**

<u>Stage-wise Approach</u>

It is proposed that the dissemination of IWRM throughout Sudan should be promoted in stages, rather than in all states at once. Table 6-3 shows an example of phased dissemination, where IWRM dissemination will first be carried out in the six states shown in the middle column on a model basis, and then the model will be followed and IWRM will be disseminated in the surrounding states in the right column.

The establishment of SWRC and WUC should be accompanied by a preliminary study reviewing previous examples like those in North Kordofan and other states at the initial stage. As the WRTO-IWRM Unit provides support in this process, it is desirable to focus the support on model states, and then follow their successful examples and expand to other states. If the WRTO-IWRM Unit tries to undertake the activities at all states at once, it will exceed its capacity to provide support, and there is a risk of failure due to inadequate support.

Table 6-3 Examples of Phased IWRM Dissemination 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	-

<u>State Action Plans</u>

Figure 6-7 shows an example of a state-by-state IWRM dissemination action plan. It is proposed that action plans like this example are prepared in each state including the establishment of SWRCs and put into practice according to the action plan. The activity items shown in Figure 6-7 follow the Bara IWRM model presented at the beginning of this chapter. They should in fact be developed according to each state's situation.

Figure 6-7. Example of an Action Plan for IWRM Promotion for a Model State

6.3.2 Recommendations on Strengthening IWRM Promotion Activities and Water Resources Management Activities in Sudan

(1) Support from WRTO IWRM Unit in Establishing IWRM Structure at State Governments

WRTO-IWRM Unit, once established, will support the IWRM promotion in each state, following steps below.

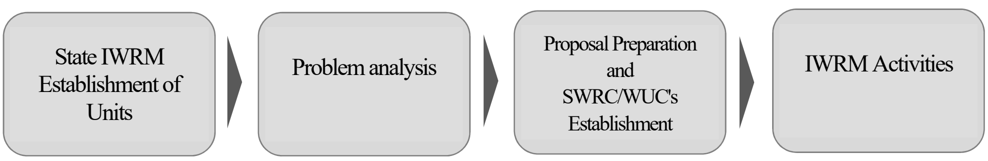


Figure 6-8. SWRC Creation Process

First, there is a need to create a working unit at the state level to lead all of the above processes. It would be desirable to create an IWRM unit like the one in North Kordofan, but it could take different forms depending on the situation in each state. It would be desirable to include government officials not only from the water resources sector, but also from agriculture, livestock, investment, and other water-related sectors.

A problem analysis will then be conducted to identify the overall water problems facing the state and the interrelationships among the individual problems. The organizational structure to be established will depend on the nature of the problems to be solved.

Based on the results of the problem analysis, an outline of the SWRC and WUC to be established in the state will be discussed and summarized as a proposal. The proposal should include the purpose, functions, structure, membership, frequency of meetings, and budget of the SWRC and WUC, etc. As for the structure of the SWRC, as was discussed in North Kordofan, there are various views on whether it should be a single-tier structure with decision-making only, or a two-tier structure with the Technical Committee (TC) coordinating the technical level and the SWRC making decisions based on the TC's proposals. Whether the SWRC should be chaired by a governor or a minister in charge of water is also a topic for discussion. The WRTO-IWRM Unit will act as a facilitator to ensure that sufficient discussion by state stakeholders takes place. The budget should be broken down into activity, recurring (e.g., salaries), and meeting expenses. Care should be taken to increase the possibility of the proposal being approved by preparing not only an ideal budget proposal but also an austerity budget plan.

As experienced in North Kordofan State, the active participation of the state governor and other senior officials is essential for the establishment of a new mechanism such as the SWRC. Although the process may be stalled by the reluctance of the upper management, the WRTO-IWRM unit should support technical-level officers to continue to make bottom-up proposals persistently.

There are several points that the WRTO-IWRM Unit should keep in mind regarding the operation of the SWRC. Standardizing the agenda for each meeting will enhance the sustainability of activities by the SWRC. By standardizing the agenda, state IWRM units will be able to prepare for each meeting in a smooth manner without having to worry about setting the agenda for each meeting. For example, sharing monitoring results and their implications at every meeting is an example of agenda standardization. The follow-up of SWRC resolutions is an important element in ensuring that SWRC activities produce results. The IWRM consensus-building cycle should be seen as perpetually rotating. In terms of managing meetings, time management is important. Aiming for a maximum of two hours for brief presentation of materials and discussion will enhance the efficiency of the meeting and should be kept in mind during the support provided by the WRTO-IWRM Unit.

(2) Support for Establishment of WUC

<u>Preparation of Establishing WUC</u>

After the problem analysis by the IWRM unit above is completed, and the target area is decided, 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 collated 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.

Establishment and Operation of 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. Then, the WUC and the IWRM unit should work together to take practical action to solve the water problems in the target areas. 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.

6.3.3 Recommendations by the Federal Ministry of Water Resources to Support the Promotion of IWRM-related Activities in Each State

(1) Monitoring and Technical Analysis Using the Results

The following are recommendations for Federal Government to promote the water resources monitoring and its technical analysis in each state of Sudan.

- The experience of monitoring groundwater and surface water in the pilot activities of this Project, and conducting water balance analysis and planning for conjunctive use of groundwater/surface water based on the results of the monitoring should be shared with other states. In particular, it is important to share the overall process, which did not end with the mere implementation of the monitoring, but included technical analysis based on the results of the monitoring. Moreover it is importat to be conveyed the implications of the results as a message to water users to encourage their activities, in other words, to share experiences based on the full understanding of what the monitoring is for. In other words, it is important to share experiences based on the full understanding of why the monitoring is implemented.
- Two methods of groundwater monitoring in North Kordofan State were used: participatory monitoring and monitoring with automatic groundwater level recorders. Participatory monitoring was conducted by the well users themselves, which helped them become aware of the finite nature of groundwater resources and the need to conserve

groundwater. On the other hand, the accuracy of the participatory monitoring remained a problem, which was solved by introducing automatic recorders. Which method (or combination of methods) is best depends on factors such as the purpose of well use, well construction method, groundwater level, and well owner awareness. CPs supported by JPT suggest that the lessons learned in North Kordofan State be used as a guide for other state to plan and implement groundwater monitoring in a way that involves well users.

- Surface water 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 4 years of measured wadi flows, 32 years of rainfall data, and a rainfall-runoff prediction model. This approach should be used to calculate long-term wadi flows in other regions as well. 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.
- Using the results of monitoring in North Kordofan State, groundwater and surface water potential were calculated and a conjunctive use plan for groundwater and surface water was developed. In Sudan, where the rainy and dry seasons are clearly separated, the conjunctive use of groundwater and surface water is essential for the sustainable use of water resources. However, the need for conjunctive use varies from region to region, but the more scarce the water resources are, the greater the need for conjunctive use. It is proposed that the method of assessing water resource availability and the conjunctive use of groundwater and surface water in North Kordofan State be used as a reference for other states to develop their own plans.

(2) 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 costs. 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.

(3) Groundwater Licensing System

Based on the Groundwater Regulation 2016, 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.

(4) Database

The following are recommendations for IWRM Unit of the Federal Government to keep in mind as it promotes IWRM throughout the entire country of Sudan

- Sharing of water resource data is fundamental to water resource management and should be institutionalized through the creation of a system in which the agencies concerned share information through consensus. Each agency has its own well inventory with its own format in line with the purpose of its activities. However, each institution shares the common philosophy of conserving groundwater resources and enabling sustainable use of groundwater. From this perspective, each organization's well inventory have information that can be shared, and information should be actively exchanged.
- In this pilot activities in North Kordofan State, a database was created to record and manage information on registered wells following the institutionalization of well applications and registration. Pilot operation of the database was started in the Bara area of North Kordofan State. The database will be expanded to all areas of North Kordofan State and then to the entire country of Sudan. It is recommended that other states use the North Kordofan State’s database to record and manage information on registered wells. This will allow for easy sharing and management of data on registered wells in each state.

6.4 Further Supports from Donors for IWRM Promotion in Sudan

This section presents a preliminary proposal on possible international cooperation to support the acceleration of IWRM promotion in Sudan. The JICA IWRM Project was successful in confirming the validity and possibility of IWRM approach through its works in three phases. The international cooperation presented here is intended to follow up the JICA IWRM Project and expand its application so that IWRM takes root widely and deeply in Sudan. In addition to technical cooperation, financial cooperation required for the development of the physical environment needed for the dissemination of IWRM, such as procurement of monitoring equipment, is proposed. Synergistic effects of assistance can be expected by combining technical cooperation and financial cooperation.

Table 6-4 shows the proposed technical cooperation projects. The following are the points to be noted

- ✓ Provide both technical and social science support.
- ✓ Select model states for assistance, rather than all states at once.
- ✓ Non-Nile states will be targeted as model areas. Non-Nile states are defined as the following states where the Nile does not flow through the state: 5 Darfur states, Kassala, Gedaref, Red Sea, South Kordofan, West Kordofan, and North Kordofan.
- ✓ Even though the Nile River flows through the state, some districts depend on water sources other than the Nile River, so these areas should also be considered.
- ✓ As a basic stance, the International Expert will make a Training of Trainers (TOT) to the WRTO-IWRM Unit to strengthen the capacity of the WRTO-IWRM to assist the states.
- ✓ The Partnership and Resource Management Unit (PRMU), established in 2021, will serve as the international aid window for MIWR. WRTO, the core of the NWRC-SWRC structure, and PRMU will work together to ensure that aid projects introduced are linked to IWRM principles-based water sector improvements.

Table 6-4 Example of technical cooperation project 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 State Water Resources Council (SWRC) and Water Users Committee (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 groundwater is the main source of water. Future expansion to other areas with different water source conditions and water use patterns, such as base 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 IWRM statewide 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 (updating the existing one prepared in 2007) • Preparation and operation of the NWRC • Organization and management of the Federal-State IWRM Partnership Committee • Selection of states for pilot project implementation (Non-Nile and states or areas 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 other areas such as the basement rock region and the Nubian sandstone region and Sikeran Wadi Basin
Cooperation period	5 years

Support Themes	Institutional organization building, participatory consensus building, legal promotion (groundwater law, surface water law, irrigation law in effect in 2016), monitoring (groundwater, surface water, water quality), water balance calculation, groundwater/surface water conjunctive use, water-saving irrigation, data management
Notes	It is necessary to confirm the readiness of the C/P fund on the part of the Government of Sudan.

Chapter 7: Activities Related to Capacity Building Support

7.1 Third Country Training

Third country training was conducted in Morocco and Tunisia.

(1) Morocco

Training Overview

The third country training was held in Morocco from May 14 to May 26, 2017. The objective of the training was to learn about watershed management for sustainable water use. The training was held at the International Water Resources Institute of the Moroccan National Electricity and Water Agency (ONEE-IEA). 20 years ago, Morocco had many problems related to water. However, after the capacity-building projects by foreign donors were completed, the country overcame its problems through its own efforts in infrastructure development and human resources development. It is significant for Sudan to learn from Morocco's best practices. Moreover, Morocco has successfully expanded drip irrigation from 10% (as of 2005) to 100% (as of 2016), controlled the decline in groundwater levels, and created mechanisms for sustainable watershed management. This was learned during the training as well.

Utilization of Training Results

After the training, the trainees held a group discussion and compiled it into an action plan. The plan was developed to identify issues in Sudan and to apply the plan to Sudan with reference to the case study in Morocco. The following are the framework of the plan.

- Importance of social and institutional frameworks and the financial resources to support them
- Scientific research and capacity building and awareness
- Improvement of technology in data collection and processing
- Secure budget and funding for water resources management
- Raise awareness of maintenance and management of user organizations in water supply facilities, and re-evaluate residents' organization activities.
- Balancing a top-bottom approach and adopting water governance

(2) Tunisia

Training Overview

The third country training was conducted in Tunisia from October 1st to October 10th 2018. The objective of the training was to learn integrated water resources management considering limited water resources and development. The Center for Water Research and Technology (CERTE) of the Tunisian Ministry of Agriculture was the host institution for the training. During the training, the participants learned efficient management techniques for water resources based on hydrology and methods to promote sustainable use of water resources. In addition, in order to consider efficient agriculture in arid regions, the participants were trained on the current state of irrigated agriculture in Tunisia. The findings and lessons learned on water resources management can be applied to the promotion of irrigated agriculture in Sudan.

Utilization of Training Results

The training program consisted of three components: lectures, field visits, and discussions. In the group discussions, based on the lessons learned from the training, participants gained a deeper understanding of IWRM by comparing and contrasting the IWRM situation in Tunisia and Sudan, and discussed a water resources management system suitable for Sudan. The group discussions were divided into three groups to give the trainees more opportunities to speak. All trainees discussed and raised issues on 10 key elements for water resources management in Tunisia. Afterwards, each group was assigned to conduct a detailed root cause analysis of each element, and each group made a presentation on the results of their study. The trainees found many features and strengths of IWRM practices in Tunisia, and as lessons learned, they hope to continue the training in Sudan, where they believe it is necessary to improve organizational management and individual capacities.

7.2 Training in Japan

The objectives of the pilot activities in Phase-2 of the Project is divided into two categories: the building and strengthening of consensus and policy-making systems in North Kordofan State (SWRC, WUC, etc.), and the strengthening of tools for monitoring and data management (groundwater and surface water monitoring, database etc.). Based on these objectives, the trainees were divided into two groups and the training content was planned and implemented in accordance with the respective objectives.

(1) Saijo City: Strengthening of Tools for Monitoring and Data Management

The training in Saijo City took place from November 15 to 25, 2022. The training objectives are shown in Table 7-1.

Table 7-1 Training Objectives

Overall Target	To understand Japanese water resource management techniques and knowledge to enhance the functioning of SWRC, North Kordofan State.
Unit Objectives - I	Understand how to conduct groundwater and surface water resource monitoring and how to use the data.
Unit Goal - II	Understand the contents and methods of water balance analysis and how to develop a water resource management plan based on the data.
Unit Objectives - III.	Understand the conjunctive use of groundwater with surface water for conservation.
Unit Objective-IV	Understand how to implement and evaluate water resource management plans and how to communicate plans to water users.

In Saijo City, the participants learned about the groundwater management plan. Through this plan, they learned that the relationship between river flow - groundwater recharge - groundwater level was determined, and river flow was adjusted to prevent the groundwater level from dropping and seawater from entering the aquifer. This is an effective coupled use of groundwater and surface water. Also, In addition, they learnt about the ordinance (laws of local municipality) and other measures enacted by Saijo City to implement the groundwater management plan. Through these various measures in Saijo City, trainees learned findings and lessons to promote necessary activities to implement the water resources management plan such as monitoring and groundwater license in North Kordofan State (for State C/P) and in other states (for Federal C/P) in the future.

(2) Kumamoto: Building and Strengthening of Consensus and Policy-making Systems

The training in Kumamoto took place from January 15 to January 26, 2023. The objectives of the training are shown in Table 7-2.

Table 7-2 Training Objectives

Overall Target	To understand Japanese water resource management techniques and knowledge to enhance the functioning of SWRC in North Kordofan State.
Unit Objectives - I	Understand the roles and responsibilities of government at different administrative levels and how to coordinate between administrative organizations.
Unit Goal - II	Understand how to involve and collaborate with various stakeholders, especially irrigated farmers.

Unit Goal - III	Understand how to operate the Kumamoto Groundwater Foundation (KGF), including how to secure a budget. Learn how to operate the Kumamoto Groundwater Foundation (KGF), being aware that it has the same functions as the SWRC.
Unit Goal-IV	Understand how to make municipal water resource management more effective, including the implementation of ordinances and water resource management plans related to the management and conservation of water resources.

In the plains of Kumamoto Prefecture, groundwater levels have been declining due to a decrease in the amount of paddy fields resulting from a decrease in rice consumption and consequently a decrease in groundwater recharge from the paddy fields. This is a typical example of how social and economic changes affect the availability of water resources. Kumamoto City established the Kumamoto Groundwater Foundation, and the government, companies, and citizens worked together to solve the problem. One of the measures to solve the problem was to promote groundwater recharge from rice paddies in winter. By learning about how to establish and operate such a consultative body, C/Ps learned methods and points to keep in mind to sustain SWRC and NWRC operations in the future.

Chapter 8 Strategic Environmental Assessment (SEA)

8.1 Importance of SEA

8.1.1 SEA Overview

SEA (Strategic Environmental Assessment) is applied at higher levels of any development, such as policies and programs, as opposed to project-based environmental assessments such as IEE (Initial Environmental Evaluation) and EIA (Environmental Impact Assessment). Inevitably, SEA is applied from the earliest stages of intervention in development, usually related to policy formulation and master planning.

Whereas EIAs primarily consider limited impacts on a project-by-project basis, SEAs assess impacts more broadly in time and space. In other words, SEA assesses not only short- and medium-term impacts, but also long-term impacts and impacts on geographic areas. It also covers all the different sectors and interests that may be affected by any development. In other words, SEA is an effective evaluation method plan for environmental development that takes "environment" in its broadest sense. SEA assesses cumulative and combined impacts and brings environmental and social considerations to the forefront within the development framework. SEA is a comprehensive, comprehensive, and comprehensive approach to development.

SEA must involve a wide range of stakeholders from the earliest stages of development interventions. This is accomplished by (1) holding stakeholder meetings and (2) disclosing and sharing relevant information.

8.1.2 Why is SEA Needed for IWRM?

SEA is essential to the evaluation of IWRM in Sudan. First, the objectives of water resource management should be considered by establishing a wide range of options, and then the general direction of policy interventions and planning should be determined. Possible directions are listed in Table 8-1.

Table 8-1 Consideration on Policy Interventions and Planning

Consideration point	Primary Viewpoint
policy intervention	• Promotion of industrial issues (industrial structure, transformation of industrial structure) • Legislation on water rights, development of water rate structure, and cost sharing • Promotion of efforts to address environmental issues (energy conservation, water conservation, recycling, etc.)
planning	• Water resources development (balancing Nile and non-Nile water systems, equalization of water resources between regions) • Industrial Development Plan (especially agriculture and livestock industry) • Core infrastructure development plans (surface water and groundwater development, water supply facilities, large-scale irrigation, etc.)

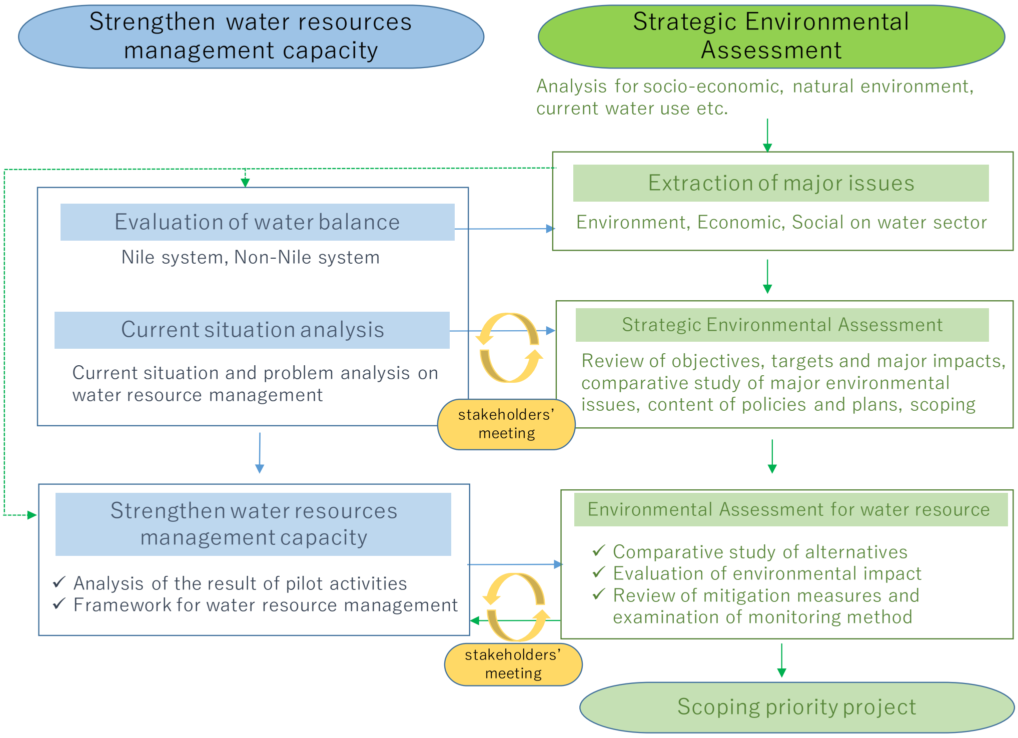
Source: JICA Project Team

Furthermore, SEA is an effective method for consensus building among the many stakeholders in IWRM, and its concepts can be applied to activities with complexity at the national and local levels.

8.2 SEA Trial

As a trial of technical transfer to C/P, assuming that IWRM will be implemented throughout Sudan, a trial SEA was conducted.

There is no law and regulation on SEA at this time. Therefore, a simplified procedure for applying SEA to IWRM in this project was first studied and assumed to be summarized in Figure 8-1. This procedure should and can be modified flexibly, taking into account the progress of the technical analysis and the current status of the water balance. In particular, the method of holding stakeholder meetings should also need to be carefully considered, including the selection of stakeholders to participate.



Source: JICA Project Team

Figure 8-1 Simplified SEA Process

Based on the above-mentioned procedure, the following process summarizes the main phases. Some related activities were conducted in this project.

Phase 1: Establish objectives, establish baselines, and determine scope of application

1-1 Identification of other relevant plans, programs and environmental protection objectives

1-2 Collection of baseline information

1-3 Identification of Major Environmental Issues

1-4 Formulation of SEA Objectives

Phase 2: Formulation and elaboration of alternatives and evaluation of their effectiveness

2-1 Evaluation of IWRM Objectives against SEA Objectives

2-2 Development of Strategic Alternatives

2-3 Predicting and comparing the effects of different strategic alternatives

2-4 Evaluation of IWRM Effectiveness

2-5 Mitigation of Adverse Effects

Phase 3: Consultation and Monitoring

3-1 Stakeholder Consultation on Draft IWRM and Draft SEA Report

3-2 Establishment of Monitoring Objectives and Methods

In the first phase, a water balance analysis and problem analysis were conducted. Then, JICA experts held 9 workshops in various ministries concerned and conducted field surveys in Khartoum and rural areas. As a result, many problems related to the water sector were identified. These issues were organized by JICA experts and C/Ps as a progress tree, identifying key issues and summarizing the relevance of each issue. These analyses provided a clear picture of the key environmental issues arising from the water sector, consisting of surface water, groundwater, urban and rural water supply, irrigation and livestock activities, and water pollution. The description of the causes and consequences associated with water issues also provided a visual identification of the relationships among these sectors.

The most important item in the SEA process is the establishment and comparative evaluation of alternatives. Therefore, in the second phase, the four alternatives shown in the table below were established with respect to the future water resources management in Sudan. Each of the water resource development alternatives has a different direction of implementation. Alternative A requires the construction of intensive water supply facilities to meet the uncontrolled and ever-increasing water demand, resulting in a large investment in water resources development. Under Alternatives B, C, and D, the required investment can be compressed through demand-side and supply-side measures. However, the approaches to water resource management differ, with both alternatives applying IWRM, but with more environmental considerations in Alternative B and a primary orientation toward socioeconomic development in Alternative C. In addition, D is a balanced alternative that considers the overall optimum by integrating B and C in a balanced manner.

Table 8-2 Comparison of each alternative

alternative plan		Major Development Issues and Measures
A	No IWRM (zero option)	✓ No change from current status ✓ Intensive development of infrastructure to meet water demand ✓ No coordination between related departments
B	Environmentally Conscious Alternative	✓ Water Quality Conservation ✓ Preservation of ecosystems and biodiversity ✓ Avoid depletion and contamination of groundwater ✓ Reducing the risk of ground subsidence
C	Socio-economic development oriented alternative	✓ Promote local economic development ✓ Promoting industrial development ✓ Expansion of irrigated area
D	Balanced Alternative	✓ Balanced urban and rural development ✓ Integration of environmental and economic/social considerations ✓ Mutual complementation of water supply and demand

Source: JICA Project Team

During the SEA process, each alternative should be compared and the most appropriate alternative selected. Alternatively, the best alternative may be proposed by combining each alternative. In this project, Alternative D was proposed as appropriate after discussions at a workshop with various stakeholders, including the Ministry of the Environment. In order to promote this alternative, a participatory approach is needed. This would involve coordination among several sectors based on the consensus of stakeholders and organizations involved. In this scenario, the engineering and social aspects need to be addressed simultaneously, and both need to be integrated.

Through a series of activities based on the analysis of problems and other issues in the first phase, 15 strategies to promote IWRM were identified. These include "coordinated use of surface water and groundwater," "water demand management in regional development plans," "conducting assessments of groundwater development," and "establishing a mechanism to coordinate disputes over water issues in the region," etc. Therefore, in the third phase, through consultations with stakeholders, an assessment of the environmental and social impacts of each strategy and monitoring methods were conducted. Through these activities related to the SEA trial, the project has contributed to strengthening C/P's capacity for SEA and environmental impact assessment.