TABLE APP.-1 GROUNDWATER RESOURCES ESTIMATION (1/2)

H. G. A. & Lithology	Area $\times 10^{6}$ (sq. km)	Rain Fall (mm)	Permeability (%)	Recharge Amount $\times 10^{6}$ (cu. m)	Ajustment Ratio (%)	Extractable Groundwater Reserves	
						$\times 10^{6}$ (cu. m)	(cu. m/sq. km)
Basement Complex Area							
I − 1	28.300	750	9	1.910	40	760	27.000
I − 2	72.600	750	9	4.901	35	1.720	23.600
I − 3	12.700	750	9	857	30	260	20.300
II − 1	43.800	1.150	10	5.037	40	2.010	46.000
II − 2	73.500	1.150	10	8.453	35	2.960	40.300
II − 3	4.600	1.150	10	529	30	160	34.500
III − 1	5.300	1.100	10	583	40	230	44.000
III − 2	22.200	1.100	10	2.442	35	850	38.500
III − 3	12.100	1.100	10	1.331	30	400	33.000
III E − 1	900	1.400	11	139	40	60	61.600
III E − 2	19.700	1.400	11	3.034	35	1.060	53.900
III E − 3	30.000	1.400	11	4.620	30	1.390	46.200
IV − 1	1.100	1.600	11	194	40	80	70.400
IV − 2	16.400	1.600	11	2.886	35	1.010	61.600
IV − 3	6.900	1.600	11	1.214	30	360	52.800
VI − 1	12.900	1.300	11	1.845	40	740	57.200
VI − 2	52.100	1.300	11	7.450	35	2.610	50.100
VII − 1	4.000	650	9	234	40	90	23.400
VII − 2	20.800	650	9	1.217	35	430	20.500
VII − 3	3.000	650	9	176	30	50	17.600
Sub Total	442.900	−	−	49.052	−	17.230	38.900

TABLE APP.-1 GROUNDWATER RESOURCES ESTIMATION (2/2)

H. G. A.	& Lithology	Area (sq. km)	Rain fall (mm)	Permeability (%)	Recharge Amount $\times 10^6$ (cu. m)	Ajustment Ratio (%)	Extractable Groundwater Reserves $\times 10^6$ (cu. m)	Extractable Groundwater Reserves (cu. m/sq. km)
Sedimentary Formation Area								
Sokoto	Ss	51.600	600	17	5.263	40	2.110	40.800
	Sc	5.900	600	17	602	35	210	35.700
	Sq	7.200	600	17	734	45	330	45.900
Chad	Cs	107.000	450	17	8.186	40	3.270	30.600
	Cq	17.200	450	17	1.316	45	590	34.400
Middle Niger	Ms	32.100	1.150	18	6.645	40	2.660	82.800
	Mq	4.900	1.150	18	1.014	45	460	93.200
Upper Benue	Trs	27.700	700	17	3.296	40	1.320	47.600
	Kgs	3.700	750	17	472	40	190	51.000
	Kpc	15.300	750	17	1.951	30	580	38.300
	Kbys	24.400	750	17	3.111	40	1.240	51.000
	Uq	6.100	850	17	881	45	400	65.000
Lower Benue	Lc	34.700	1.250	18	7.808	30	2.340	67.500
	Lq	3.300	1.250	18	743	45	330	101.300
South-E. Basin	Kroc	29.300	1.600	19	8.907	30	2.670	91.200
South-C. Basin and South-W. Basin	Kucs	19.400	1.600	19	5.898	40	2.360	121.600
	Tbs	3.200	1.800	19	1.094	40	440	136.800
	Tmc	16.600	1.800	19	5.677	30	1.700	102.600
	Cpq	40.700	1.800	19	13.919	45	6.270	153.900
	Dq	30.600	2.000	19	11.628	45	5.230	171.000
Sub total		480.900	–	–	89.145	–	34.700	72.200
Total		923.800	–	–	138.197	–	51.930	56.200

TABLE APP.-2 WELL DEVELOPMENT AND PUMPING TEST DATA

QUESTIONNAIR

1. Borehole location
   (a) Town/Village..
   (b) Local Government Area ....
   (c) State ....
2. Owner/Controlling Agency of borehole...
3. When was pumping test carried out ....
4. How long was pumping test carried out ? ....
   (a) Time pumping started...
   (b) Time pumping stopped...
5. Water level before pumping..
6. Maximum drawdown attained (m) ....
7. Thickness of aquifer (m)..
8. Transmissivity of aquifer, T, ...
9. Storativity of aquifer, S, ...
10. Yield of aquifer (litres/sec.)..
11. Pumping test data (see overleaf)...
12. Pumping test diagrams (see overleaf)...

TABLE APP.-3 PUMPING TEST DATA AND ANALYSIS (1/2)

STATE	L. G. A.	TOWN/VILLAGE

SOURCE	OWNER/BOREHOLE No.	DRILLED BY

DATE	TIME		PUMPING RATE (l/sec.)	PUMPING LEVEL (m)	STATIC WATER LEVEL (m)	DRAWDOWN (m)	REMARKS
	HOUR	MIN.					

TABLE APP.-3 PUMPING TEST DATA AND ANALYSIS (2/2)

DATE	TIME		PUMPING RATE (l/sec.)	PUMPING LEVEL (m)	STATIC WATER LEVEL (m)	DRAWDOWN (m)	REMARKS
	HOUR	MIN.					
RECOVERY TEST							

	DATE:

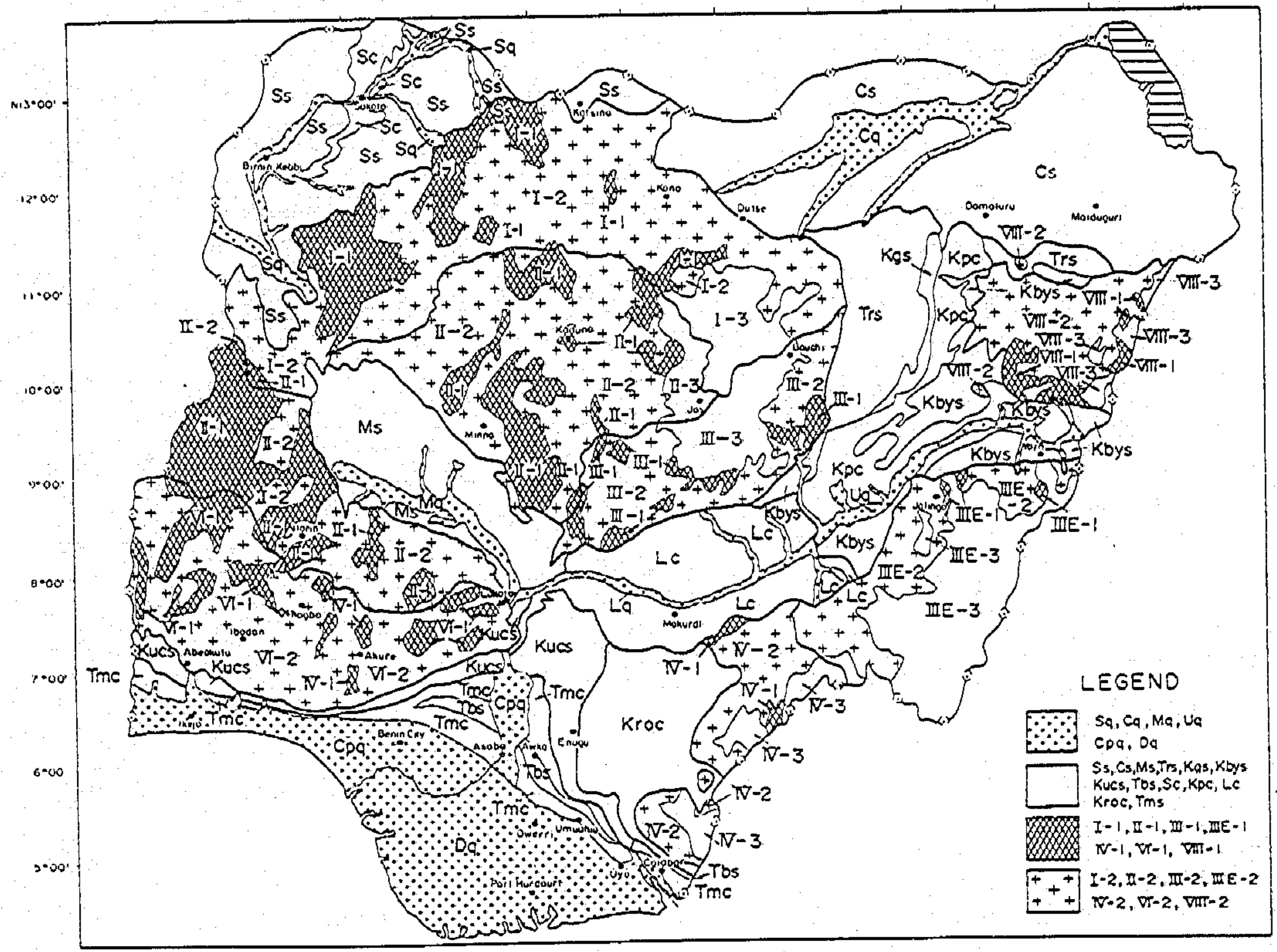

FIGURE APP-1 AREA INDEX OF GROUNDWATER RESOURCES ESTIAMTION

CHAPTER 4. WATER SOURCE WORKS

CHAPTER 4: WATER SOURCE WORKS

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Appendix

CHAPTER 4: WATER SOURCE WORKS

LIST OF TABLES

CHAPTER 4. WATER SOURCE WORKS

4.1 GENERAL BACKGROUND

Rivers in Nigeria have a large runoff fluctuation presenting a rich runoff in wet season / year, and poor in dry season / year. Under this situation, effective surface water use for irrigation, water supply, hydropower, inland fishery, etc. could not be achieved without dams to store rich runoff in wet period and use it during dry period. Accordingly many dams have been planned and constructed in Nigeria for water source works. Pumping stations also have been constructed to withdraw water from rivers in the southern region having discharge to some extent in rivers even in dry season.

Since dams are the main water source works and has faced many technical problems in their plan, design, construction and operation and maintenance in the recent years, the Master Plan for water source works is focussed on dam. Pumping station plan for water source works is set up in the irrigation sector.

Many reservoir dams have been proposed, constructed and operated since 1920's by the following agencies;

RBDA	;	mainly for large dams for irrigation, of which some have a function of water supply and mini-hydropower
MANR	;	mainly for small dams for irrigation
SWA	;	mainly for small dams for water supply, of which some have irrigation function
NEP	;	for large scale hydropower
NESCO	;	for mini-hydropower
ADPs	;	for multipurpose rural water development

Since technical data related to the existing and proposed reservoirs and dams are very scarce and scattered in different agencies, such as RBDA, MANR, SWA etc, NWRIS of reservoirs and dams was conducted as a component of the study by domestic consultants under the supervision of the JICA Team together with the counterpart of FMWRRD. In addition, the JICA Team has directly requested the agencies concerned to collect and submit the data for the existing and proposed reservoirs and dams. Data surveyed by NWRIS included location, executing agency, objective, hydrological condition, reservoir outline, dam dimension, construction cost, year of completion for the existing dams, stage of implementation for projected dams (i.e. feasibility study, detailed design, construction), irrigation area, power output and water supply population, etc. The data collected by NWRIS and data supplied by the various agencies concerned were in many cases incomplete and inaccurate due to lack of technical data in each agency.

The JICA Team examined the data collected by the domestic consultants and agencies concerned based on the maps of 1 to 50,000 scale, the site survey, and the available reports, etc.

The following modification / adjustment / correction were made to the collected data;

- Dams, which were not identified on the maps and dimension not given in the collected data, were excluded from Water Resources Inventory Survey, as review for such dams was not possible.
- Rainfall and reservoir inflow at damsite were carefully reviewed by the JICA Team based on hydrological observation data of the 1980s which were collected from each gaging station during the NWRIS period, as the hydrological condition in the 1980s has changed by the influence of the Sahlian Drought.
- As for the dams lacking data on catchment area, reservoir area and reservoir capacity, estimations were made from the map of 1 to 50,000 scale.
- For the irrigation areas downstream of the existing and proposed dams, which were not provided in the collected data, assumption has been made based on available effective reservoir capacity, reservoir inflow, irrigation demand per ha, etc.
- Dam height, dam length, dam embankment volume, outlet discharge capacity, spillway design capacity, construction cost, etc. were all based on the collected data, as it was not possible to check these data during the study period.

Preliminary Database Summary (Water Resources Inventory Survey) of the above data was incorporated in the Interim Report and submitted to

FMWRRD and agencies concerned for checking and verification of their accuracy, and the Water Resources Inventory Survey (Vol. Three) was prepared by additional and amended data submitted by FMWRRD and agencies concerned.

Due to lack of data in the respective agencies, some portions of the dam data under the Water Resources Inventory Survey could not be completed. Thereby, it is strongly recommended that necessary survey for the existing dam dimensions to be carried out and to check and complete the lacking data.

In addition to the NWRIS, the JICA Team has carried out site survey of a number of existing and proposed dams and their river conditions and studied problems and needs related to planning, design, construction and operation and maintenance of dams. As a result, countermeasures and basic plan for proposed dams towards the year 2020 have been formulated.

Possibility of the inter basin water transfer projects to be proposed by FMWRRD was also studied preliminarily in accordance with the site survey.

4.2 SALIENT FEATURE OF DAMS

4.2.1 Natural Condition at Damsite

(1) Damsite Topography and Geology

Dams in Nigeria are mostly planned and constructed at the sites where rivers flow down on very gentle slopes and in undulated hilly areas. Damsite and reservoir areas are mostly situated in devastated area without vegetation, causing easy erosion by heavy rainfall, which brings about large amount of sediment transport. Only damsites and reservoir areas in the southern region are covered with dense forest.

Damsites are geologically selected on Basement Complex Formation consisting of granite and covered with thin overburden and weathered rock. Although dam foundation consisting of fresh and consolidated granite rock has enough bearing capacity to support dam body and appurtenant structure and presents less permeability, the foundation covered with weathered rock or formed with rock including crack and fissure presents high permeability. Overburden lying on rock formation is formed with coarse sandy materials without cohesion and presents considerably high permeability. Damsites at the Sedimentary Formation consisting of sand stone and shall along the Niger and Benue rivers and in the southern region, however, present less permeability in their foundation, because those foundations are covered with impervious clayey and silty material.

Construction materials of earth and rock for fill dams are sufficient and easily available at hilly area surrounding damsite. It is rather difficult, however, to find impervious earth materials for core zone in fill dams, as the earth materials are generally composed of coarse and no cohesion property. Sufficient impervious materials are usually found at damsites lying on sedimentary formation.

Damsite runoff differs considerably in the northern, central and southern region and fluctuates largely seasonally and annually.

(2) Damsite Hydrology

Northern Region

Average annual rainfall is as little as 400 to 700 mm; Rainfall occurs in wet season from June to October. Annual evaporation reaches a large value of 3,000 to 3,500mm of which 70 percent takes place in dry season. River runoff also occurs only in wet season and its specific yield is as small as 30 to 100mm due to less rainfall and high evaporation rate in the river basin area being formed with very flat topography.

Central Region

Region presents moderate rainfall of 800 to 1,200mm, which also appears only in wet season. Evaporation value shows 2,000 to 2,500mm, of which 70 percent occurs in dry season. River runoff appears largely in wet season but small runoff exists in some rivers located at the upper river basin. The runoff specific yield is evaluated at 250 to 300mm in the mountain area with rich rainfall and 150 to 200mm at hilly or flat area with moderate rainfall.

Southern Region

Region presents high rainfall of 1,500 to 2,500 mm, of which 80 to 90% appears in wet season and 10 to 20 percent in dry season. Evaporation value is as small as 1,500 to 2,000 mm. Rivers have abundant runoff in wet season and some runoff even in dry season. The runoff specific yield reaches the high value of 300 to 500 mm. The yield in the Cross river with the highest rainfall of more than 2,500 mm reaches considerable high value of 800 to 1,000 mm.

All rivers in Nigeria, especially in the northern and central region have tendency to bring about large sediment transport from the devasted upper river basin. Large sediment transport appears in rivers of Anambra State, because large scale gully erosion has developed in the basin.

4.2.2 Outline of Dams and Reservoirs

(1) Dam Type and Size

Dams in Nigeria are planned and constructed mainly with fill type from viewpoint of topographical and geological condition and available embankment materials at damsites. Dams are generally designed with low dam height, long dam length and large reservoir capacity with large reservoir surface area. Size of the existing dams is as shown in Table 4.2.1 and summarized as follows;

Dam Height

High dams with height of more than 30 m are only 18, and dams with height of 15 to 30m count 142. A number of small dams with height of less than 15m are 97.

Dam Length

Out of 126 samples, 45 dams are constructed with long dam length of more than one km and 32 dams with the length of 0.5 to 1.0 km due to wide river width at damsite.

Reservoir Capacity

Out of 132 samples, 20 dams have large reservoir capacity of more than 100 MCM and 44 dams with capacity of 10 to 100 MCM.

Reservoir Area

Out of 94 samples, 12 dams occupy large reservoir area of more than 100 km^2 and 36 dams with the area of 5 to 100km^2.

(2) Dam and Appurtenant Structure

A number of fill dams for irrigation and water supply is designed with the following structure.

(a) Dam Foundation

Deep cut-off trenches to be treated by grouting works and backfilled with impervious material are provided at dam foundation in order to prevent leakage through previous dam foundation.

(b) Dam Body

Dam body is designed with zone type fill for large dams and homogeneous type fill for small dam. Filter drain in dam body and relief well at the downstream toe of dam also are installed to make seepage line lower in the downstream dam zone, to drain seepage water smoothly through dam body and to reduce piping energy at the downstream toe of dam.

(c) Outlet

Outlet structure in large irrigation dam mostly consists of intake tower, conduit steel pipe in concrete culvert embedded in river bed, and control valves at the end of steel pipe. Outlet structure in small dam consists of drop inlet, concrete conduit and control valve.

(d) Spillway

Spillway structure is designed mostly with Ogee type weir without control gates. Only some large dams with mini-hydropower plant or flood control function are designed with gate control spillway.

(3) Reservoir Operation and Water Use

(a) Reservoir Operation

Reservoir operation is carried out so as to reach the full water level in the reservoir in September storing wet season inflow appearing in a short period from July to September and to cope with the water demand during long dry season period. Some reservoir water in previous year is to be carried over to meet the water demand of the following year which may face water shortage resulting in less reservoir inflow. Outflow from the reservoirs for irrigation and water supply is generally made to meet the water demand at beneficial area taking into account the water required for the downstream area and river maintenance. However, some existing reservoirs were operated without careful consideration for the water right at the downstream area.

(b) Reservoir Water Use

Designed active reservoir capacity is generally fulfilled in September by reservoir inflow during wet season and its water is released to meet the water demand during dry season.

Available reservoir water for the water demand, however, is reduced by evaporation loss from reservoir surface area, storage capacity to be carried over to next year, and downstream water release to the wetland. In this respect, available reservoir water in the northern region for dry season for irrigation and water supply will be about 40 to 60 percent of the active reservoir capacity.

In the central region, available water will be more than that of the northern region, owing to less evaporation loss. Available water for dry season will be 70 to 80 percent of active reservoir capacity.

In the southern region, available water corresponds to active reservoir capacity, because there are some reservoir inflow even in dry season and can compensate for evaporation loss and downstream water release.

The reservoir water of hydropower dam is fully used at present for power generation under proper reservoir operation by NEPA. The reservoir water for irrigation and water supply, however, is currently not used effectively due to incomplete irrigation and water supply system at service area. In case of irrigation dams, only 10 to 20 percent of reservoir water is used at present.

4.2.3 Regional Distribution of Existing Dams

(1) Nationwide

Many reservoir dams were constructed in the 1970s to 1980s for irrigation, water supply and hydropower purpose. The notable dams with large active capacity constructed or under construction are shown in Table 4.2.2.

List, outline and dimension of the existing dams were prepared through NWRIS and summarized in the Water Resources Inventory Survey and their location is shown on Database Map (14). Classification of dams under NWRIS followed the international guideline, large dams with height of more than 15m and small dams less than 15 m.

65 large dams and 95 small dams have been completed or under construction in the country, and their total active reservoir capacity would be about 30,700 MCM. Number and active capacity of the existing dams on objective basis are tabulated below.

Main Objective	Large		Small		Total	
	No	A.C	No	A.C	No	A.C
Irrigation	29	10,800	42	370	71	11,160
Water Supply	30	740	53	160	83	910
Hydropower	6	18,600	0	0	6	18,600
Total	65	30,140	95	530	160	30,670

Remark; A.C. Active reservoir capacity (MCM)

Distribution of reservoir dams in each SHA and Region is shown in Table 4.2.3 and 4.2.4 respectively.

(2) North West Region (HA-1)

Large irrigation dams such as Jibiya, Zobe, Bakolori and Goronyo are situated at the northern tributaries of the Gada. Bunshuru, and Sokoto in the Sokoto-Rima basin and their total active capacity reaches about 1,500 MCM, which could control most of river runoff at the tributary basins. Reservoir water of Jibiya and Bakolori dam is partially used for irrigation area, but that of the other dams is not being used at all due to incomplete irrigation system in service area. A large irrigation dam of Kubli with the active capacity of 62 MCM is constructed at the Swashi river flowing down to the Niger and its reservoir water is to be used for irrigation in service area.

In addition to the above large irrigation dams, dams with small active capacity were constructed for water supply and irrigation at the northern tributaries and small tributaries of the Malando and Bambiri located at the left bank of the Niger. Those dams have mainly water supply function for urban area and their reservoir water is being used effectively. The largest hydropower dam of Kainji was constructed with huge active capacity of 11,500 MCM at the Niger and under operation for hydropower generation controlling abundant runoff of the Niger.

Although the Gawon Gulbi, Zamfara, Gulbinka, etc., large tributaries of the Sokoto-Rima, and small tributaries emptying into the Niger have rich runoff, water resources development by dams in these tributaries have not progressed.

(3) North East Region (HA-8)

A number of irrigation and water supply dams have been constructed in the upper basin of the Hadejia and their total active capacity reaches about 3,000 MCM. Notable dams are Gari, Challawa Gorge, Watari, Tiga, Guzuguzu, Tomas, Jakara, Bagauda, etc. and their reservoir water use has been concentrated to meet the water demand for irrigation and water supply in Kano

State. The reservoir water of Challawa Gorge dam is to be used for the Hadejia Valley irrigation project located at Jigawa State.

Those dams, however, have faced water shortage problem due to less reservoir inflow compared to active reservoir capacity. In addition, the wet land located downstream has also faced water shortage problem, as almost all river runoff in the upper basin have been stored by many dams.

Kafin Zaki dam with huge active capacity of 2,500 MCM has been planned at Jamaàre upper basin. The dam construction was commenced at 1981, but has been suspended, as the project was considered economically unsound and also shortage of construction fund.

If the dam should be constructed under present reservoir and irrigation plan, considerable water shortage will take place in the reservoir and the downstream wetland area, because the reservoir inflow at damsite is assumed at only 800 MCM p.a. on an average, which is 30 percent of active reservoir capacity.

The reservoir inflow of Kafin Zaki dam may be assumed at a large volume even with the absence of runoff observation in the planning stage. The reservoir inflow at the damsite is estimated at 1,100 MCM p.a. in the 1980s based on the observation data at Bunga bridge station and the catchment area rate between damsite and the gaging station.

In the other river basins such as Dingaiya, Yedseram, Kamaduga Gama, etc., there is no existing dam except small dam of Alau for irrigation and water supply near Miduguri city in the Ngadda river due to scarce runoff in rivers and non-existance of suitable damsite.

(4) Central West Region (HA-2)

There are 19 large and 13 small dams for irrigation and water supply in the region. Those dams are mostly distributed at the upper basins of the Kaduna and Gurara as well as small rivers at right bank basin of the Niger. Notable dams are Kontagora and Omi under construction for irrigation and Asa, Kangimi, Suleja and Usuman are under operation for water supply. The largest hydropower dams of Jebba and Shiroro with active reservoir capacity of

1,000 MCM and 6,050 MCM respectively in the region are under full operation for hydropower generation controlling abundant runoff of the Niger and the Kaduna.

Although the upper basin of the Kaduna and many river basins such as the Gbako, Oli, Moshi, Oshin, Ove flowing into the Niger river have rich runoff and fertile land, the water resources development by dams is not dormant.

(5) Central East Region (HA-3 and HA-4)

There are 32 large and small dams for irrigation and water supply and three small dams for mini-hydropower in the region. Those dams are mostly situated in Jos in the upper basins of the Gongola.

Large irrigation dams of Dadin Kowa with the capacity of 1,770 MCM and Kiri with 325 MCM were constructed at the middle and lower basin of the Gongola respectively. Although the reservoir water of Kiri dam is being used for irrigation of sugar cane plantation, that of Dadin Kowa is not being used at all due to no irrigation system at the downstream service area and no installation of mini-hydropower plant. Total active reservoir capacity of existing dams excluding the above two large dams is only 320 MCM.

Although a number of large tributary basins along the Benue in the region such as the Kilange, Mayo Ine, Mayo Belwa, Taraba, Donga, Shemonkar, Mada, Katsina-Ala have abundant runoff, the water resources development by dams has not been programed.

(6) South West Region (HA-6)

There are few existing large dams in the region. Only Oyan was completed and Ikere Gorge is under construction for multipurpose of irrigation, water supply, mini-hydropower and flood control and its active capacity is 254 MCM and 565 MCM respectively. Oyan dam does not contribute to irrigation at present due to incomplete irrigation system in the service area, but contribute to the water supply and flood control for larges urban area of Lagos.

Four large and 26 small dams for irrigation and water supply in addition to the above Oyan and Ikere Gorge are distributed at tributary basins in the northern plateau of the region. Those dams have mostly water supply function to a number of urban areas being scattered in the region. Although those dams are constructed with small active capacity of two to five MCM, they have function to supply sufficient water to service area, because rich runoff is available at damsite even in dry season. Many dams have function of diversion dams to raise up the water level of rivers during dry season.

Although a number of urban area demanding domestic water is expanding in the region, there are only a few existing dams for water supply. This is due mainly to the delay of water resources development.

(7) South East Region (HA-5 and HA-7)

Existing dams for irrigation and water supply are very few and are of small scale like diversion dams. There are no need for urgent water resources development by dam, as there are abundant rainfall and river runoff in the region. The region, however, has a number of urban areas and many fertile agricultural lands which require domestic water and dry season irrigation water, thereby number of small scale reservoir dams in tributary basins will be required in future.

4.3 PROBLEMS AND NEEDS

4.3.1 Existing Dams and Reservoirs

160 dams are constructed or under construction, and their total active reservoir capacity would be 11,200 MCM for irrigation, 900 MCM for water supply and 18,600 MCM for hydropower. Although reservoir water in hydropower dams has been used fully carrying out proper reservoir operation and hydropower generation of 1,900 MW, the water for irrigation and water supply has not been used effectively and its water using rate is only 10 to 20 percent, due to the absence of reservoir operation rule and non-completion of water distribution facilities in the service area.

In addition, some existing dams have deteriorated and have defects from viewpoint of dam safety. The major problems and needs for the existing dams and reservoirs are described as follows:

(1) Insufficient Reservoir Inflow against Active Reservoir Capacity

Some of large irrigation dams in the northern region are constructed with large active reservoir capacity as compared with reservoir inflow. The reservoir of these dams could not be filled to their designed full water level at the end of wet season due to less reservoir inflow and could not meet the planned irrigation water demand for the service area. In these dams, the reservoir water use plan shall be reviewed by the reservoir operation study. Otherwise, the irrigation area set up in the original plan will always suffer from water shortage problem during irrigation season owing to insufficient reservoir water. The existing irrigation dams having problem of less reservoir inflow is as shown in Table 4.3.1 as a result of the survey made by the JICA Team.

The reservoir inflow to the Kainji hydropower dam has decreased, due mainly to the decrease of the white flood from Nigeria's own river basin and the black flood flowing down from the other country of Mali and Niger. The white flood has decreased by Sahlian drought and affected by the irrigation and water supply projects at the Sokoto-Rima basin, while the black flood decreased not only by Sahlian drought but water resources developments in the Niger upper basin in the territories of Mali and Niger. As a result, the river runoff at Jiddre Bode station located at the upstream of Kainji dam decreases to 25,100 MCM p.a in 1980s from 34,100 MCM in 1970s.

The water use allocation for the Sokoto-Rima basin and Kanji dam shall be set up in future between FMWRRD and NEPA, while the water use agreement for the Niger black flood also shall be established among Nigeria and the other countries, otherwise the reservoir inflow to Kainji dam will decrease year by year, as a result its hydropower generation will suffer big damage.

(2) High Evaporation Loss from Reservoir Surface Area

In large dams at the northern region, there are high evaporation losses from their large reservoir area with high evaporation rate of 3,000 to 3,500 mm in Pan-Evaporation, as a result 30 to 40 percent of reservoir inflow has been lost and available reservoir water for irrigation and water supply in dry season is considerably decreased. Evaporation losses of the existing large dams are estimated as shown in Table 4.3.2.

In those dams with high evaporation losses, the irrigation area set up in the original plan could not be irrigated due to decreasing available reservoir water. It is necessary, therefore, to review the available reservoir water for irrigation and water supply demand in dry season taking into account evaporation losses.

(3) Need of Reservoir Water Release to Downstream Area

Large Fadama is developed at the downstream area of the existing large dams in the northern region and under cultivation using runoff flowing down from the upper river basin. These areas suffer water shortage, as large amount of runoff is being stored by many dams with large reservoir capacity. In the Hadejia and the Sokoto-Rima river basins, water shortage in the wet land area by large dams causes big social problem, consequently expansion of irrigation area in some dams in the northern area is suspended. It is necessary to study the water allocation at the downstream area and to release the allocated water from the existing dams to the area in order to guarantee the water right of the area and also maintain good environmental condition in the rivers. It is not necessary, however, to pay particular attention for the downstream water release from dams in the river basins which have much runoff in the basin between damsite and the downstream area.

(4) Unknown Available Reservoir Water

Although active reservoir capacity is clearly grasped and reservoir inflow is approximately estimated in the existing dams, the available reservoir water for irrigation and water supply is not known at all in many dams, as there is no study made in planning and design stage, especially for the reservoir operation study.

As mentioned hereinbefore, the available reservoir water is decreased by less reservoir inflow, evaporation loss and large downstream water release, etc. as compared with the active reservoir capacity.

The JICA Team studied approximately the available reservoir water in order to grasp the supply capacity of each dam for irrigation and water supply. The study was made under the following conditions;

(a) Active Reservoir Capacity

Active capacity is in principal considered to be provided for water demand of service area in dry season and to be filled up at the end of wet season by reservoir inflow. The water demand in wet season is considered to be covered mostly by effective rainfall and reservoir inflow in wet season, which is directly used through reservoir without storage.

The reservoir inflow, however, is regarded as the active capacity, if the inflow is smaller than the capacity, because the reservoir cannot be filled by the inflow.

(b) Evaporation Loss

Reservoir water stored up to the full water level at the end of wet season is decreased by evaporation losses during reservoir operation in dry season.

(c) Carry Over Water

Some of reservoir water corresponding to 10 to 20 percent of the active capacity is to be carried over to next year taking into account the less reservoir inflow in next dry year. When reservoir is planned with small active capacity as compared with very large reservoir inflow, it is not necessary to consider the carry over water for next dry year, because the reservoir will be filled even in next dry year.

(d) Available Reservoir Water for Dry Season

Accordingly, the available reservoir water for dry season is estimated as follows;

Case 1: The average annual reservoir inflow is mostly same as the active reservoir capacity.

active capacity - (evaporation loss + carry over water)

Case 2: The average annual reservoir inflow is less than the active reservoir capacity.

average annual inflow - (evaporation loss + carry over water)

Case 3: The average annual reservoir inflow is remarkably larger than the active reservoir capacity.

available water is the same as the active capacity.

(e) Reservoir Water Use

- The downstream release water is considered in accordance with the downstream condition such as the water right in Fadama Area. The water of 10 to 20 percent against the active capacity will be released to the downstream area in dry season to serve the private irrigation in Fadama Area.

- Available reservoir water for irrigation and water supply is estimated by deducting the downstream released water from total available water estimated by the above (d).

The evaluation result for available reservoir water in each existing dam by the JICA Team is as shown in Table 4.3.3 and 4.3.4.

Summary of evaluation result is as follows;

- Nationwide available reservoir water in dry season is assumed at about 5,100 MCM corresponding to 40 percent of the total active capacity of 12,100 MCM. Although rate of available reservoir water against the active capacity in the central and southern region is as high as 70 to 90 percent, the rate in the north east is considerably low at only 36 percent. The reason for the low rate is caused mostly by Challawa, Tiga and other dams, which are planned with the large active capacity as compared with the reservoir inflow and present high evaporation losses.

- In the North West region, Goronyo and other dams also present the low rate in available reservoir water. The major existing dams presenting the low rate is shown in the following table.

unit (MCM)

		Reservoir Inflow	Active Capacity	Evapo-Loss	Available Water	Rate %
Challawa	HA-8	460	900	130	330	37
Tiga	HA-8	910	1,845	270	700	38
Kafin Zaki	HA-8	1,170	2,500	400	860	34
Watari	HA-8	75	93	32	20	29
Gorony	HA-1	710	933	342	344	37
Zobe	HA-1	265	170	76	104	61

Available water in the above table includes the downstream water release.

(5) Small Reservoir Water Use

In accordance with evaluation of the available reservoir water as shown in Table 4.3.3, the available reservoir water for irrigation and water supply on the nationwide basis is assumed at 3,800 MCM and 1,300 MCM respectively, if the reservoir could be operated properly. The actual water use for the public irrigation and water supply of the surface water, however, is only 360 MCM and 530 MCM respectively. The water use rate is as low as 10 percent for irrigation and 40 percent for water supply.

The reason for the low rate of the reservoir water use are as follows:

- Incomplete irrigation system and water supply facility in service area.
- Lack of hydrological information due to the absence of gaging station and no continuous observation at the stations.
- No reservoir operation study, as a result no rule of reservoir operation and unknown available reservoir water.
- No information for changing irrigation water demand during irrigation period due to lack of close coordination of OM staff between dam and service area.

It is necessary to solve the above small water use problem urgently in order to obtain benefit from service area. Since it takes a relatively long period to implement and complete the irrigation system and water supply facility in service area, it is recommendable to release the reservoir water in dry season to the downstream wetland tentatively and to serve the private irrigation in its area for quick benefit return from reservoir water use.

(6) Decreasing Active Reservoir Capacity by Sediment Transport

Some of existing dams designed with small dead reservoir capacity have decreased their active reservoir capacity by sediment transport and lost their reservoir function. It is necessary in dam maintenance to survey decreasing active reservoir capacity by sediment transport and to review available reservoir water for the designed water demand in service area. The dead reservoir capacity in the existing dams was evaluated by the JICA Team based on the magnitude of catchment area and dam life of 50 years as shown in Table 4.3.5.

Some dams are designed with the small specific yield of sediment transport of less than 100 cum / km^2 as shown in Table 4.3.5. It will be necessary in the dams planned at the devasted catchment area without vegetation to adopt the specific yield of 150 to 200 cum / km^2 in the large catchment area of more than 500 km^2 and the yield of 200 to 300 cum / km^2 in the small area of less than 500 km^2.

Where there would be fear that the active capacity would decrease considerably by sediment transport, the Sabo dam to allow deposit of sediment transport would be required at the upstream river of the reservoir. Forestation in the surrounding area of the reservoir also shall be considered to protect sediment transport caused by sheet and gully erosion.

(7) Insufficient Spillway Flood Capacity

Spillway at some existing dams is designed with the small flood capacity and could not spill flood smoothly and safely during flood period. Bagauda dam in Kano State and Birnin Gwari dam in Kaduna State were destroyed recently due to flood overflow from dam crest caused by insufficient spillway flood capacity. The specific yield of the existing dams was examined by the JICA Team based on the design flood capacity and the catchment area at damsite as shown in Table 4.3.5. It is urgently necessary in those spillway with small flood capacity to expand the overflow crest length of spillway.

As a result of the NWRIS for the existing dams, the spillway flood capacity is unknown in many dams due to non-availability of data at the executing agencies. It is necessary to estimate the flood capacity at the agencies by measuring overflow depth and length of spillway and by the following hydraulic formula.

$$Q = C \cdot L \cdot H^{3/2}$$

Where, Q = Design flood capacity, L = Overflow crest length,
H = Overflow depth
C = Overflow coefficient; 2.0 for Ogee type
and 1.7 for trapezoid type crest.

(8) Seepage Through Dam Foundation

Some existing dams suffered seepage problems through dam foundation, especially in Goronyo dam. When large seepage water appears, dam will collapse by its piping energy.

The monitoring work of the dam maintenance for the seepage water shall be carefully and periodically carried out with the following method;

- Monitoring work by dam instrument and relief well as well as at the downstream dam slope and toe.
- Drawing the seepage line on the dam cross section drawings in accordance with the monitoring result.
- Measurement of seepage quantity at the dam downstream toe and its colour.
- Analysis of seepage line and quantity for abnormal condition as compared with the design criteria.
- Report of monitoring result to RBDA main office from OM office.

(9) Need of Rehabilitation Works

Some dams have the following problems in addition to the above mentioned in (6), (7) and (8);

- Gully erosion on the downstream dam slope and dense vegetation and shrub on the upstream dam slope.
- Sweeping out of riprap material on the upstream dam slope by waving energy of reservoir water.
- Scouring at the downstream basin of the outlet and spillway.
- Defective portion of concrete structure at the outlet and spillway as well as mechanical parts such as gate and valve.
- Dense aquatic weed covering reservoir area and closing the intake mouth.

The existing dams with problems as mentioned above are shown in Table 4.3.6. Rehabilitation works in those dams are of an urgent necessity in dam maintenance work from viewpoint of dam safety and recovery of dam function.

(10) Need of Proper Operation and Maintenance

Many existing dams have faced the following problems and difficulty in their operation and maintenance.

- Lack of technical materials in OM office.
- Lack of hydrological station and data at damsite.
- Non preparation of reservoir operation rule and proper maintenance rule.
- Insufficient OM facility and equipment in OM office.
- Lack of OM staff training.

Proper operation and maintenance for dams shall be carried out by the Guideline on Operation and Maintenance prepared by the JICA Team and shown in Appendix 4-3.

4.3.2 Procedures of Planning, Design and Construction

The existing dams have many problems as mentioned above. These problems are mostly caused by improper planning, design and construction procedures. In this connection, reference is made to para. 12.4.4 "Strategic Issues in Project Undertakings" as compiled in Chapter 12 of Sector Report.

(1) Planning

The feasibility study with the following items shall be required basically for dam planning:

- Hydrological analysis at damsite including rainfall and evaporation, reservoir inflow, sediment transport, and flood capacity for spillway.
- Topographical survey for reservoir area with scale of 1 : 10,000 and at damsite with scale of 1 : 1,000. In addition, the profile and cross section survey along the dam axis.
- Geological survey at dam foundation and appurtenant structure site.
- Construction material survey including test pits and laboratory test.
- Reservoir plan including reservoir operation study.
- Preliminary design of dam and appurtenant structure including drawings and quantity.
- Construction plan and cost estimation.
- OM plan including organization, equipment and facility and OM cost.
- Environment impact study.
- Implementation program including work schedule and disbursement schedule.
- Economic and financial analysis and project evaluation.
- Environmental impact assessment for the damsite and reservoir area and for the river flow condition after completion of dam.

In accordance with the study result of the JICA Team for the feasibility study reports prepared by FMWRRD, many reports do not include the study for the above items and are reconnaissance or pre-feasibility level from viewpoint of the international standard. It is necessary to carry out the proper feasibility study to assess the technical and economical feasibility and environmental impact.

(2) Detailed Design

Detailed design for dams also has not been performed sufficiently by FMWRRD. In some dams, the detailed design for structure has been carried out by contractor during construction works. Many design variations take place for structure design, quantity and construction cost during construction. The proper technical specifications and bill of quantity are not prepared in the detailed design stage. The following study items shall be included in the detailed design works for dams.

- Additional detailed topographical, geological and construction material survey at damsite.
- Design for dam foundation treatment taking into account protection of seepage water.
- Design for dam standard section from viewpoint of available construction materials and dam stability.
- Design of intake and outlet structure to enable the outflow of the reservoir water to the irrigation area by gravity system.
- Design of spillway analyzing design flood capacity and hydraulic condition.
- Preparation of design drawings showing detailed structure dimension.
- Bill of Quantity classifying the kinds of works in accordance with design criteria and construction plan.
- Construction schedule based on construction plan.
- Technical specifications based on design condition and construction method.

(3) Construction Cost

The large dam construction has been carried out by the contractor's finance without tender, as a result the construction cost of the large dam is rather high. The JICA Team has collected the bill of quantity for the dam construction of the Challawa Gorge dam completed recently, Kafin Zaki and Kawali contracted recently, Kontagora and Kagara under construction and Rafin Jatau recently proposed by the contractor, and has evaluated the construction cost as shown in Table 4.3.6, and 4.3.7. The evaluation result is as described below;

(a) Challawa Gorge Dam

Although the construction cost of Challawa Gorge dam increases by the contract variation due to variation of executed quantity and unit price for the works, the construction cost for dam embankment is quoted at US$10.4/m^3, which is rather cheap.

(b) Kafin Zaki Dam

Although dam construction includes the slurry trench works which accounts to high construction cost, the construction cost for dam embankment is at US$14.6/m^3, which is an ordinary price, because the dam cost is determined mostly by the large embankment volume.

(c) Kwali Dam

Since the Kwali dam is the large diversion dam with the large concrete volume and gates and also the slurry trench works, the construction cost / dam embankment unit price is as high as US$38.3/m^3. Unit price of the earthworks such as excavation and dam embankment is mostly as same as that of Kafin Zaki.

(d) Rafin Jatau Dam

The construction cost / dam embankment for the Rafin Jatau is at US$22.7/m^3, which is an ordinary price.

(e) Kontagora Dam

The construction cost / dam embankment for the Kontagora dam is as high as US$28.9/m^3, because the construction cost includes the cost of canal works in the service area. The cost/m^3 excluding canal cost is US$23.8 which is considered reasonable.

(f) Kagara Dam

The construction cost / dam embankment for the Kagara is at a very high price of US$40/m^3, because the construction works have been suspended for a long period and are reopened recently, accordingly some additional cost for the reopening works is included. In addition the cost for grouting works accounts to 20 percent of total dam cost due to poor geological condition of dam foundation. The rate of grouting cost against the total dam construction cost in the other dam is about 5 to 10 percent.

(g) Integrated Evaluation

Dam construction cost/dam embankment in the ordinary dam is about US$15 to 20/m^3, when the dam construction contract is concluded under the competitive tender. Dams to be implemented in future should be constructed by the contractor selected by the competitive tendering including the pre-qualification of tenderers and strict evaluation of the proposed tender documents.

(4) Large Upward Contract Variation by Quantity Increases

Quantity of the works is not classified into the detailed kinds of works in the bill of quantity and estimated ambiguously in the original contract, as a result many and large quantity variations and new works take place during construction and at the final statement stage after completion of works.

In the Challawa and Kontagora dams, quantity for dam excavation and concrete works in spillway and outlet is considerably increased in the variation contract as shown in Table 4.3.8. In the other dams under construction, large quantity variation for the earth and concrete works occurred. The detailed design for dams should be carefully performed with the detailed investigation works at the site in order to minimize design and quantity variations during construction period.

4.4 NWRMP TOWARDS THE YEAR 2020

4.4.1. General Strategies and Priority

(1) Needs of Surface Water Resources Development

The surface water demand for irrigation to achieve the food security and for water supply to respond to the basic human needs towards the year 2020 will increase remarkably to 16,900 MCM a year comprising of 13,500 MCM for irrigation and 3,400 MCM for water supply as are described in Chapters 5 and 6.

Out of the water demand of 16,900 MCM, 3,800 MCM for the public irrigation and 1,300 MCM for water supply could be supplied by the existing reservoirs in accordance with the evaluation of the available reservoir water as shown in Table 4.3.3. The additional water of 11,800 MCM, therefore, will be newly developed by the proposed water resources development mainly by the proposed dams towards the year 2020, although some of the water resources will be developed by primary pumping stations and intake facilities which could withdraw directly the water from the river without the dam.

(2) Water Management in Existing Dams

Abundant reservoir water has been developed since 1970s and stored in the existing dams for irrigation, water supply and hydropower. Although the reservoir water for hydropower has been fully used under well arranged reservoir management, the water for irrigation and water supply has not been used properly yet due to improper water management in the reservoir and the delay of provision for the water distribution facilities in the service area.

It is a prerequisite to improve the water management practice in the existing reservoirs which already have the completed water distribution facilities in their downstream area and also to formulate the reservoir water operations plan for the existing dams, whose irrigation facilities are to be developed.

In the Hadejia and Sokoto-Rima river basins located at the North region, the FMWRRD shall emphasize especially the water resources management in the existing dams with the following reasons:

- The North region belongs to the semi-arid area and suffers water shortage for irrigation and water supply. In addition, the limited water resources in the region have decreased due to Sahelian Drought.
- Many large and small dams with total active reservoir capacity of 7,700 MCM corresponding to 65 percent of the nationwide capacity have been constructed and are under operation or ready for operation. Those abundant reservoir water has not been used effectively due mainly to the lack of proper water management of the reservoir water.

(3) Rehabilitation of Existing Dams

Some of the existing dams have deteriorated and could not fulfill their function sufficiently, thus the reservoir water cannot be used properly so as to meet the water demand in the service area. In addition, some dams are placed at dangerous stage from viewpoint of dam safety. Those dams should be rehabilitated with high priority.

(4) Implementation of Proposed Dams

Implementation of the proposed dams will be commenced after completion of the water management and rehabilitation works in the existing dams and the water distribution facility works in the service area taking into account the limited budget for the water resources development in FMWRRD. The preparatory work of the proposed dam such as the pre-feasibility and feasibility study, however, shall be commenced and continued in parallel with the water management and rehabilitation works.

(a) Region with Priority for the Proposed Dams

The Central and South regions will have the priority to develop the surface water resources by the proposed dams with following reason;

- The Central region has abundant surface water in wet season and large land resources for agriculture to support the food security in the country, but its water resources have not been developed yet. There are many suitable damsites which would provide large storage capacity by medium and small dams in tributary basins of the region.

- The South region has the largest population engaging in commercial and industrial activity in the country and requires huge amount of domestic and industrial water towards the year 2020. This region also has the high potential agricultural area, especially rice cultivation under rich rainfall, fertile soil and skilled farmer. The surface water resources development, however, has not been accelerated as the region is blessed with sufficient rainfall and river water.

  Although the region has rich water resources in wet season, they are scarce in dry season and their effective use for irrigation and water supply is rather difficult without reservoir dams. In the region, large surface water resources could be developed with less investment of the medium and small dam, as only the supplemental surface water for the rather short dry season are to be supplied to the service area. Especially, agricultural development for rice production will gain large benefit with small investment for the water resources development.

(b) High Priority for Medium and Small Dams

Although there are potential for the water resources development by large dams in the Central region, the priority for the proposed dam towards the year 2020 will be placed at the medium and small dam from the following reasons:

- Many agricultural areas and villages are extending along the small tributaries in the Central and South regions and their surface water could be easily developed by medium and small dams (M/S) with low investment cost. The water resources development by large dams is limited in the basins of the tributaries.
- The reservoir water in M / S dam could be used for the multipurpose of irrigation, water supply, inland fish culture, village forest, recreation, etc. in the rural area.
- Plan and implementation of M / S dam could be carried out easily and quickly by RBDA, and its operation and maintenance could also be managed easily by RBDA and with the participation of the beneficiaries.

- Immediate benefit return against project investment could be obtained after completion of the project due to easy management of M / S facility and extension service for agriculture by governmental agencies.
- Limited budget for the water resources development shall be allocated equally to the rural area nationwide.
- Stabilization of the rural economy which is the main objective of FMWRRD, could be achieved in a relatively short period by job creation and income generation in the rural area.
- Environmental impact such as resettlement in reservoir area and submerged forest and agriculture land will not exist and even if there were it would be small.
- Tributary basins will be placed at the better environmental condition by reforestation surrounding reservoir and village areas and by soil conservation of irrigated agriculture.

(5) Improvement of Dam Engineering

The dam engineering in Nigeria is still placed at low level to carry out the water management and rehabilitation works and the OM works in the existing dams, and also to manage the planning, design, and construction for the proposed dams.

FMWRRD shall emphasize the improvement of dam engineering with top priority, otherwise those works above mentioned could not be properly and successfully achieved towards the year 2020, even if sufficient budget for the water resources development is provided.

4.4.2 BMR for Existing Dams

The Balanced Modernization and Rehabilitation (BMR) for the existing dams will be comprised of the proper water management work to use the reservoir water effectively and the repair and improvement works for the dam and appurtenant facility to maintain proper function of the reservoir dam.

(1) Reservoir Operation Study

Reservoir operation study for the optimum water management has not been made at all in many existing dams, thus the OM offices in the existing dams have no operation rule of the reservoir and cannot control adequately the reservoir inflow and outflow to meet the water demand properly in the service area. The JICA Team has carried out the operation study for the representative dams with available data for the study and the results are described below:

(a) Method of Reservoir Operation Study

- Monthly runoff at damsite and monthly rainfall on the reservoir area are considered to be the reservoir inflow.
- Reservoir evaporation loss is estimated based on 70 percent of Pan-Evaporation value and reservoir area. Since the reservoir area is varied by fluctuation of reservoir water level during reservoir operation, the varied area is estimated by the reservoir H-A and H-Q curve.
- Designed active capacity is adopted for the reservoir capacity, which generally should be filled up to the full water level at the end of wet season. The inflow entering into the reservoir after the full water level is spilled through spillway.
- Outflow from the reservoir is estimated based on the irrigation and water supply demand in service area and the downstream water to be released to Fadama area and for river maintenance. That water is assumed approximately by the JICA Team taking into account the service area and downstream wetland conditions, because those data are not available in RBDA.
- The reservoir operation in abnormal dry year with the return period of once in 10 years may allow water shortage for irrigation demand. In such case, the irrigation intensity for the next dry season should be decreased so that the remaining reservoir water at the end of previous wet season could be made available for irrigation.

(b) Reservoir Operation Result

The reservoir operation result is shown in the Database Drawings (15) and summarized in Table 4.4.1. Evaluation for the operation result for each dam is described hereinafter;

Tiga and Challawa Dams

Both dams have large active capacity of 2,750 MCM and large reservoir area of 280 km^2 in total against the less reservoir inflow of 1,370 MCM in total and their reservoir operation brings about the following result:

- Evaporation loss from the large reservoir area will reach 400 MCM corresponding to 30 percent of the reservoir inflow.
- The public irrigation area of 38,500 ha could be irrigated under the condition of the irrigation intensity of 100 and 50 percent in wet and dry season respectively. Namely, some irrigation area of 4,000 ha could be expanded in addition the proposed irrigation area of 22,000 ha in Kano I and 12,500 ha in Hadejia Valley.
- The domestic water of 220 MCM p·a could be supplied to population of 2.5 million towards the year 2020 in the Kano district.
- The downstream water of 400 MCM p·a corresponding to 30 percent of the reservoir inflow could be supplied in dry season to the downstream Fadama area along the Hadejia.

The above water allocation is tentatively assumed taking into account the present public irrigation condition, the water demand of water supply in Kano district and the private irrigation in the Fadama area. If FMWRRD intends to change the water allocation pattern, it is easy to carry out the operation study by the operation computer program submitted to the Data Bank in FMWRRD by the JICA Team.

Proposed Kafin Zaki Dam

Kafin Zaki dam has large active capacity of 2,500 MCM and large reservoir area of 235 km^2 against the estimated average annual reservoir inflow of 1,200 MCM and its operation result brings about the following problems:

- The evaporation loss of 400 MCM corresponding to 35 percent of the reservoir inflow will take place from the reservoir area.
- Although the irrigation area of 125,000 ha is proposed in the original plan, the area of 50,000ha will be irrigable under the condition to supply the downstream water of 310 MCM corresponding to 30 percent of the reservoir inflow.

It is recommendable, therefore, to review the Kafin Zaki dam project from viewpoint of the project economy, because the irrigation project cost will be more than US$ 8,000 / ha taking into account the expense for the irrigation system of US$ 2,000 / ha in addition to the huge construction cost of more than US$ 300 million corresponding to US$ 6,000 / ha under the irrigation area of 50,000 ha

Goronyo Dam

Goronyo dam also has large active capacity of 930 MCM and large reservoir area of 200 km^2 against the reservoir inflow of 710 MCM. The proposed area of 17,000 ha in the original plan, however, could be irrigated under the condition of the evaporation loss of 340 MCM and the downstream water release of 130MCM.

Zobe Dam

Although Zobe dam has a relatively large runoff against the active capacity, the proposed irrigation area of 8,200 ha in the original plan will be decreased to 5,000ha under the condition of the evaporation loss of 76 MCM and the downstream water release of 22MCM, because the water of 34 MCM is allocated for the water supply in Kasina urban area.

Other Dams

The other dams could irrigate sufficiently the proposed area in the original plan, except Watari dam, which could irrigate the area of 1,500 ha as compared with 1,700 ha in the original plan. Some dams, such as Tomas and Tungen-Kawa, have the possibility to increase the irrigation area as compared with the area in the original plan.

The operation study of those dams is made based on the limited available data at present, and its review will be required by collecting, surveying and analyzing the input data into the computer program of the operation submitted by the JICA Team to the Data Bank.

(2) Establishment of Water Management in Reservoir

(a) Review of Irrigation Area Size

FMWRRD intends to implement the incomplete irrigation system in the service area under the existing irrigation dams in order to use the reservoir water effectively and to raise benefit from the irrigated agricultural area. The proposed irrigation area of the existing dams, however, is not set up clearly in the original plan based on the available reservoir water. The area may be changed in accordance with the available reservoir water to be estimated by the reservoir operation study result.

It is very important and necessary to review the final irrigation area size by the reservoir operation study prior to implementation of the irrigation system taking into account the suitable irrigation intensity in dry season, its water demand and downstream release water; otherwise, the water management under the implemented irrigation system could not be properly made due to less or excess reservoir water against the irrigation area size.

(b) Formulation of Reservoir Operation Rule

In order to carry out the proper water management in the reservoir, the reservoir operation rule including the reservoir rule curve as shown in Appendix 4-3 "Guideline of Operation and Maintenance" shall be set up. The reservoir water will be managed based on the rule curve monitoring the reservoir water level to be fluctuated by the inflow and outflow and controlling the outflow to be changed under irrigation schedule. For the above purpose, automatic water gage is to be installed in the reservoirs with active reservoir capacity of more than 50 MCM and staff gage in the other small reservoirs.

(c) Establishment of the New Operation Water Level

The new operation water level at the end of wet season will be established instead of the designed full water level in the reservoir with very large active reservoir capacity against the reservoir inflow such as Tiga, Challawa, Watari, Goronya, etc, because the reservoir will never reach the full water level at the end of wet season except in a very wet year. If the operation is carried out so that the reservoir water level reaches the full water level at the end of wet season, the large evaporation loss takes place due to large reservoir surface area at the full water level, as a result the potential reservoir water decreases.

In accordance with the operation study result by the JICA Team, it is recommended that the new operation water level at Tiga and Challawa will be placed below four to five meters from the design full water level. It is necessary to study the new operation water level in the other dams with the larger active reservoir capacity than the reservoir inflow in the northern region in order to minimize the high evaporation loss by reducing the reservoir area.

(d) Control of Outflow

Dam OM office shall set up the standard outflow schedule on weekly or 10 days basis prior to irrigation season discussing with OM office in the service area, because the irrigation requirements varies with the crop grown.

In dry season, the reservoir outflow will be made generally based on the standard outflow schedule due to no effective rainfall. In supplemental irrigation at wet season, the above standard outflow will be slightly modified by effective rainfall at the service area and released from the reservoir, otherwise unnecessary water is supplied to the service area. At any rate, the control of reservoir outflow is one of the most important water management in the reservoir and has to be carried out with close coordination of OM office between dam and service area.

(e) Management of Flood through Spillway

It is not necessary to pay particular attention for management of flood through spillway in the dams, such as Tiga and Challawa, with very large reservoir capacity against the reservoir inflow, as the flood will be controlled at the large reservoir capacity between the full water level and the new operation water level.

When the dam has very large reservoir inflow against the active reservoir capacity, the flood will appear often after storage of the reservoir water to the full water level in wet season and spill through the spillway. In such dam, it is desirable to set up the operation water level for the flood control, which will be placed at one or two meters below the full water level during August to the beginning of September. Namely the flood appearing in the above period will be controlled by the surcharging capacity between the full water level and the flood control operation level by releasing a part of flood through the outlet or spillway gate. The reservoir will be filled up finally to the full water level by the rich inflow appearing from the middle to the end of September. The flood influence to the downstream area will be minimized by the above flood control management. The flood control will be required for dams, such as Ikere Gorge, Oyan, etc.

(3) Rehabilitation Works in Existing Dams

Special large problems are not found in the existing dams from viewpoint of dam safety except the Goronyo dam. Many existing dams, however, have the following deteriorated and defective parts and require the rehabilitation works to maintain the stability of the dam and appurtenant structure and to keep the reservoir function in good condition.

- Removal of dense vegetation and shrub on dam slope.
- Protection for a little seepage through dam foundation by additional toe embankment with drainage facility.
- Expansion of crest length of spillway with insufficient flood capacity.
- Improvement of scouring condition at the downstream of the outlet and spillway

- Repair of defective gate and valve.
- Improvement of the deteriorated concrete structure
- Removal of a aquatic weed covering the reservoir surface area and clogging the intake.
- Improvement of access and OM roads
- Provision of communication system for Dam OM office, RBDA head office, OM office in the service area, etc.

Existing major dams requiring above rehabilitation works are shown in Table 4.3.6. In addition to the dams as shown in Table 4.3.6, there are many dams requiring the rehabilitation works. Accordingly, FWWRRD should carry out the detailed inventory survey for the rehabilitation works. Those rehabilitation works will be implemented with the priority under the dam OM works providing sufficient budget.

Goronyo dam has large seepage through dam foundation and is placed in the dangerous state from viewpoint of dam safety. The dam is constructed on alluvial plain consisting of alternate layer of previous and impervious materials, and large seepage is caused by piping action which break the previous layer.

Although the rehabilitation works are proposed by the slurry trench at the dam upstream toe, the method to stabilize the downstream dam body by the counterweight berm with drainage pipe protected by filter is to be studied from the following reasons:

- Construction cost of the counterweight berm method will be cheaper than that of the slurry trench method.
- Large seepage water will be allowed, if the piping energy and seepage line at the downstream dam body could be reduced by the toe drainage facility.
- Large seepage water is collected by the drainage ditch and guided to the river and will be used for the downstream wetlands. For the above purpose, the following survey and analysis of dam stability shall be required.
    - Survey of the existing seepage line by installing piezometor at the dam crest, dam slope between dam crest and toe, and the dam toe

- Measurement of seepage quantity
- Sampling of the undisturbed material at the the downstream dam body and its soil mechanical test.
- Dam stability analysis under the counterweight berm.

(4) Mini-Hydro Power Plant at Existing Dams

Mini-hydro power plants are provided or are to be provided in some existing irrigation dams. FMWRRD has to study and implement the following items in those power plants in order to get the power benefit by using the reservoir water.

(a) Reservoir Operation

Irrigation dams are generally operated so as to store the reservoir inflow in wet season and release the reservoir water for irrigation demand in dry season. In order to produce the power energy without fluctuation throughout the year, some of the reservoir water shall be released even in wet season through the power outlet. For this purpose, the balanced reservoir operation study to meet the irrigation requirements in dry season and the power outflow in wet season shall be studied taking into consideration the available reservoir inflow for the reservoir storage and power outflow.

(b) Bakolori Dam

The operation of power plant in Bakolori dam has been suspended due to large leakage through the intake chamber of the power outlet, so that urgent rehabilitation works are required.

(c) Dadin Kowa Dam

Dadin Kowa dam with large active capacity of 1,770 MCM was constructed in 1988 for the multipurpose of irrigation for 38,000 ha and hydropower of 34 MW. Such large irrigation area, however, is not existing at the downstream of the dam, and the power plant is not provided.

The reservoir is always filled up by rich reservoir inflow and its water is only released through spillway without utilization.

It is recommendable that the dam shall be used mainly for the hydropower purpose and to install urgently the power plant in order to get the power benefit from the reservoir water use. Annual power production of 200Gwh could be obtained at least under 34mw plant, and its annual income will reach 400 million Naira by assumption of two Naira/kwh. If Dadin Kowa power is produced mainly in dry season, such power will be very useful to complement the dry season power in Kainji and Jebba power plant which suffers from power shortage problem due to decreasing black flood in their reservoir.

It is necessary to discuss about the hydropower of Dadin Kowa between FMWRRD and NEPA.

4.4.3 Establishment of Integrated Water Management Rules in the North Region

In the North region, many dams for irrigation and water supply have been constructed since the 1970s to supply the reservoir water to the service area suffering from critical water shortage problem and their total active reservoir capacity reaches the large volume of 7,700 MCM occupying 65 percent of the nationwide active capacity of 12,100 MCM. The reservoir water of those dams, however, have not been managed effectively with the following reasons:

- The active reservoir capacity of large dams, such as Tiga, Challawa, Goronyo, etc, is very large as compared with the reservoir inflow, so that the optimum reservoir operation rule is not set up yet.
- The reservoir inflow at Challawa and Goronyo will be influenced by the reservoir water use of the dams which are under operation at the upstream basin of both dams.
- Service area size, irrigation intensity, irrigation water demand, etc. under the existing dams are not clearly set up due to unknown available reservoir water.
- Allocation of reservoir water use to the downstream Fadama area are not studied yet.

- Water losses or side flow along the river from the damsite to the downstream Fadama area are not studied yet.

From the above reasons, studies shall be made to establish the integrated water management rule.

(1) Integrated Water Management in the Hadejia River

Although 14 dams including the large dams of Tiga and Challawa are constructed in the Hadejia river and their active reservoir capacity is 3,000 MCM, available reservoir water will be only 1,100 MCM due to limited inflow of 1,700 MCM and large evaporation loss of 480 MCM from the reservoir surface area as shown in Table 4.4.2. The actual irrigation area is only 15,000ha at present against the potential area of 41,000 ha. In addition, there are large seepage losses in the Hadejia river on the way to the wetlands.

Accordingly the integrated water management including the following items, shall be studied in order to use the limited surface water properly in the river basin and to gain the benefit from the potential service area.

- Installation of gaging station at the upstream river of the reservoir to observe the reservoir inflow and at the reservoir to monitor the reservoir water level.
- Installation of gaging station along the Hadejia river to monitor the discharge to be released from the reservoir.
- Reservoir inflow analysis by the runoff model.
- Review of water demand for irrigation and water supply
- Integrated reservoir operation study for the existing reservoirs taking into account the downstream water
- Rehabilitation plan for the existing water distribution facilities
- River improvement plan along the Hadejia river to minimize water loss.

The detailed study plan for the integrated water management is as shown in Appendix 4-1 and the Database Map (23).

(2) Integrated Water Management in the Sokoto-Rima River

Large dams of Jibiya, Zobe, Goronyo and Bakalori are provided in the upper basin of the Sokoto-Rima. Reservoir water in Goronyo dam is to be used not only for the immediate downstream service area but also water supply and groundwater recharge at the area surrounding Sokoto City. Goronyo reservoir inflow, however, will decrease by the reservoir water use of Jibiya and Zobe dams which are located at the upstream basin of the Goronyo. A part of reservoir water to be released from the dam to the downstream Sokoto area will be lost by seepage along the river flowing down the alluvial plain consisting of sandy previous materials.

Accordingly the similar water management study as mentioned in the above (1) shall be required in the Sokoto-Rima upper basin taking into account the reservoir water allocation, reservoir water operation, water loss along the river, etc.

4.4.4 Implementation of the Proposed Dam Projects

(1) General

The proposed dam projects with priority will be studied by the year 2000 and implemented towards the year 2020. Mainly, the proposed dam projects in the Central and South regions, will be studied, where there is a great water resources potential in many tributaries and large agricultural land under rainfed condition. Most of the proposed dam projects will be of the small and medium scale based on the following additional reasons to that as described under para. 4.4.1(4)(b).

- The rate of available reservoir water against the active reservoir capacity in the Central and South regions is high as 70 to 90 percent due to less evaporation loss from the reservoir surface area and some available inflow in dry season. Accordingly, the service area in the region could be larger than that in the North region under the same active reservoir capacity. Namely the irrigation project in the Central and South regions could be implemented with the less dam investment cost per ha as compared with that in the North region.

- The reservoir area of the medium and small dam is mostly located at the tributary basins which are not developed yet and have no or less resettlement problem as compared with that of the large dam. Namely the project implementation could be easily and quickly commenced.
- Irrigation canal system under the dam could be easily and quickly implemented and managed properly by the beneficial participation under the technical guidance of RBDA, because the service area is located at the immediate downstream of the damsite and its irrigation canal capacity is as small as 0.5 to 3.0 cu·m/sec.

The reservoir water to be developed by the medium and small dam projects could be used for the multipurpose as explain below, because the dams are located near the service area and their reservoir water could be managed easily by the water user in the service area.

- Irrigated agriculture for field crops.
- Domestic water supply for rural inhabitant
- Drinking water supply for livestock by village ponds to be provided along the irrigation canal and near village.
- Provision of fish ladders and other passage ways for fish movement.
- Fish culture and garden crop irrigation for vegetable by the above village pond.
- Village forest such as orchard surrounding village by using the above pond water.
- Reservoir forest surrounding the reservoir area to harvest fuel wood for village inhabitant and to prevent sediment transport caused by sheet and gully erosion.
- Mini-hydropower for rural electrification, if there are sufficient reservoir inflow and water head.
- Recovery of agricultural land in the wetlands located at the downstream of damsite by the flood control function under the large reservoir area.

The JICA Team proposes tentatively the guideline for the size of medium and small dams to fulfill the above mentioned purpose as follows in accordance with the study result for topographical and hydrological conditions at damsite and the past experience of the JICA Team in the other developing countries, where a number of medium and small dam projects were planned and implemented.

	Medium Dam	Small Dam
Catchment Area	50 to 300 km^2	less than 50 km^2
Dam Height	15 to 25 m	below 15 m
Average Active Capacity	35 MCM	5 MCM
Maximum Active Capacity	50 MCM	7 MCM

Tributaries in plateau and flat plain in the Central and South regions have gentle river slope and could obtain large reservoir capacity by the low dam height as shown above.

The study of the implementation of the proposed dam projects has been made mainly for irrigation and water supply dams as described below; because their water demand will reach huge amount towards the year 2020.

(2) Identification of Proposed Dams towards the Year 2020

The JICA Team has identified the proposed dam for irrigation and water supply towards the year 2020 with the following method taking into account the priority of the medium and small scale dams.

(a) Collection of Map

Although the JICA team has tried to collect the map with the scale of 1 to 250,000, 1 to 100,000 and 1 to 50,000 during the field work in Nigeria, only 60 percent of the nationwide map covering the important river basin for the water resources development were collected, as shown in the Database Map (4).

(b) Identification of the Proposed Dams by Inventory Survey Result

The JICA team has studied the identified dams by the inventory survey which has been carried out by the domestic consultant. Those dams are mostly identified based on conceptional plan and have no firm dam dimension. The following dams in the inventory survey are excluded from the proposed dams:

- Dams without dimension or with random dimensions for catchment area, reservoir area, reservoir capacity, dam length and dam height, because of impossible evaluation.
- Dams with height of more than 35m and length of more than 3,500m, because of high construction cost.
- Dam without damsite location because it is impossible to check on the map.
- Proposed dams at the North East region, because of scarce water resources to construct the large and medium dams.

Although many dams are proposed in the Central-West and the Central East region, the other regions propose very few dams due to no identification of the proposed dams by the agencies. The proposed dams by the State in the Central East have random dimensions such as small reservoir capacity against large reservoir area and very high dam, so that many proposed dams are excluded from the identification study. About 50 proposed dams including the large and medium dams are identified finally under the inventory survey result.

(c) Identification of Proposed Medium Dams by the JICA Team

The JICA Team has carried out the site survey of the major river basins which will have the high potential of the proposed medium dams based on the map of 1 to 50,000 scale and studied the proposed dams towards the year 2020 with the following identification guideline.

- Damsite with moderate catchment area of 50 to 300 km^2 on the map of 1 to 50,000 taking into account its river average runoff of 10 to 100 MCM p. a.
- Damsite with dam height of 15 to 25 m on the map showing the contour interval of 15m.
- Damsite with the suitable reservoir area of 2.0 to 5.0 km^2 which is measured on the map showing the contour interval of 15 m.
- Damsite with the short dam length of 300 to 1500 m which also is measured on the map.
- Damsite with agricultural lands and villages at the downstream or surrounding area of the damsite.

- Reservoir area without resettlement problem such as town, village, road, railway, etc.
- Reservoir area and catchment area formed with gentle slope without steep mountain area which will bring about high peak flood and large sediment transport by soil erosion.
- Damsite with the potential of the large reservoir capacity by short dam length and low dam height,

About 260 proposed dams mainly consisting of the medium scale have been identified by the above guideline.

(d) Proposed Small Dams

It is difficult to identify the proposed small dams with dimensions on the map of 1 to 50,000 scale. The JICA Team, therefore, will allocate only the number of the proposed dams to the potential river basins by observation of the map taking into account the catchment area of 10 to 30 km^2 which will present the runoff of 5 to 10MCM and also the distribution of agricultural area and village, as a result 820 units of the small dams are proposed towards the year 2020.

(3) Distribution of Proposed Dam on the Regional Basis

List and outline of the proposed large and medium dams identified by the above mention method is as shown in the Water Resources Inventory Survey and its distribution on the regional basis is summarized in the Table 4.4.3.

TABLE 4.4.3 NUMBER, ACTIVE CAPACITY AND AVAILABLE WATER IN THE PROPOSED DAMS

Items	H-A								Total
	1	2	3	4	5	6	7	8	
1. Large / Medium Dam									
(1) Number	14	74	39	53	14	41	29	0	264
(2) Active Capacity (MCM)	700	2,940	2,090	1,250	340	910	630	0	8,860
(3) Available Water (MCM)	480	2,140	1,460	890	330	830	590	0	6,720
For Irrigation (MCM)	430	1,930	1,310	800	200	500	470	0	5,640
For Water Supply (MCM)	50	210	150	90	130	330	120	0	1,080
2. Small Dam									
(1) Number	50	230	110	160	35	100	115	20	820
(2) Active Capacity (MCM)	250	1,150	550	800	175	500	575	100	4,100
(3) Available Water (MCM)	150	920	440	640	160	450	520	60	3,340
For Irrigation (MCM)	135	830	395	575	140	405	465	55	3,000
For Water Supply (MCM)	15	90	45	65	20	45	55	5	340
3. Total									
(1) Number	64	304	149	213	49	141	144	20	1,084
(2) Active Capacity (MCM)	950	4,090	2,640	2,050	515	1,410	1,205	100	12,960
(3) Available Water (MCM)	630	3,060	1,900	1,530	490	1,280	1,110	60	10,060
For Irrigation (MCM)	565	2,760	1,705	1,375	340	905	935	55	8,640
For Water Supply (MCM)	65	300	195	155	150	375	175	5	1,420

Remark; (1) Rate of available irrigation water for the total available water in the large and medium dams is as follows taking into account the large water demand for the water supply in the south region.
HA-1, 2, 3 and 4 ··· 90%, HA-5 and 6 ··· 60%, HA-7 ··· 80%

(2) Active capacity and available water in the small dams is estimated as follows;
- Average active capacity 5MCM/unit
- Average available water .... 3MCM for HA-1 and 8
.... 4MCM for HA-2, 3, and 4
.... 4.6MCM for HA-5, 6, and 7
- Available irrigation water 90% for the above available water

North West Region

The surface water in the Gada, Bunshur and Sokoto river basins has been developed already by the existing large dams. Accordingly new large and medium dams except those under planning by RBDA are not proposed in those basins. The surface water at the Gagere river, however, has not been developed yet in the north basin and will be developed by proposed dams. The south river basins, such as the Gulbin Ka, the Danzaki and the Malendo, will have sufficient surface water, and many agricultural lands, and their surface water will be developed mainly by the medium and small dams. Although the Gawan Gulbi and Zamfara rivers will have the potential water resources to be developed by the large dams, such development will give some influence to the

Kainji reservoir inflow, thus new dams will not be proposed towards the year 2020.

North East Region

The surface water resources in the North East region is very scarce except the Hadejia river which has already many existing dams. In addition, the large Fadama area is expanding at the lower basin of major rivers, such as the Dingaiya, Ngadda, Yedseram, etc., and has used the river water for its agriculture land, thus there are less possibility to develop the surface water by dams. Only some small dams will be proposed at the upper basin of the Yedeseram which has a little rich runoff and suitable damsite for the small dams.

Central West Region

The upper basin of the Kaduna, the Gbako, and the other rivers, such as the Oshun, Oshin, Awun, etc, flowing into the Niger have abundant surface water which is not developed yet and also have the large potential agricultural areas. Many large, medium and small dams, therefore, will be proposed towards the year 2020 in order to extend to the irrigated agriculture and to support the food security in the country. Especially the Oshun and Awun basin lying on the right bank on the Niger, the Galma and Karami tributary basin of the Kaduna, and the Gbako basin will have high potentiality for water resources development by proposed dams.

Central East Region

Although the abundant surface water and fertile agricultural lands are existing in the Central East region, the water resources development has not been carried out except the Gongala upper basin surrounding Jos plateau. Many river basins flowing into the Benue have the potential surface water development and agricultural development by reservoir dams. In accordance with the study of the JICA Team based on available map of 1 to 50,000 scale, many medium and small dams will be proposed at the following basins.

- The Mayo Ine and Belwa basin
- The Kilange and Hawal basin

- The Mada basin
- The Shemankar and Ankwe basin
- The Katsina-Ala basin

Although the other river basins, such as the lower basin of the Taraba and the Donga, will have the potential for water resources development, the water resources in these basins will be developed mostly with the large dams.

South West Region

The upper basin of the Ofiki, Ogun, Oshun, Owena, Osse, etc. in the South West region has abundant surface water. It is rather difficult to develop the surface water by large dams due to resettlement problem in the reservoir area covered with dense population and town. Since many towns and villages in the region presently suffer from water shortage for domestic water supply, the water resources development for water supply by the medium and small dams in the tributary basins will be promoted towards the year 2020. In accordance with the study on the available map of 1 to 50,000 scale, the upper basin of the Ogun and Oshun will have the high potential surface water resources development by the medium and small dams. The reservoir water will be used not only for domestic water supply but also the irrigated agriculture mainly for paddy cultivation.

South East Region

The river basins in the South East region also has rich runoff to be developed by the medium and small dams, especially by small dams such as diversion dams, because some runoff is available even in dry season. The priority basin by the proposed dams will be as follows based on the stage of water shortage for domestic water and the possibility of the proposed dams.

- Tributary basin of Awka and Onisha area mainly for domestic water supply.
- Tributary basins of the Aboine, Aloma, and Aya for the domestic and irrigation water supply.

(4) Procedures taken for Identification of the Proposed Dam

The following study procedures have been taken, in order to provide the proposed dam outline, such as the catchment area, reservoir area, active reservoir capacity, available reservoir water, dam length and height on the master plan level.

(a) Inventory Survey Result

Dimension of the proposed dam shown in the NWRIS has been checked, based on the map of 1 to 50,000 scale.

(b) Dimension of the Proposed Dam

Approximate measurements for the catchment area, reservoir area, dam length and height, etc. have been made by the map of 1 to 50,000 scale with the contour interval of 15m.

(c) Reservoir Inflow

Reservoir inflow is estimated by the catchment area size and the specific runoff yield taking into account the hydrological condition in the river basin where the dam is proposed.

(d) Active Reservoir Capacity

Active reservoir capacity is estimated by the reservoir area and effective reservoir depth. The effective depth is estimated taking into account the following condition.

- Dam dead water depth based on the required dead reservoir capacity by sediment transport and the low water level to be able to adopt the gravity irrigation system.
- Spillway overflow depth and dam free board from the full water level of the reservoir.

The following table shows the guideline for the effective depth.

Dam Height (m)	Dead Water Depth (m)	Spillway Overflow depth (m)	Dam Free Board (m)	Effective Depth (m)
10	4.0	1.5	1.5	$3.0 \times 0.8 \fallingdotseq 2.4$
15	5.5	2.0	2.0	$5.5 \times 0.8 \fallingdotseq 4.4$
20	6.5	2.5	2.0	$9.0 \times 0.8 \fallingdotseq 7.2$
25	8.5	2.5	2.5	$11.5 \times 0.8 \fallingdotseq 9.2$
30	10.0	2.5	2.5	$1.5 \times 0.8 \fallingdotseq 12.0$

In the above table, the value of 0.8 in the effective depth is the rate of average reservoir area between the full water level and the low water level. The active capacity is estimated approximately by multiplying the reservoir area and effective water depth.

(e) Available Reservoir Water

The active reservoir capacity estimated by the above method is considered to be filled up in the reservoir at the end of the wet season and to be made available for the water demand in the dry season. A part of reservoir water, however, will be lost by the evaporation loss during the reservoir operation in dry season and carried over in the reservoir taking into account the possibility of less reservoir inflow in the next dry year. In addition, some reservoir water will be released to the downstream wetlands and river maintenance in dry season. Accordingly, the actual available reservoir water for dry season is to be smaller than the active reservoir capacity. When dam is planned at the damsite with very large inflow against the active capacity and with the inflow even in dry season to compensate the evaporation loss, the active capacity will be corresponding to the available reservoir water in dry season.

Accordingly, the available reservoir water is estimated taking into account the above condition. The available water in the North region is generally 60 to 70 percent of active capacity due to high evaporation loss and the carry-over water to the next dry year, while that in the South region will reach 90 to 100 percent of the active capacity due to available runoff even in dry season and abundant runoff in the proposed damsite.

(5) Outline of the Proposed Dams

(a) Dam Standard Section

The proposed dam is planned and designed mostly by the earth fill type from viewpoint of geological condition, rich available earth material at damsite and construction cost. The standard section of the proposed dam for dam height of 10 m, 15 m, 20 m and 25 m is shown in the Database Drawings (24).

(b) Typical Size of the Proposed Dam

The large and medium dams of 260 units composed of various size are proposed as shown in the Water Resources Inventory Survey. The typical size of the proposed dams is different by topography, potential water resources, river feature, etc. at the region. The typical size of the proposed dams is shown in Table 4.4.4 and summarized as follows on the regional basis.

In the North region, the proposed dams include several large dams with the active reservoir capacity of more than 50 MCM, thus the typical size of the proposed dams is a little larger than that of the other region as shown in the reservoir area of 11 km^2, the active capacity of 50 MCM, and dam length of 1,200 m, under dam height of 25 to 15 m. The proposed dams are placed at the damsites with sufficient inflow and their available reservoir water will reach 70 percent of the active capacity. In the Central region, the proposed dams are mostly composed of the medium size and their typical size is 7 km^2 in reservoir area, 37 MCM in active capacity and 800 m in the dam length, under the dam height of 25 to 15 m. The available reservoir water will reach 80 percent of the active capacity under the damsites with rich runoff. In the South region, all proposed dams are the medium size with the reservoir area of 4km^2, the active capacity of 23 MCM and the short dam length of 600 m under the low dam height of 20 to 15 m. The active reservoir capacity will become mostly the available water due to less evaporation loss and some inflow in dry season.

As for the small dams; the typical size is planned with the reservoir area of 1.5km^2, the active capacity of 5 MCM, the dam length of 300m under the dam height of 15 to 10m in all region.

The available water, however, is considered to be 3 MCM, 4.0 MCM and 4.5 MCM in the North, Central and South region respectively under the same active capacity of 5MCM due to different evaporation loss and available inflow in dry season.

(c) Dam Project Cost

Dam construction cost/unit is estimated simply based on the following method;

Dam embankment volume × average unit price/m^3,

The unit price/m^3 is estimated at N400/m^3 based on the study for the data in the Bill of Quantity as shown in Table 4.3.7 and the prevailing unit price for the dam embankment in the other developing countries.

The unit price/m^3 is also studied by the typical size dam with the embankment volume of 250,000 m^3 as shown in Table 4.4.5.

The unit price of the small dam will be cheaper than that of the medium dams, because the dam construction works could be easily made under RBDA force account basis.

The dam construction cost/unit is estimated by the dam embankment volume and unit price/m^3 as shown in the following table;

	Medium Dam			Small Dam		
	Embank Volume 10^3 m^3	Unit Price (N)	Dam Cost (N10^6)	Embank Volume 10^3 m^3	Unit Price (N)	Dam Cost (N10^6)
	300	400	120	50	300	15
Central Region South Region	250	400	100	50	300	15
	200	400	80	50	300	15

The dam project cost for the medium dam of 264 units and the small dams of 820 units to be proposed towards the year 2020 will be 41,000 billion Naira for nationwide as shown in the following table;

(unit N10^6)

Items	North West HA-1	North East HA-8	Central West HA-2	Central East HA-3/4	South West HA-6	South East HA-5/7	Total
1. Medium Dam							
Number	14	0	74	92	41	43	264
Dam Cost/unit (10^6 N)	120	-	100	100	80	80	-
Total Cost (10^6 N)	1,680	0	7,400	9,200	3,280	3,440	25,000
2. Small Dam							
Number	50	20	230	270	100	150	820
Dam Cost/unit (10^6 N)	15	15	15	15	15	15	-
Total Cost (10^6 N)	750	300	3,450	4,050	1,500	2,250	12,300
3. Total Dam Cost	2,430	300	10,850	13,250	4,780	5,690	37,300
4. Administrative and engineering Cost	240	30	1,090	1,330	480	570	3,740
5. Total Project Cost	2,670	330	11,940	14,580	5,260	6,260	41,040
≑	2,700	300	11,900	14,600	5,300	6,300	41,100

(d) Allocation of Dam Project Cost

The reservoir water of the proposed dam is used mainly for irrigation in the North and Central region, while 40 to 50 percent of the reservoir water in the South region will be used for water supply. Some reservoir water also is used for the fish culture and mini hydropower.

The dam project cost, therefore, will be allocated as follows;

(unit N10^6)

Objective	North & Central		South		Nation wide	
	Rate	Cost	Rate	Cost	Rate	Cost
Irrigation	80	23,600	55	6,400	73	30,000
Water Supply	15	4,40	40	4,600	22	9,000
Others	5	1,500	5	600	5	2,100
Total	100	29,500	100	11,600	100	41,100

Remarks: Rate in the above table is allocation percent for each objective.

TABLE 4.4.4 TYPICAL SIZE OF PROPOSED DAM

Items		North Region	Central Region	South Region
1. Large and Medium Dam				
(1) Number		14	167	80
(2) Reservoir Area	(km^2)	11	7	4
(3) Active Capacity	(MCM)	50	37	23
(4) Available Water	(MCM)	35	27	22
(5) Dam Length	(m)	1,200	800	700
(6) Dam Height	(m)	25-15	25-15	20-15
(7) Dam Embankment Volume	(10^3 m^3)	300	250	200
(8) Average Unit Price/cu m	(N)	400	400	400
(9) Dam Project Cost	(N10^6)	120	100	80
2. Small Dam				
(1) Number		70	500	250
(2) Reservoir Area	(km^2)	1.5	1.5	1.5
(3) Active Capacity	(MCM)	5	5	5
(4) Available Water	(MCM)	3	4.0	4.5
(5) Dam Length	(m)	300	300	300
(6) Dam Height	(m)	12	12	12
(7) Dam Embankment Volume	(10^3 m^3)	50	50	50
(8) Average Unit Price/cu m	(N)	300	300	300
(9) Dam Project Cost	(N10^6)	15	15	15

TABLE 4.4.5 ANALYSIS OF UNIT PRICE FOR PROPOSED DAMS

(1) Medium Dam (Embankment Volume of 250,000m^3)

Items	Quantity	Rate (N)	Amount (10^3 N)	Remark
(1) Dam Embankment	250,000 m^3	150	37,500	
(2) Dam Excavation	50,000 m^3	75	3,750	(1)×10%
(3) Foundation Treatment	L.S	-	3,750	(1)×10%
(4) Spillway Concrete	2,000 m^3	6,000	12,000	(1)×32%
(5) Outlet Concrete	1,000 m^3	6,000	6,000	(1)×16%
(6) Outlet Valve	L.S	-	1,500	(1)×5%
(7) Miscellaneous	L.S		3,750	(1)×10%
(8) Subtotal	L.S		68,250	
(9) General Item			10,250	(8)×15%
(10) Total (8) + (9)			78,500	
(11) Contingency			11,500	(10)×15%
Total (10) + (11)			100,000	

100,000,000Naira ÷ 250,000m^3 = 400Naira/cu.m

(2) Small Dam (Embankment Volume of 50,000m^3)

Items	Quantity	Rate (N)	Amount (10^3 N)	Remark
(1) Dam Embankment	50,000 m^3	130	6,500	
(2) Dam Excavation	10,000 m^3	65	650	(1)×10%
(3) Foundation Treatment	L.S	-	330	(1)×5%
(4) Spillway Works	450 m^3	5,000	2,250	(1)×35%
(5) Outlet Works	250 m^3	5,000	1,250	(1)×20%
(6) Miscellaneous	L.S		650	(1)×10%
(7) Subtotal			11,630	
(8) General Item	L.S		1,170	(1)×10%
(9) Total (7) + (8)			1,280	
(10) Contingency			1,900	(9)×15%
Total (9) + (10)			14,700	
			≒15,000	

15,000Naira ÷ 50,000m = 300Naira/cu.m

Remarks: Unit price for small dams are cheaper than that for medium dams due to easy construction works which could be executed by RBA's force account.

(6) Priority River Basin for the Proposed Medium and Small Dam Package Program

Although 260 large/medium and 820 small dam projects are proposed to be implemented toward the year 2020 as mentioned hereinbefore, the pre-feasibility and the feasibility study on basinwide will be required prior to their implementation in order to examine the balanced allocation of the water resources to be developed for the water demand and also formulate the package program of the proposed dams to be implemented with priority.

The proper medium and small dam package program will be implemented at first as a regional model by RBDA selecting the priority river basin. For this purpose, one river basin with high priority which will become the regional model and be implemented by each RBDA is selected with the following conditions,

- Potential water resources, High
- Existing water resources development, Few
- Potential medium and small dams, Many
- Population density, High
- Per capita farm land, Large
- Irrigable area proposed, High
- Increase rate of demand for water supply,
  (Demand in 2020 / Actual supply in 1991), High
- Surface water withdrawal rate in 2020, High
- Convenience for the management by RBDA and the demonstration effect for the other basins in similar nature from locational point of view, Good
- Access to the site, Easy
- Map of 1 to 50,000, Available
- Basin area size for the study, Moderate

17 priority river basins for the proposed medium and small dam package program have been selected firstly from a number of the river basins under the above selection condition and their outline is shown in Table 4.4.6.

The following nine river basins are selected as the high priority basins to be studied by each RBDA.

-	Danzaki basin	(SHA 110)	Sokoto-Rima RBDA
-	Gbako basin	(SHA 214)	Upper Niger RBDA
-	Awun basin	(SHA 204)	Lower Niger RBDA
-	Kilange basin	(SHA 301)	Upper Benue RBDA
-	Katsina-Ala basin	(SHA 4052~3) ...	Lower Benue RBDA
-	Mamu basin	(SHA 504)	Anambra-Imo RBDA
-	Upper Ogun basin	(SHA 6022~3) ...	Ogun-Oshun RBDA
-	Osse basin	(SHA 608)	Benin-Owena RBDA
-	Aya basin	(SHA 702)	Cross River RBDA

Major reason to select the above river basin is as shown in Table 4.4.7 and described below:

(a) The Danzaki Basin

The north river basins in the North West region have been developed by the large dams, such as Jibiya, Zobe, Goronyo and Bakolori, but the south river basins are left at the depressed area without the water resources development. In the south river basins, the Danzaki basin belonging to SHA 110 presents high population density, sufficient water resources, potential of the medium and small dams, and will become the model of the medium and small dam package program for the water resources development in the south river basins.

(b) Gbako Basin

The Gbako basin is lying on the south of Minna city where the Upper Niger RBDA is located and has the large agricultural area of about 650,000ha occupying 85 percent of the basin area. RBDA also has made preliminary studies on the water resources development by the large and medium dams. Agricultural area extend along many tributaries in the basin and consisting of fertile soil. Many skillful farmers have engaged in paddy cultivation under rainfed. Accordingly, the water resources development for irrigation project will bring about the large effect for agricultural production under the fertile soil and available skilled farmers.

The basin also has advantage of being situated near Minna city and the capital of Abuja city which have the large market of agricultural products.

(c) The Awun Basin

The Awun basin is located at the north of Irorin city, the State capital of Kwara, where the Lower Niger RBDA is newly established. Agricultural area in the basin is 410,000 ha occupying 60 percent of the basin area. The demand for the water supply in the year 2020 in the basin reaches the large volume of 118 MCM p.a.

The water resources development mainly by the medium dams has been studied preliminary by the Niger RBDA in the basin including the Oshun basin. Although Kwara State has many medium scale river basins including the Awun basin, their water resources have not been developed yet. The Awun basin is located at the center of Kwara State and its water resources development by the medium and small dam package program will become the model in the basins of Kwara State and also the Lower Niger RBDA. The study and implementation of the project will be managed easily as the area is situated near Ilorin city.

(d) The Kilange Basin

There are many potentials for the water resources development in the Upper Benue basin. The Kilange, Hawal and Belwa basins are selected for the priority basin to be developed by the medium and small package program.
Out of the above three basin, the Kilange is selected as the high priority basin with the following reason;

- The basin is situated near the State capital of Yola, where the Upper Benue RBDA is located. The Belwa and the Hawal is located a little farther out from Yola city.
- Agricultural area in the Kilange occupies 40 percent of the basin area, while that in the Hawal and the Belwa is 35 and 25 percent respectively.
- The Kilange basin is developed mostly by the medium and small dams, while the other basins are mostly by large dams.

- Population density in the Hawal is as small as 84/km², while that in the Kilange is 125/km².
- Rate of agricultural area per population in the Belwa is as small as only 0.1 ha/capita, while that of the Kilange is 0.31ha/capita.

(e) The Katsina-Ala Basin

The Lower Benue river basin also has abundant surface water resources but its development has not been progressed yet. Although three basins of the Katsina-Ala, Ankwe and Mada are selected for the priority basins, the Katsina-Ala will have high potential for water resources development by the proposed dams with the following reason;

- The basin is located near Makurdi city, the Benue State capital, where the Lower Benue RBDA is existing.
- The basin has abundant surface water of 21.800 MCM.
- The middle and the lower basin in the Katsina-Ala has the large and fertile agricultural land of 700,000 ha occupying 80 percent of the basin area.
- Agricultural area per capita also is as high as 0.42 ha as compared with the other basins of 0.16 to 0.22 ha.
- Increase rate of water supply reaches 12 times that of the present water supply capacity.
- The basin is located at the center of Benue State and its water resources development by the medium and small dams will become the model in the State and the Lower Benue RBDA.

(f) The Mamu Basin

The Mamu basin including small tributary basin surrounding Awka city is selected as the high priority basin to be developed by the proposed dams under Anambra-Imo RBDA with the following reasons:

- Many cities including Awka, the State capital of Anambra, are scattered in the basin and their population reaches more than 5 million. The population density also is as high as 1370/km².

- Many cities have faced water shortage problem for domestic water supply and require the huge volume of 50 MCM to be developed by the surface water towards the year 2020.
- Although agricultural area is as small as 153,000ha occupying 35 percent of the basin area, the intensive agriculture under fertile land and rainfed has been carried out.
- There is the large potential of water resources development by small dams mainly for water supply.

(g) The Upper Ogun Basin

Although the existing large dams of Ikere Gorge and Oyan are provided in the Upper Ogun Basin, their reservoir water is planned to be used mainly for water supply of Lagos, and other large cities and for agricultural area along the Ogun river. The tributary basins of the Upper Ogun, however, have not been developed yet. The major reason to select the Upper Ogun basin for the water resources development by the medium and small dams is as follows;

- Large agricultural area of 1.3million ha occupying 35 percent of that in the South West region is distributed at the tributary basins of the Upper Ogun. Accordingly, agricultural area per capita is very high as 0.51 ha.
- The basin will be one of the most important agricultural development area to support the national food security towards the year 2020.
- The water supply demand in the basin in the year 2020 is also very high as 50MCM, which is 12.5 times of the present supply capacity.
- The basin is located at the north area of Abeokuta city where the Ogun-Oshun RBDA is existing, accordingly the water resources development will be managed easily and properly by RBDA and become the model in the Ogun and Oshun river basin.

(h) The Osse Basin

The Osse basin has the largest population of 4 million in the year 2020 and also the largest agricultural area of 460,000 ha in the river basins to be managed by the Benin-Owena RBDA. The domestic water demand at the basin in the year 2020 also is as very high as 89 MCM. Accordingly, the Osse basin is selected for the water resources development with high priority.

(i) The Aya Basin

Although the Aya, Aloma and Abo Ine basins have large potential for water resources development mainly by the medium and small dams, the Aya basin is selected as the high priority basin with the following reasons:

- Large agricultural land of 700,000 ha is existing in the Aya basin, while that of the other two basins is 500,000 ha.
- The basin has the high potential of water resources development by the medium and small dams as compared with the other two basins.
- There are many fertile agricultural areas and skilled farmers engaging in mostly paddy cultivation under rainfed in basin, especially Ogoja and Ikom area in the basin.
- The water supply demand in the year 2020 is as high as 11MCM.
- Although the Abo Ine basin will have the high potential of the water resources development and large population of 6 million, some resettlement problem in the reservoir area will occur due to tributary basin covered with dense population and many villages.

(7) Potential Hydropower Dam

(a) Zungeru Dam

The Zungeru hydropower dam is proposed at the downstream of the existing Shiroro hydropower dam in the Kaduna river. The feasibility study and the detailed design for the Zungeru has been already completed by NEPA but its construction is not commenced yet due to the financial constraint. Zungeru dam is planned by the rockfill dam and with the large reservoir area of 970 km^2, total reservoir capacity of 29,500 MCM and the power capacity of 950 MW under the dam height of 113m. The dam, however, will bring about the large resettlement and environment problems due to its large reservoir area. The above study shall be carefully carried out prior to the implementation of dam.

In addition the reservoir water could be used for irrigated agriculture at the downstream agricultural area which are currently under rainfed in the Kaduna lower basin. The study for the above irrigation project will be required in order to use the Zungeru water for multipurpose.

(b) Katsina-Ala Dam

NEPA also has the plan of Katsina-Ala hydropower dam in the Katsina-Ala river. Once the dam was proposed with high dam and the large reservoir capacity to control the abundant runoff of 21,000 MCM, its plan was reviewed with the small scale of the active reservoir capacity of 2,450MCM and power capacity of 440 MW, since the reservoir backwater reaches the Cameroon territory.

The above active capacity is too small to control the huge reservoir inflow of 21,000 MCM, which appears mostly in wet season.

In accordance with the evaluation for the reservoir operation of the Katsina-Ala by the JICA Team, the power outflow in dry season will be reduced to 25 percent of that in wet season as shown in Table 4.4.8. The dry season outflow will be used only for the peak power. Accordingly the Katsina-Ala dam is not as attractive as that of Zungeru.

Large agricultural area is extending to the downstream of the proposed damsite, so that Katsina-Ala dam shall be planned as multipurpose dam, including the irrigation component.

(c) Medium Scale Hydropower Dam

The potential of medium scale hydropower dams is found in the upper basin of the Taraba and the Suntai river in accordance with the study on the map of 1 to 50,000 scale and the reconnaissance site survey by the JICA Team. The conceptional plan of these hydropower dams are as shown in Table 4.4.9.

4.4.5 Implementation Procedures of the Medium and Small Dam Package Program

(1) Multipurpose

It has been observed that very little attention has been given to the maximization of reservoir water in the existing dams for the multipurpose use, such as irrigation, water supply and hydropower generation. As for the plan and implementation of the proposed medium and small dam package program, the multipurpose concept shall be introduced. The medium and small dams will be implemented mostly for irrigation and water supply, especially at the dam projects in the South region which require the large water supply demand for urban and rural area. For the above purpose, the following attention shall be paid for the formulation of dam plan.

(a) Coordination between RBDA and State Agencies

The water supply plan is generally set up by the water supply agencies of the State government. RBDA shall coordinate with the agency and discuss the followings prior to formulation of dam plan:

- Service population and its projected water demand.
- Intake point of raw water for water supply and intake facility such as pumping station.
- Raw water conveyance route to service area from damsite.
- Operation and maintenance after completion of the project.

(b) Project Cost Allocation

It is necessary to allocate the multipurpose dam project cost for irrigation and water supply between the RBDA and the Water Supply agency of the State. Dam project cost will be divided into irrigation and water supply in proportion to their water demand. The pumping station to withdraw the raw water for water supply and the outlet structure for irrigation water is to be shared by each project, respectively. The operation and maintenance for the dam will be carried out by the RBDA; thus, its shared cost for water supply also shall be allocated to the RBDA. When dams are used for the other purposes such as mini-hydro power generation, the dam construction and OM costs shall also be allocated through discussion with the concerned agency.

For detailed procedures, reference is made to para. d) "Cost Allocation in Multipurpose Water Resources Projects" as is compiled in (3) of para. 12.3.2 of Chapter 12.

(2) Master Plan or Pre-feasibility Study

The master plan or pre-feasibility study for the river basins by the proposed medium and small dams will be carried out at first on the map of 1 to 50,000 scale and by the site survey in the basin. The following items are approximate survey and study;

- Existing water resources development.
- Potential site to be developed by the medium and small dams.
- Present status of socio-economy, agriculture, water supply, etc. in the service area.
- Topographical, geological and hydrological conditions at the damsite.
- Problems and needs at the service area related to agriculture and water supply.
- Available runoff at the damsite and water demand in the service area.
- Outline of dam and reservoir
- Outline of service area such as the irrigation area and service population for water supply.
- The accessibility to site for further study.

The detailed scope for the study is described in Appendix 4-2 "Guideline for Planning of Medium and Small Dam Package Program". After formulating the package program, the tributary basin with priority is selected for the feasibility study. Tributary basin with priority will consist of 1,000 to 2,000 km^2 and include more than 10 proposed dam.

(3) Preparatory Work

Prior to the feasibility study, the following preparatory work will be carried out.

- Preparation of the map of 1 : 10,000 at the priority tributary basin;
- Installation of gaging station and undertaking of hydrological observation.

(4) Feasibility Study

Feasibility study will be made at the priority tributary basin in accordance with Guideline provided as Appendix 4-2. The package program for the medium and small dams to be implemented shall be worked out in the feasibility study. One package program will be implemented in about five years and budget scale of 600 to 800 million Naira, which will cover the medium and small dams of 10 to 15 units and irrigation area of 8,000 to 10,000 ha in total.

(5) Implementation

The detailed design and construction will be carried out as shown in the following table:

		1 st	2 nd	3 rd	4 th	5 th
(1) First Package	3~5dams	D.D	Const.			
(2) Second Package	-do-		D.D	Const.		
(3) Third Package	-do-			D.D	Const.	

Detailed Design   Construction (2 years)

The implementation of the package program will be made by RBDA's in-house engineering staff on force account or by employing the consultants and the contractor on contractual basis. It is recommendable, however, that the small dams shall be implemented by RBDA providing their engineering staff and construction equipment to minimize the construction cost and promote the beneficiaries' participation to the project. If the standard guideline for the design and construction for the small dams is prepared by FMWRRD, their implementation could be managed by RBDA without difficulty.

4. 4. 6 Study of the Inter-Basin Water Transfer Project

The following four inter-basin water transfer projects are proposed in an attempt to increase the potential water resources in the areas where critical water shortage prevails.

(1) Outline of the Project

(a) Dindima Basin Water Transfer Project

The project aims to transfer the Gongola river water to the Misau basin located at the upper basin of the Dingaiya and to supply irrigation water to the service area in the Komadugu-Yobe basin which suffers severe drought. According to the Dindima Transfer Planning Report prepared by Diyam Consultants (Nigeria), the project outline is as follows:

Proposed Dam

Dindima dam is proposed at Dindima site in the Gongola river to control a bulk runoff of about 2,000 MCM per annum in the Gongola river and to transfer the water of 900 to 1,000 MCM to the Misau. Misau dam is planned as diversion dam to regulate the transferred Gongola water. Following is a brief outline of both dams:

Item		Dindima	Misau
Catchment Area	(km^2)	9,500	2,300
Annual Average Inflow	(MCM)	2,000	240
Reservoir Surface Area	(km^2)	235	10.8
Active reservoir Capacity	(MCM)	2,500	40
Dam Height	(m)	49	14
Dam Length	(m)	5,100	2,400

Water Conveyance Tunnel

Long water conveyance tunnel from the Dindima dam to the Misau basin is required as follows:

Alternative I, Dindima to Misau by direct transfer

- Tunnel length of 61.7km with diameter of 6.4 m

Alternative II, Dindima to Misau via Bishi regulating dam

- Tunnel length of 17.6km with diameter of 5.5 m from the Dindima to the Bishi.
- Tunnel length of 31.8km with diameter of 7.0 m from the Bishi to the Misau.

Proposed Irrigation Area

About 100,000 ha along the downstream of the Komadugu-Yobe.

(b) Hawal Basin Water Transfer Project

The project is planned to transfer the upper basin water of the Hawal to the upper basin of the Ngadda and to use the transfer water for irrigation and water supply at the downstream area of the Ngadda.

The Hawal dam with the dam height of 28 m and the reservoir capacity of 480 MCM is proposed at the conjunction point of the Hawal and the Kolongelen. Since the detailed data related to the project were not available for the project, the JICA Team carried out the site survey at the Hawal basin and the preliminary study on the map of 1 : 50,000 scale, and it is to be noted that the project will require water conveyance tunnel of 8 km from the Hawal upper basin to the upper tributary basin of the Ngadda, will also require large reservoir area of 60 km^2 which will accelerate the evaporation losses of the reservoir.

(c) Gurara Basin Water Transfer Project

The project is planned to transfer the Gurara water to the upper basin of the Kaduna river in order to increase the hydropower generation for the existing Shiroro dam and the proposed Zungeru dam. The project also aims to supply domestic water to the Capital area of Abuja. The project outline based on Futmin Consultant, Federal University of Technology, Minna in 1992, is as follows;

Upper Jere Dam

The Upper Jere Dam is proposed at the upper Jere site of the Gurara river with the following dimensions:

Catchment area	4,000 km^2
Annual average runoff	3,000 MCM
Active reservoir capacity	3,000 MCM
Dam height	60m
Dam length	5.9 km
Water supply to F. C. T	355 MCM (In 2000)
Transfer to Shiroro	1,600 MCM
Releases to Gurara Falls	100 MCM

(d) Zamfara Basin Water Transfer Project

The project aims to transfer the Zamfara water to the Sokoto river and to supply the supplemental water to the service area developed by the existing Bakolori dam and the surrounding Sokoto district. Anka dam is proposed at the Zamfara river with the reservoir capacity of 950 MCM. The project study, however, is still at conceptional level.

(2) Possibility of the Water Transfer Project

(a) The Dindima Water Transfer

Although the downstream area of the Komadugu-Yobe river has suffered large water shortage, the Dindima water transfer project will not be recommendable due to the estimated huge construction cost for the water conveyance tunnel with the length of about 60 km. The tunnel construction cost will be about 12,600 million Naira based on the following assumption;

- Tunnel section area of $30m^2$ with the diameter of 6m.
- Unit price of 7,000 Naira/m^3 including excavation, concrete lining and also access tunnel and shafts of more than 10 units for construction with long distance tunnel.
- Tunnel cost, ₦7,000 /m^3 $\times$ $30m^3$/m $\times$ 60,000m = 12,600 million Naira

(b) The Hawal Water Transfer

The project may be feasible, as the tunnel length is about 8 km which will be constructed without access tunnel from both ends of the inlet side and outlet side. The construction cost of the tunnel will be about 720 million Naira under the following conditions:

- Discharge capacity, $20m^3/sec$
- Annual transfer water, 500 MCM
- Tunnel section area $15m^2$ with the tunnel diameter of 4.4 m
- Unit price of ₦6,000 / m^3 without access tunnel
- Tunnel cost ; ₦6,000 $/m^3 \times 15m^3/m \times 8{,}000m = 720$ million Naira

It is recommendable to carry out the feasibility study of the project towards the year 2020 taking into consideration the following items:

- Available water to be transferred shall be determined based on the hydrological study at the Hawal basin and the water allocation to the downstream area of the proposed Hawal damsite.
- Dam with small reservoir area to minimize the evaporation loss. For example, the alternative two dams at the Hawal and at the Kolongelen damsites which is located at the upstream of conjunction point of both rivers. Two dams could be easily connected with the open channel.
- Preparation of the map of 1 : 10,000 scale for the study.
- Geological investigation at the damsite and along the tunnel alignment.

(c) The Gurara Water Transfer

The Gurara water transfer will be technically and economically feasible. It is not recommendable, however, to commence the project implementation towards the year 2020, because of the following reasons:

- Huge construction cost will be required.
- Domestic water for FCT will be sufficiently supplied by the existing dams of the Umaisha, Sulejia, etc towards the year 2020.

(d) The Zamfara Water Transfer

It is also not recommendable to implement the Zamfara water transfer project towards the year 2020, because the Bakolori dam will have sufficient water to cover its irrigation area and the water for Sokoto districts could be supplied by the proper water management of the existing Goronyo dam.

4.4.7 Implementation Program

(1) The Integrated Water Management Study in the North Region

The water management study in the North region shall be carried out by the year 2000 together with the implementation of the incomplete irrigation and water supply system in the service area under the existing dams.

The water management study period will be three years including installation of gaging station, monitoring of the actual reservoir operation, measurement of water loss along the river and formulation of the water management rule.

The water management study for Hadejia basin shall be commenced first and followed by Rima basin. The cost of the water management work is estimated at 50 million Naira for each basin.

(2) Rehabilitation Works at the Existing Dams

Rehabilitation works at the existing dams will be carried out under the dam maintenance works by OM office. The works also are planned to be completed by the year 2000. The rehabilitation cost is estimated as follows;

(a) Ordinary Rehabilitation Works by the year 2000

The rehabilitation works for 50 dams corresponding to about 30 percent of 160 existing dams will be required with average cost of 5 million Naira / unit

5 million Naira × 50 dams = <u>250 million Naira</u>

(b) Rehabilitation Works of Goronyo Dam by the Year 2000

If the counterweight berm method for the rehabilitation works is adopted, the cost will be as follows:

- Embankment Volume
  Unit area: 5m × 20 m = $100m^2/m$
  $100m^2/m$ × Dam Length of 3,000m = $300,000m^3$
- Cost
  N $350/m^3$ × $300,000m^3$ ≑ <u>100 million Naira</u>
  where, N $350/m^3$ includes the cost for drainage system

(c) Rehabilitation works of Inlet Chamber at Power Plant in Bakolori Dam by the year 2000
<u>50 million Naira</u>

(d) Improvement of access roads, communication system and OM facilities
<u>100 million Naira</u>

(e) Total Cost ((a)+(b)+(c)+(d)) <u>500 million Naira</u>

(3) Proposed Dams

The master plan and feasibility study for the priority river basin including many potential medium and small dams will be made firstly by the year 2000. The study for the other basin will be continued toward the year 2020. The implementation of the proposed dam, therefore, will be started after the year 2000. The proposed dam cost is 41,100 million Naira composed of 3,800 million Naira for the administration & engineering, and 37,300 million Naira for construction.

(4) Implementation Schedule

The implementation schedule for the dam project towards the year 2020 is planned as follows:

(Unit: 10^6 Naira)

Item	1996~ 2000	2001~ 2005	2006~ 2010	2011~ 2015	2015~ 2020	Total
1. Work Schedule						
(1) Water Management						
(2) Rehabilitation						
(3) Proposed Dam						
Master Plan & Feasibility Study						
Implementation						
2. Cost Schedule						
(1) Water Management	100					100
(2) Rehabilitation	500					500
(3) Proposed Dam						
Administration & Engineering	200	800	900	900	1,000	3,800
Construction	-	6,500	8,500	10,000	12,300	37,300
Subtotal	200	7,300	9,400	10,900	13,300	41,100
total	800	7,300	9,400	10,900	13,300	41,700

4.4.8 Environmental Management

The NWRMP Study has demonstrated that it is inconceivable that a systematic environmental impact consideration was carried out for any of the dam and reservoir projects, and also pointed out that the water and environmental quality monitoring is a very neglected and uncoordinated activity in these large social investments that may greatly change the pre-existing environment. The environmental problems and impacts of dams are detailed in para. (1) of 11.2.2 in Chapter 11, and the matters related to the reservoir fishery, the interception of fish movement up and down the stream, and the disturbance of various riverine ecosystems including the wetland fishery are described in paras. 10.1.4 and 10.2.2 of Chapter 10. And, the watershed deterioration that is progressing at an alarming rate and may lead towards the reduction of reservoir life span and the enlargement of dam spillway capacity is examined in paras. 7B.1.1 of Chapter 7 and (4) of 11.2.3 of Chapter 11.

The environmental protection and conservation of natural resources related to the water source works projects should be made as an integral part of development, and the objective environmental impact assessment should be considered as a pre-requisite for the approval of development plans and projects from the beginning of any project cycle. In addition, an integrated environmental monitoring, evaluation and feedback are essential to ensure the