3C.7 NATIONAL WATER MASTER ACTION PLAN TOWARD'S 2000

3C.7.1 Selection of Priority Stations

Among 1,772 of hydro-meteorological gaging stations to be newly erected or rehabilitated under the proposed NWRMP towards the year 2020, priority for early implementation during the period form 1996 to 2000 is given to the establishment of the network of the BRCP (23 locations) to monitor the status of water resources over the country, the installation of new hydro-meteorological gaging stations for the existing reservoirs (20 locations) with the total storage capacity of more than 50 MCM, and the installation of new hydro-meteorological gaging stations for the selected 20 priority SHAs where there are high potentialities of large scale water resources development.

The importance of the monitoring of the large reservoirs is clearly observed in the northern region of the country, HA-I and VIII with less rainfall and high evapotranspiration. A series of dams has been constructed on the headwaters of the region; however, the reservoirs are being operated without sufficient data and information on hydro-metorology, resulting in low water use efficiencies. For the selected 20 SHAs, hydro-metorological observation should be initiated as early as possible so as to collect data and information for rational planning and designing of water resources development projects conceived in the SHAs.

3C.7.2 Plan Implementation Program

At the BRCP and the existing reservoirs, four kinds of gaging stations of rainfall, evaporation, river discharge and sediment discharge will be installed, whereas three kinds of gaging stations of rainfall, river discharge and sediment discharge will be installed at the selected priority SHAs for water resources development. The total number of hydro-meteorological gaging stations to be installed under the National Water Master Action Plan towards the Year 2000 is 232: 63 rainfall stations, 43 evaporation stations, 63 river discharge stations and 63 sediment discharge stations, as given as follows:

Distribution of Stations

- Unit: Nos. of Stations -

Station	I	II	III	IV	V	VI	VII	VIII	Total
Rainfall	10	13	14	5	3	8	5	5	63
Evaporation	9	9	9	2	2	5	2	5	43
River	10	13	14	5	3	8	5	5	63
Sediment	10	13	14	5	3	8	5	5	63
Total	39	48	51	17	11	29	17	20	232

The total project cost is estimated at 208.3 million Naira consisting of 136.6 million Naira for the installation of gaging stations, 20.9 million Naira for procurement of monitoring equipment and 50.8 million Naira for operation and maintenance of the projects. The project cost by HA is summarized below:

Project Cost by HA

- Unit: Million Naira -

Cost Item	I	II	III	IV	V	VI	VII	VIII	Total
Installation	29.0	31.4	25.0	4.7	3.1	18.8	4.6	20.0	136.6
Monit. Equipment	2.0	3.5	3.5	2.1	3.6	2.1	2.1	2.0	20.9
O & M	9.8	10.4	9.0	2.7	2.7	6.7	2.7	6.8	50.8
Total	40.8	45.3	37.5	9.5	9.4	27.6	9.4	28.8	208.3

Except for the evaporation stations, all the stations will be equipped with automatic recording gages and, for the existing reservoirs with the total storage capacity of 50 MCM, river inflow to the respective reservoirs will be observed together with reservoir water levels, water release from the reservoirs and sediment discharge. Water for analysis of sediment discharge is sampled at the proposed river discharge gaging stations so that any particular facilities are not required for the sediment discharge gaging stations. In addition to measuring gages to be equipped at the stations, the project will provide eight nos. of such equipment as current meters, vehicles of 4WD- car and pickup truck, boats, sediment analysis equipment and micro computer for eight HA as monitoring equipment. The procurement of monitoring equipment also includes echo-sounders to be provided at HA-I, III and V for hydrographical survey of the River Niger and Benue.

The observation of hydro-meteorological parameters and maintenance of the gaging stations will be entrusted to the River Basin Development Authorities concerned under the control of the proposed Regional

Administration Offices of the FMWRRD. Eight of field teams in total, one for each HA, will be organized for periodical discharge measurement to prepare rating curves and sampling of river water to estimate sediment discharge. Sediment analysis will be done by the RBDAs concerned with the equipment to be procured under this project. To ensure continuous observation with sufficient accuracy, the National Water Resources Institute will provide training courses of engineering staff from water agencies for maintaining the observation network, and knowledge and experiences gained through the training courses will be transferred to staff working at the sites.

TABLE 3C-1 MEAN ANNUAL RUNOFF IN THE 1980s AT SELECTED STATIONS

HA	Station	River	Catchment Area (km²)	Mean Annual Runoff	
				MCM	mm
	Yola	Benue	108,400	14,167	131
	Ibi	Benue	258,700	49,158	190
	Makurdi	Benue	305,500	75,085	246
	Umaisha	Benue	335,000	76,668	229
	Jiddere Bode	Niger	-	25,100	-
	Kainji Dam	Niger	569,800	22,422	39
	Jebba Hydropower	Niger	631,800	24,319	38
	Baro	Niger	730,300	43,345	59
	Lokoja	Niger	1,089,500	137,909	127
	Idah	Niger	1,095,100	147,292	135
	Onitsha	Niger	1,100,800	141,900	129
I	Gusau	Sokoto	2,570	371	144
	Bakolori Dam	Sokoto	4,800	601	125
	Goronyo Dam	Rima	21,450	724	34
	Wamako	Rima	40,160	1,141	28
	Anka	Zamfara	4,140	528	128
	Bananga Dam	Gulbinka	3,170	352	111
	Malendo Bridge	Malendo	9,954	1,345	135
II	Komi	Kontagora	2,250	283	126
	Wuya	Kaduna	59,180	14,861	251
	Shiroro Hydropower	Kaduna	36,100	7,216	200
III	Gombe Abba	Gongola	17,650	2,062	117
	Dadin Kowa	Gongola	30,460	2,491	82
	Bali	Taraba	10,850	6,324	583
	Gassol	Taraba	20,700	9,518	460
	Tela	Taraba	22,350	11,628	520
	Mbu / Tepkwar	Donga	2,120	1,395	658
	Manya	Donga	6,350	7,695	1,212
	Gindin Dorowa	Donga	18,800	15,535	826
	Maisamari	Jigwal	562	215	383
	Suntai Bakurdi	Suntai	2,600	2,522	970
	Bantaji	Suntai	5,350	2,788	521
IV	Katsina Ala	Katsina Ala	16,770	21,210	1,265
	Sevav	Katsina Ala	22,100	25,810	1,168
VI	Sepeteri	Ogun	1,060	253	239
	Apoje	Oshun	8,170	3,460	424
	Ilaji - Ile Road	Oyan	1,460	215	147
	Awe - Ife Odan	Oba	930	117	126
	Oyo - Ogbomosho Road	Oba	1,580	259	164
	Ofiki Town	Ofiki	438	137	313
	Iganna / Iwere	Ofiki	2,780	644	232
VII	Ikom	Cross	16,900	26,809	1,586
	Adonatam	Cross	18,900	36,927	1,954
	Obubra	Cross	35,800	41,148	1,149
	Afikpo	Cross	46,200	50,036	1,083
	Ikot Okpara	Cross	48,300	51,011	1,056
	Ugwu NKPA	Eme	230	71	309
	Ndimoko	Imo	160	99	619
	Umuna	Imo	490	319	651
	Umuopara	Imo	1,450	1,236	852
	Obigbo	Imo	5,600	4,061	725
	Ulakwo	Oramiriukwa	795	64	81
VIII	Tiga Dam	Kano	6,553	695	106
	Chiromawa	Kano	6,975	664	95
	Challawa Gorge	Challawa	3,859	337	87
	Challawa Bridge	Challawa	6,889	604	88
	Wudil	Hadejia	16,380	1,641	100
	Hadejia	Hadejia	25,900	938	36
	Bunga Beidge	Jama'are	7,380	1,265	171
	Kari	Misau	5,865	147	25
	Chai Chai	Gaya	1,710	44	26
	Gwarzo Road	Watari	1,450	177	122
	Gashua	Yobe	55,700	814	15
	Geidam	Yobe	58,500	595	10
	Bama Bridge	Yedseram	-	115	-

TABLE 3C-2 FLUCTUATION OF MONTHLY DISCHARGE AT SELECTED STATIONS

HA	River	Station	Catchment Area (km^2)	Monthly Discharge (m^3/s)			
				Max.	Min.	Mean	Period
	Niger	Jiddere Bode	-	2,530	1	940	'70 - 89
		Kainji Dam	569,800	2,430	400	900	'70 - 89
		Baro	730,300	5,860	420	1,590	'70 - 89
		Lokoja	1,089,500	22,800	860	4,820	'70 - 89
	Benue	Yola	108,400	3,550	40	550	'78 - 87
		Makurdi	305,500	10,900	150	2,610	'78 - 89
I	Sokoto	Bakolori	4,800	170	0	23	'70 - 85
	Rima	Wamako	40,160	310	0	39	'70 - 85
II	Kaduna	Wuya	59,180	4,970	5	470	'80 - 89
III	Gongola	Dadin Kowa	30,460	410	1	64	'81 - 87
	Taraba	Tela	22,350	2,690	1	370	'81 - 87
	Donga	Manya	6,350	960	12	250	'81 - 87
IV	Katsina Ala	Katsina Ala	16,770	3,540	47	750	'75 - 85
VI	Osun	Apoje	8,170	220	37	110	'82 - 86
VII	Cross	Ikot - Okpara	48,300	5,580	97	1,670	'80 - 86
VIII	Kano	Tiga Dam	6,553	220	0	26	'70 - 85
	Challawa	Challawa Bridge	6,889	290	0	26	'70 - 89
	Hadejia	Hadejia	25,900	140	0	24	'70 - 88
	Yobe	Gashua	55,700	410	0	28	'70 - 88

TABLE 3C-3 ANNUAL RUNOFF COEFFICIENT AT SELECTED STATIONS

HA	River	Station	Catchment Area (km^2)	Annual Runoff Coefficient	
				Mean	Range
I	Sokoto	Gusau	2,570	0.18	0.15 - 0.20
		Bakolori Dam	4,800	0.15	0.09 - 0.19
	Rima	Goronyo Dam	21,450	0.05	0.04 - 0.08
		Wamako	40,160	0.05	0.03 - 0.08
	Zamafara	Anka	4,140	0.16	0.11 - 0.20
	Gulbinka	Banaga Dam	3,170	0.15	0.09 - 0.23
	Malendo	Melendo Bridge	9,954	0.13	0.06 - 0.16
II	Kontagora	Komi	2,250	0.12	0.07 - 0.15
III	Gongola	Gombe Abba	17,650	0.15	0.11 - 0.19
		Dadin Kowa	30,460	0.08	0.05 - 0.10
	Jigwal	Maisamari	562	0.23	0.16 - 0.26
VI	Osun	Apoje	8,170	0,34	0.31 - 0.37
	Oba	Awe Ife Odan	930	0.18	0.15 - 0.21
VII	Imo	Umuna	490	0.27	0.22 - 0.36
		Umuopara	1,450	0.34	0.30 - 0.38
		Obigbo	5,600	0.32	0.30 - 0.35
VIII	Kano	Tiga Dam	6,553	0.13	0.09 - 0.17
		Chiromawa	6,975	0.08	0.04 - 0.13
	Challawa	Challawa Gorge	3,859	0.15	0.10 - 0.29
		Challawa Bridge	6,889	0.13	0.10 - 0.30
	Hadejia	Wudil	16,380	0.14	0.05 - 0.26
		Hadejia	25,900	0.06	0.04 - 0.09
	Bunga	Bunga Bridge	7,380	0.17	0.08 - 0.22
	Jama'are	Kari	5,865	0.04	0.01 - 0.08
	Gaya	Chai Chai	1,710	0.03	0.01 - 0.06
	Watari	Gwarzo Road	1,450	0.07	0.01 - 0.21
	Yobe	Gashua	55,700	0.03	0.01 - 0.11

TABLE 3C-4 POTENTIAL SURFACE WATER RESOURCES

HA and Station	Catchment Area (km^2)	River Runoff (MCM)	River Yield (mm)
(1) Niger and Benue River			
1. HA - I (Kainji Dam)			
- Border with Niger	461,500	18,400	40
- Jiddere Bode	563,500	25,100	45
- Kainji Dam Outflow	569,800	22,400	39
2. HA - II			
- Jebba Dam Outflow	632,000	24,300	38
- Kaduna and Niger Confluence	708,700	40,900	58
- Baro	730,300	45,500	62
- Lokoja on Benue River	751,300	55,000	73
3. HA - III and IV			
- Border with Cameroon	98,000	12,800	130
- Yola	108,400	14,200	130
- Numan	168,000	22,000	130
- Agwan Taru	206,700	27,000	130
- Upper / lower Benue Border	256,900	55,000	214
- Makurdi	305,500	80,000	262
- Confluence of Niger and Benue	338,200	83,000	245
4. HA - V			
- Lokoja : Niger and Benue	1,089,500	138,000	127
- Onitsha	1,100,800	142,000	129
- Aboh	1,112,800	148,000	133
- Potenial at River Mouth of River Niger : Total (1)	1,143,400	158,000	138
(2) Rivers in South West Region			
- HA - VI : South West Region	100,500	35,400	352
(3) Rivers in South East Region			
- HA - VI : South East Region	73,200	65,700	898
(4) Rivers in Lake Chad Basin : HA - VII			
1. Komadugu Yobe			
- Hadejia River at Wudil	16,400	1,640	100
- Iggi, River at Iggi	6,400	960	150
- Jama'are River at Bunga	8,000	1,270	159
- K. Yobe River at Gashua	55,700	810	15
- Misau River at Kari	5,870	180	30
- K. Yobe River at Damasak	82,600	540	7
- Lake Chad	99,500	0	0
Sub - total	99,500	5,400	54
2. Yedseram and Orher Rivers			
- Yedseram Upper Basin	1,700	170	100
- Alau Dam	4,100	200	50
- Komadugu Gama	11,300	830	73
- Other Rivers in Desert Area	46,500	0	0
Sub - total	63,600	1,200	19
3. Rivers along Border with Niger	24,900	1,600	64
Total (4)	188,000	8,200	44
Country Total : Total of (1) to (4)	1,505,100	267,300	178

TABLE 3C-5 MEAN MONTHLY RAINFALL AND EVAPOTRANSPIRATION (ET) (1/2)

(Unit: mm)

Month	Bauchi		Calabar		Enugu		Remarks
	Rainfall	ET	Rainfall	ET	Rainfall	ET	
Jan.	0	146	19	115	2	158	Average for 5 years (1986 - 90)
Feb.	0	167	28	106	2	160	
Mar.	2	198	152	127	42	180	
Apr.	22	204	211	126	138	168	
May	80	192	287	124	187	149	
Jun.	133	174	408	105	205	120	
Jul.	216	161	516	90	281	118	
Aug.	254	164	280	90	298	112	
Sep.	129	165	378	90	250	114	
Oct.	29	177	315	99	196	140	
Nov.	0	159	127	111	12	150	
Dec.	0	149	42	115	5	155	
Total	865	2,046	2,763	1,298	1,618	1,724	

Month	Ilorin		Kano		Maiduguri		Remarks
	Rainfall	ET	Rainfall	ET	Rainfall	ET	
Jan.	15	143	0	127	0	192	Average for 5 years (1986 - 90)
Feb.	17	148	0	126	0	196	
Mar.	56	183	0	164	0	205	
Apr.	68	165	8	183	6	255	
May	109	180	29	195	15	248	
Jun.	192	138	90	165	55	210	
Jul.	114	121	211	146	151	202	
Aug.	143	118	262	136	179	146	
Sep.	194	126	100	144	84	180	
Oct.	102	146	13	164	8	220	
Nov.	5	141	0	141	0	198	
Dec.	9	140	0	124	0	155	
Total	1,024	1,749	713	1,815	498	2,407	

MEAN MONTHLY RAINFALL AND EVAPOTRANSPIRATION (ET)
(2 / 2)

(Unit: mm)

Month	Makurdi		Minna		Sokoto		Remarks
	Rainfall	ET	Rainfall	ET	Rainfall	ET	
Jan.	0	161	0	189	0	155	Average for 5 years (1986 - 90)
Feb.	0	154	0	202	0	146	
Mar.	7	198	12	223	6	220	
Apr.	61	183	55	219	1	201	
May	134	174	140	186	22	183	
Jun.	124	138	150	141	86	180	
Jul.	188	118	175	127	169	133	
Aug.	260	127	236	121	148	136	
Sep.	221	132	232	129	91	135	
Oct.	101	149	89	164	11	174	
Nov.	0	156	4	183	0	183	
Dec.	6	174	0	174	0	180	
Total	1,102	1,864	1,093	2,058	534	2,026	

Month	Yola		Jos		Kaduna		Remarks
	Rainfall	ET	Rainfall	ET	Rainfall	ET	
Jan.	0	149	0	233	0	245	Average for 5 years (1986 - 90) for Yola, 29 Year (1951-79) for Jos and 15 years (1966-80) for Kaduna
Feb.	0	148	0	218	2	230	
Mar.	0	192	21	276	6	285	
Apr.	33	195	91	216	38	225	
May	107	183	163	174	78	180	
Jun.	103	156	223	138	166	141	
Jul.	231	136	283	115	186	127	
Aug.	192	146	272	112	323	124	
Sep.	159	144	197	132	247	129	
Oct.	57	180	49	195	56	177	
Nov.	4	165	0	216	0	222	
Dec.	0	152	0	223	0	233	
Total	886	1,946	1,299	2,248	1,102	2,318	

TABLE 3C-6 WATER BALANCE BY SHA (1/3)

SHA	Rivers	Chatchment Area (km²)	River Yield (mm)	River Runoff (MCM)	Irrigation and Water Supply Demand			Downstream Demand		Total Demand (MCM)	Water Balance (MCM)	Water Use Rate (%)
					Irrigation (MCM)	Water Supply (MCM)	Total (MCM)	(%)	(MCM)			
HA-I												
101	Gada	4,030	70	280	95	10	105	30	84	189	91	68
102	Bunshur	8,490	70	590	161	8	169	30	177	346	244	59
103	Gagere	8,660	80	690	170	15	185	30	207	392	298	57
104	Sokoto	12,220	80	980	295	15	310	30	294	604	376	39
105	Rima	9,240	20	180	178	34	212	5	9	221	▲41	100
106	Gawon Gubli	8,690	120	1,040	130	6	136	5	52	188	852	18
107	Along Sokoto River	8,480	30	250	152	-	152	5	13	165	85	66
108	Zamfara	17,130	130	2,230	75	44	119	5	112	231	1,999	10
109	Gulbinka	11,380	130	1,480	104	-	104	5	74	178	1,302	12
110	Damzaki	8,130	140	1,140	200	10	210	5	57	267	873	23
111	Malendo	11,780	130	1,530	85	19	104	5	77	181	1,349	12
112	Along Border	8,880	20	180	-	-	-	5	9	9	171	5
113	Ouara and Maiel	10,000	100	1,000	104	4	108	5	50	158	842	16
114	Swashi and Dore	4,490	120	540	94	2	96	10	54	150	390	28
	Sub-total	131,600	92	12,110	1,843	167	2,010		1,269	3,279	8,831	27
HA-II												
201	Oli and Wuruma	9,930	120	1,190	80	-	80	5	60	140	1,050	12
202	Moshi	10,210	120	1,230	57	5	62	5	62	124	1,106	10
203	Kontagora	8,970	120	1,080	194	10	204	5	54	258	822	24
204	Oshun and Awun	7,150	150	1,070	369	118	487	5	54	541	529	51
205	Oshun, Oi and Ove	10,800	180	1,940	266	50	316	5	97	413	1,527	21
206	Kojin Maringo	17,800	200	3,560	114	-	114	10	356	470	3,090	13
207	Eba	7,730	210	1,620	346	-	346	10	162	508	1,112	31
208	Kampe	12,310	220	2,710	312	16	328	10	271	599	2,111	22
209	Tubo	7,470	150	1,120	160	38	198	10	112	310	810	28
210	Koringa	5,350	200	1,070	68	3	71	10	107	178	892	17
211	Galma	11,630	150	1,740	384	110	494	10	174	668	1,072	38
212	Upper Kaduna	9,420	310	2,920	243	163	406	10	292	698	2,222	24
213	Sarikin Powa	7,550	250	1,890	80	-	80	10	189	269	1,621	14
214	Gbako	12,120	220	2,670	642	52	694	5	134	828	1,842	31
215	Small Tributaries	2,580	250	650	323	3	326	5	33	359	291	55
216	Gurara	17,080	480	8,200	144	70	214	5	410	624	7,576	8
	Sub-total	158,100	219	34,660	3,782	638	4,420		2,567	6,987	27,673	20
HA-III												
301	Kiriange and Others	9,450	130	1,230	244	6	250	10	123	373	857	30
302	Mayo Ine and Others	10,700	250	2,700	297	34	331	10	270	601	2,099	22
303	Hawal and Others	16,140	120	1,940	408	7	415	10	194	609	1,331	31
304	Upper Gongola	31,550	120	3,790	133	27	160	20	758	918	2,872	24
305	Middle Gongola	6,110	120	730	73	-	73	20	146	219	511	30
306	Small Tributaries	4,230	150	630	-	-	-	5	32	32	598	5
307	Mayo Belwa	7,560	300	2,270	374	23	397	10	227	624	1,646	27
308	Pai	16,350	100	1,640	73	-	73	10	164	237	1,403	14
309	Fan	5,750	120	690	87	-	87	10	69	156	534	23
310	Duchi	10,810	100	1,080	73	8	81	10	108	189	891	18

TABLE 3C-6 WATER BALANCE BY SHA (2/3)

SHA	Rivers	Chatchment Area (km²)	River Yield (mm)	River Runoff (MCM)	Irrigation and Water Supply Demand: Irrigation (MCM)	Water Supply (MCM)	Total (MCM)	Downstream Demand (%)	Downstream Demand (MCM)	Total Demand (MCM)	Water Balance (MCM)	Water Use Rate (%)
311	Taraba and Lower Donga	10,100	910	9,190	455	18	473	10	919	1,392	7,798	15
312	Suntai	5,350	610	3,260	27	0	27	10	326	353	2,907	11
313	Upper Taraba	12,730	590	7,510	-	-	-	10	751	751	6,759	10
314	Upper Donga	12,070	1,100	13,280	137	15	152	10	1,328	1,480	11,800	11
	Sub - total	158,900	314	49,940	2,381	138	2,519		5,415	7,934	42,006	16
HA-IV												
401	Shemankar	6,000	200	1,200	293	25	318	10	120	438	762	37
402	Rity and Fiyu	4,530	200	910	93	6	99	10	91	190	720	21
403	Ankwe and Others	11,550	120	1,390	289	11	300	10	139	439	951	32
404	Asku and Guma	6,520	200	1,300	166	20	186	10	130	316	984	24
405	Katsina - Ala	12,820	1,400	17,900	290	17	307	10	1,790	2,097	15,803	12
406	Small Tributaries	6,490	300	1,950	169	57	226	10	195	421	1,529	22
407	Mada	8,730	120	1,050	301	17	318	10	105	423	627	40
408	Akini	11,430	120	1,370	174	30	204	5	69	273	1,097	20
409	Small Tributaries	4,930	150	740	77	-	77	5	37	114	626	15
	Sub - total	73,000	381	27,810	1,852	183	2,035		2,676	4,711	23,099	17
HA-V												
501	Osordo, Udo and Oril	8,810	800	7,050	176	31	207	5	353	560	6,490	8
502	Anambra	11,490	500	5,750	242	29	271	5	288	559	5,191	10
503	Asa and Others	6,340	330	2,090	121	14	135	5	105	240	1,850	11
504	Along River Niger	8,530	330	2,810	245	56	301	5	141	442	2,368	16
505	Forcados	18,730	320	5,990	235	-	235	5	300	535	5,445	9
	Sub - total	53,900	440	23,690	1,019	130	1,149		1,187	2,336	21,354	10
HA-VI												
601	Wuru, Kobo and Ove	4,800	150	720	-	4	4	5	36	40	680	6
602	Ogun and Oyan	22,060	300	6,620	852	114	966	10	662	1,628	4,992	25
603	Yewa	5,670	300	1,,700	73	694	767	5	85	852	848	50
604	Ondo	5,640	400	2,260	131	273	404	5	113	517	1,743	23
605	Oshun	10,130	400	4,050	218	86	304	5	203	507	3,543	13
606	Owena	10,900	400	4,360	146	5	151	5	218	369	3,991	8
607	Silko	5,750	400	2,300	86	30	116	5	115	231	2,069	10
608	Osse	13,730	350	4,810	159	89	248	5	241	489	4,321	10
609	Lagoon	11,520	400	4,610	15	333	348	5	231	579	4,031	13
610	Ossimo	10,300	400	4,120	65	59	124	5	206	330	3,790	8
	Sub - total	100,500	354	35,550	1,745	1,687	3,432		2,110	5,542	30,008	16
HA-VII												
701	Upper Cross	7,490	550	4,120	211	9	220	5	206	426	3,694	10
702	Okpanku	8,660	550	4,760	309	11	320	5	238	558	4,202	12
703	Middle Cross	9,490	1,200	11,390	293	5	298	5	570	868	10,522	8
704	Middle Cross	8,470	1,400	11,860	55	95	150	5	593	743	11,117	6
705	Lower Cross and Imo	13,370	1,400	18,720	266	144	380	5	936	1,316	17,404	7
706	Lower Cross	5,590	1,400	7,830	304	24	328	5	392	720	7,110	9
707	Small Tributaries	6,730	1,100	7,400	66	18	84	5	370	454	6,946	6
	Sub - total	59,800	1,105	66,080	1,504	276	1,780		3,305	5,085	60,995	8

TABLE 3C-6 WATER BALANCE BY SHA (3/3)

SHA	Rivers	Chatchment Area (km^2)	River Yield (mm)	River Runoff (MCM)	Irrigation and Water Supply Demand			Downstream Demand		Total Demand (MCM)	Water Balance (MCM)	Water Use Rate (%)
					Irrigation (MCM)	Water Supply (MCM)	Total (MCM)	(%)	(MCM)			
HA-Ⅷ												
801	Tagwai	8,070	100	810	-	49	49	0	0	49	761	6
802	Gari	10,080	100	1,010	257	12	269	0	0	269	741	27
803	Challawa and Watari	6,650	100	670	74	234	308	0	0	308	362	46
804	Kano	7,660	120	920	320	9	329	0	0	329	591	36
805	Bunga and Jama'are	13,780	100	1,380	272	93	365	0	0	365	1,015	26
806	Iggi	6,430	150	960	45	7	52	0	0	52	908	5
807	Gaya and Hadejia	15,680	60	940	642	10	652	0	0	652	288	69
808	Along Border	12,820	0	0	-	-	-	0	0	0	0	-
809	Katagun	9,910	0	0	460	-	460	0	0	460	▲460	-
810	Misau and Dingaiya	28,610	6	170	108	-	108	0	0	108	62	64
811	Yobe	4,710	6	29	29	-	29	0	0	29	0	100
812	Along Lake Chad	19,270	0	0	221	-	221	0	0	221	▲221	-
813	Ngaddo	23,490	15	352	74	48	122	0	0	122	230	53
814	Yedseram	9,530	20	190	122	23	145	0	0	145	45	76
815	Komadugu Gama	11,310	75	850	-	-	-	0	0	0	850	0
	Sub-total	188,000	44	8,281	2,624	485	3,109		0	3,109	5,172	38
	Total	923,800	279	258,121	16,750	3,704	20,454		18,529	38,983	219,138	15

TABLE 3C-7 LIST OF BASIC REFERENCE CONTROL POINTS

SHA	River	Locations
1031	Niger	Near Border
1032	Niger	Jiddere Bode
1113	Niger	Kainji Dam
1052	Rima	Goronyo Dam
2082	Niger	Kaduna Conflu.
2032	Niger	Jebba
2130	Kaduna	Shiroro Dam
2122	Kaduna	Kaduna South
3021	Benue	Wuroboki
3070	Benue	Numan
3030	Hawal	Hawal
3042	Gongola	Gonbe Abba
3111	Taraba	Tela

SHA	River	Locations
3120	Donga	Manya
4062	Benue	Makurdi
4052	Katsina-Ala	River Mouth
5011	Niger	Lokoja
5031	Anambra	Asaba
6023	Ogun	River Mouth
6080	Osse	River Mouth
7041	Cross	Ikom
7060	Cross	Ikot Okapara
8092	Yobe	Gashua

TABLE 3C-8 LIST OF NEW STATIONS FOR PROPOSED DAMS

SHA	River	SHA	River
1030	Gagere	4010	Shemankar
1100	Danzaki*	4030	Ankwe*
2040	Awun*	4050	Katsina-Ala*
2050	Oshin	4070	Mada*
2080	Kampe*	5010	Osod/Ebin
2090	Tubo	5020	Upper Anambra
2110	Galma/Karam*	5030	Asa
2120	Upper Kaduna	5040	Mamu*
2140	Gbako*	6020	Ofiki/Ogun*
2150	Small Rivers	6040	Omi/Ondo
2160	Gurara	6050	Oshun*
3010	Kilange*	6060	Omi
3020	Moyo Ine	6080	Osse*
3030	Hawal*	7010	Aloma*
3070	Mayo Belwa*	7020	Aya*
3110	Taraba Upper Basin*	7030	Abo Ine*
3120	Suntai	8140	Yedseram
3140	Donga*		

Note: Stations with * are recommended to be installed by 2000 for early implementation of projects.

TABLE 3C-9 LIST OF HYDRO-METEOROLOGICAL GAGING STATIONS

Station	I	II	III	IV	V	VI	VII	VIII	Total
1. Rainfall									
- BRCP	4	4	6	2	2	2	2	1	23
- Existing Dams	5	5	3	-	-	3	-	4	20
- Priority SHAs	2	9	7	4	4	5	3	1	35
- Supplement	106	190	122	78	107	252	71	145	1,071
Total	117	208	138	84	113	262	76	151	1,149
2. Evaporation									
- BRCP	4	4	6	2	2	2	2	1	23
- Existing Dams	5	5	3	-	-	3	-	4	20
- Priority SHAs	-	-	-	-	-	-	-	-	-
- Supplement	2	3	5	2	1	5	3	2	23
Total	11	12	14	4	3	10	5	7	66
3. River Discharge									
- BRCP	4	4	6	2	2	2	2	1	23
- Existing Dams	15	25	16	10	9	26	10	19	130
- Priority SHAs	9	20	16	12	8	10	8	1	84
- Supplement	11	3	7	-	44	43	64	25	197
Total	39	52	45	24	63	81	84	46	434
4. Sediment Discharge									
- BRCP	4	4	6	2	2	2	2	1	23
- Existing Dams	5	5	3	-	-	3	-	4	20
- Priority SHAs	2	9	7	4	4	5	3	1	35
- Supplement	-	-	-	-	11	9	19	6	45
Total	11	18	16	6	17	19	24	12	123

TABLE 3C-10 **IMPLEMENTATION SCHEDULE OF HYDRO-METEOROLOGICAL NETWORK**

- Unit: Nos. of Stations -

Station	Total	1996 - 2000	2001 - 2005	2006 - 2010	2011 - 2015	2016 - 2020
Rainfall Station						
- BRCP	23	23	-	-	-	-
- Existing Dam	20	20	-	-	-	-
- Priority SHA	35	20	15	-	-	-
- Supplement	1,071	-	270	270	270	261
Total	1,149	63	285	270	270	261
Evaporation Station						
- BRCP	23	23	-	-	-	-
- Existing Dam	20	20	-	-	-	-
- Priority SHA	-	-	-	-	-	-
- Supplement	23	-	23	-	-	-
Total	66	43	23	-	-	-
River Discharge Station						
- BRCP	23	23	-	-	-	-
- Existing Dam	130	20	110	-	-	-
- Priority SHA	84	20	18	18	17	11
- Supplement	197	-	50	50	50	47
Total	434	63	178	68	67	58
Sediment Discharge Station						
- BRCP	23	23	-	-	-	-
- Existing Dam	20	20	-	-	-	-
- Priority SHA	35	20	15	-	-	-
- Supplement	45	-	12	12	12	9
Total	123	63	27	12	12	9
Grand Total	1,772	232	513	350	349	328

FIGURE 3C-1 TRENDS OF ANNUAL RUNOFF OF THE NIGER RIVER

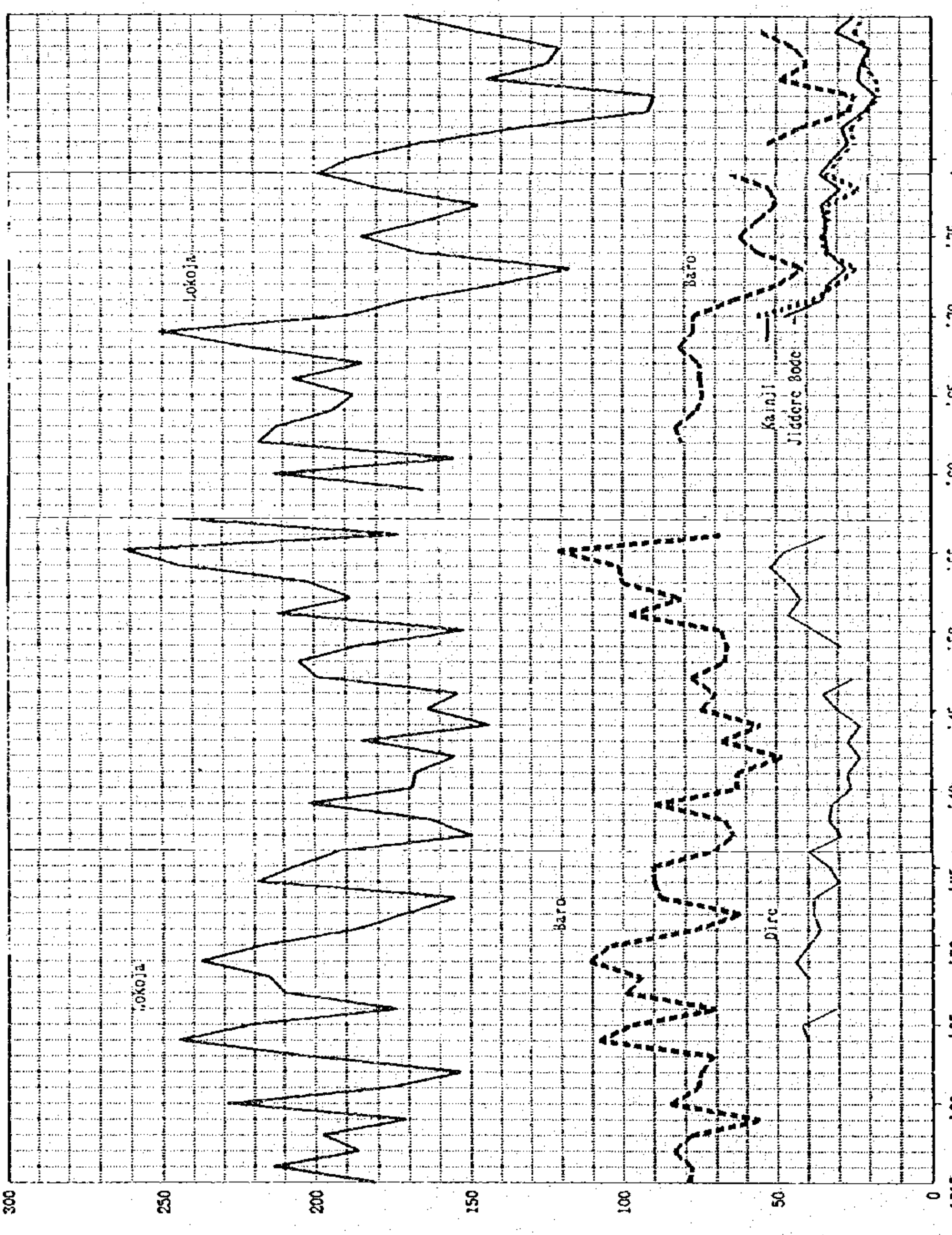


FIGURE 3C-2 TRENDS OF ANNUAL RUNOFF OF THE BENUE RIVER

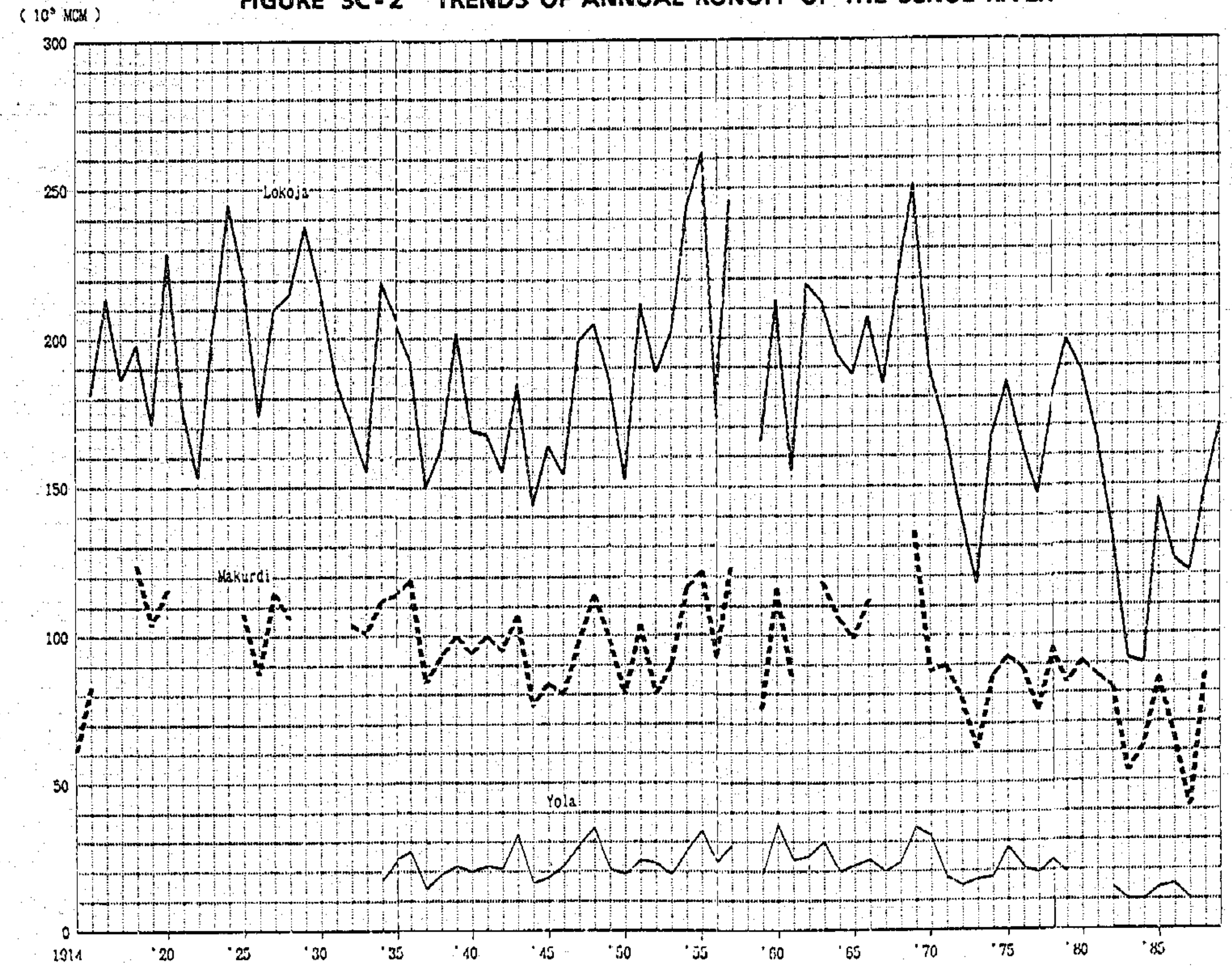
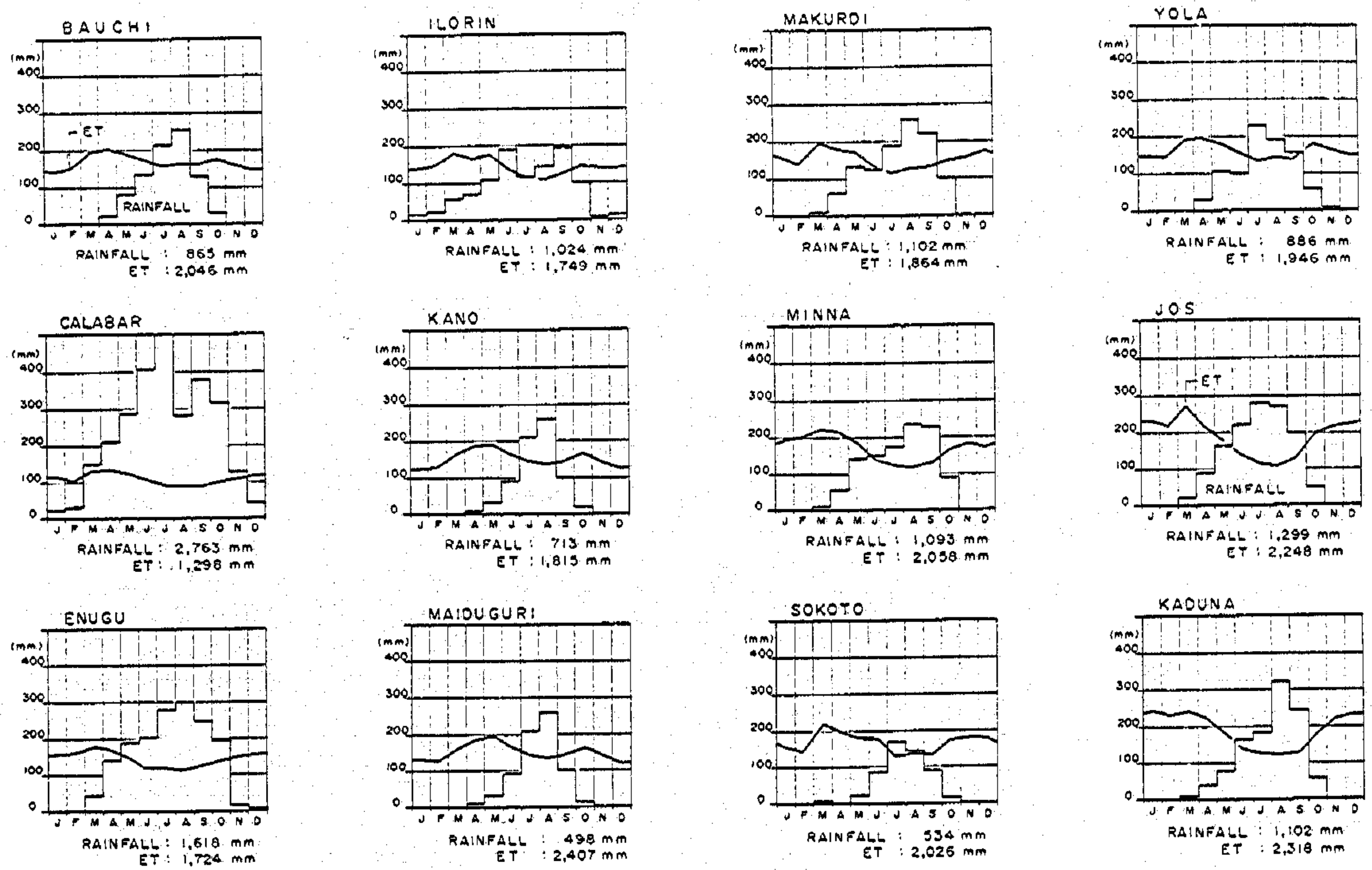


FIGURE 3C-3 CLIMATIC WATER BALANCE AT SELECTED STATIONS



PART 3D GROUNDWATER RESOURCES

3D. 1 JICA-NWRIS AND DATABASE

3D. 1. 1 Introduction

Groundwater has the following advantages as a water resource.

- The water quality is usually excellent.
- The investment required for exploitation is relatively small.

Compared to the water facilities using surface water as a water source, in the case of groundwater, users are very close to the water source. Therefore, it is enough to simply install a well equipped with a pump to act as a water delivery facility.

- It is easy to select the position of water delivery and utilization facilities.

The surface water extraction facilities must be mainly installed along rivers, that is, a linear restriction is placed on their locations. On the other hand, the groundwater facilities can be installed anywhere within the areal expanse of aquifers, thereby providing an infinitely greater choice of possible water extraction sites.

- There are not so many seasonal restrictions on water extractions.

Even in a dry area where a great part of the surface water dries up at the end of the dry season, groundwater can be extracted. In places where surface water cannot be easily obtained or the water quality is poor or in villages where large quantities of water are not needed, groundwater has long been extensively used because of the above mentioned advantages. Even now groundwater development is being promoted to a great extent. Upon execution of this NWRMP in Nigeria, special emphasis was placed on the collection of data related to groundwater, particularly collection of data required to understand the present situation of groundwater utilization and the nature of groundwater resources in NWRIS.

3D. 1. 2 Existing Borehole Wells

(1) Dimensions and Distribution of Borehole Wells

(a) Number

Table 3D-1 shows the results of NWRIS. The number of borehole wells in the entire country totals 23,234. The number of wells separately obtained in the water supply sector is 27,026 as is explained in Tables 6.1, 6.3 and para. 6.13 of Chapter 6 "Water Supply and Sanitation".

The difference in totals is attributed to the fact that different data sources were used to compile these figures and that the total number of wells in the water supply sector includes a number of large diameter, hand-dug wells that have been excluded from Table 3D-1. Information on the number of privately owned wells was not available for this Study, and therefore these wells are not included in Table 3D-1.

The number of borehole wells in each Region is shown below:

Number of Wells in Region

Region	States Included	No. of Wells	Percent
North-West	Kebbi, Sokoto, Katsina	5,322	22.9
North-East	Kano, Jigawa, Yobe, Borno, Bauchi	6,764	29.1
Central-West	Kawara, Niger, Kaduna, Kogi, F.C.T	3,341	14.4
Central-East	Adamawa, Taraba, Plateau, Benue	2,641	11.4
South-West	Oyo, Ogun, Oshun, Lagos, Ondo, Edo, Delta	4,081	17.6
South-East	Anambra, Imo, Rivers, Enugu, Abia, Akwa-Ibom, Cross River	1,085	4.7
	Total	23,234	100.0

The number of wells in eight States of the North Region is 12,086, and these States contain the majority of wells making up 52 percent of the total. As is seen above, the number of borehole wells in the north dry area represents a high percentage which clearly shows the importance of groundwater. In the North Region, groundwater is not only used as a domestic water source but also large quantities are used by livestock and agricultural activities in the dry season.

This North Region has a drought-prone environment. The then FMWR prepared a report "Borehole Data Inventory and Pumping Test Analyses for Groundwater Development in Drought-Prone Area of Nigeria" and investigated the groundwater situation related to the borehole wells of 10 States in the North Region. The number of borehole wells is almost the same as that of this inventory survey. The number of wells in the Central and South Regions is smaller than that in the above-mentioned North Region. This may be due to an increase in the use of surface water as rainfall increases as well as the diversification of water collection facilities such as spring water, dug wells, rain harvest, etc.. However, among these regions the South-West Region has high value in terms of both the number of wells and the percentage of wells in the entire country. Table 3D-2 shows borehole well density of a state basis. Lagos State has a remarkably high borehole well density among these states, followed by Osun State and North Region states.

(b) Depth

Among the borehole wells all over the country obtained in the inventory survey, the NWRIS adopted reported data related to depth and unconfirmed information which was considered to be appropriate in the case where no date was officially reported. Well depths were classified into four class ranges as shown in Table 3D-1.

The depth of a borehole well is closely related to geology. The well data on depth in some typical states by geology is shown below.

Sedimentary Formation Area

		>151m		101~150m		51~100m		50m>	
State	No. of Wells	No.	ratio	No.	ratio	No.	ratio	No.	ratio
Sokoto	1,622	82	5	350	22	700	43	490	30
Katsina	456	-	-	11	2	75	16	370	81
Kebbi	850	16	2	72	8	389	46	373	44
Total	2,928	98	3	433	15	1,164	40	1,233	42

Basement Complex Area

State	No. of Wells	>151m		101~150m		51~100m		50m>	
		No.	ratio	No.	ratio	No.	ratio	No.	ratio
Sokoto	450	1	-	4	1	75	17	370	82
Kebbi	187	-	-	1	1	26	14	160	86
Katsina	722	-	-	66	9	282	39	374	52
Jigawa	170	-	-	2	1	35	21	133	78
Total	1,629	1	-	73	5	418	27	1,037	68

Chad Formation Area

State	No. of Wells	>151m		101~150m		51~100m		50m>	
		No.	ratio	No.	ratio	No.	ratio	No.	ratio
Bauchi	100	14	14	7	7	41	41	38	38
Borno	716	525	73	35	5	139	19	17	2
Jigawa	1,079	2	-	45	4	559	52	473	44
Total	1,895	541	29	87	5	739	39	528	28

The wells in the sedimentary formation area are dispersed down to deep levels (101 to 150 m, >151 m), which shows that aquifers are relatively deep in this area. On the other hand, the majority of the wells in the basement complex area are as shallow as 50 m or less, which shows that the weathering layer near the surface acts as an aquifer. In the basement complex area this tendency is common all over the country. The wells in the Chad formation area are divided into two types: one is 100 m deep or less and the other is 150 m deep or more. These well depths indicate two different aquifer systems in this area. The distribution of the wells in Borno State clearly shows this tendency. The table below shows the well depth information in the South Region grouped into areas in which the oldest sediments are of Cretaceous Age and in area in which Quaternary Sediments are present.

Sedimentary Formation Area (Cretaceous and Tertiary Age)

State	No. of Wells	>151m		101~150m		51~100m		50m>	
		No.	ratio	No.	ratio	No.	ratio	No.	ratio
Enugu	125	102	82	11	9	11	9	1	1
Anambra	102	88	86	10	10	3	3	1	1
Imo	78	32	41	35	45	11	14	-	-
Total	305	222	73	56	18	25	8	2	1

Sedimentary Formation Area (Quaternary Age)

State	No. of Wells	>151m No.	>151m ratio	101~150m No.	101~150m ratio	51~100m No.	51~100m ratio	50m> No.	50m> ratio
Imo	145	20	14	36	25	89	61	-	-
Akwa-Ibom	195	23	12	67	34	70	36	35	18
Rivers	296	58	20	38	13	180	61	20	7
Lagos	1,219	161	13	43	4	110	9	905	74
Total	1,855	262	14	184	10	449	24	960	52

In areas where only Cretaceous and Tertiary Sediments are present the deep borehole wells predominate and indicates the existence of a deep aquifer. In Enugu and Anambra States the densely populated area are located in topographically high positions and this tendency is accentuated. In the areas in which Quaternary Sediments are present the borehole wells concentrate at a depth of 50 to 100 m in the regions along the Niger river or along the coast. Both regions consist of an unconsolidated layer and groundwater is recharged from rivers. These regions are rich in groundwater so that water can be extracted from shallow borehole wells. In these areas the deep borehole wells are those that supply water for industrial uses requiring large quantities of water.

(c) Water Table

The water table is the distance from the ground surface to the water level in a well. In the case of unconfined groundwater, it means the water level in the aquifer or phreatic level. In the case of confined groundwater, it means the pressure head. The water table has seasonal fluctuation, which is not taken into consideration in the following discussion.

The water table has a close relationship to the regional geology. The water table data in states grouped according to geology is as follows:

Basement Complex Area

State	No. of Wells	>31m		11~30m		10m>	
		No.	ratio	No.	ratio	No.	ratio
Sokoto	451	25	6	257	57	169	37
Katsina	635	24	4	434	68	177	28
Kebbi	183	7	4	74	40	102	56
Bauchi	256	2	1	59	23	195	76
Osun	829	-	-	2	0	827	100
Ondo	521	12	2	-	-	509	98
Total	2,875	70	2	826	29	1,979	69

As shown in this table, the water table is about 30m deep or less in the basement complex area where it exists in the weathered layer. Of the states in the basement complex area those in the South Region, namely, Osun and Ondo States, have water tables that are 10m deep or less. It is considered that this is due to the long rainy seasons and heavy rainfall in this area. The summary of the water tables in the sedimentary formation area in the North Region is shown in the table below.

Sedimentary Formation Area (North Region)

State	No. of Wells	>31m		11~30m		10m>	
		No.	ratio	No.	ratio	No.	ratio
Sokoto	1,592	721	45	590	37	281	18
Katsina	329	119	36	181	55	29	9
Kebbi	812	223	27	330	41	259	32
Total	2,733	1,063	39	1,101	40	569	21

The water tables in the sedimentary formation area display a trend that is opposite to that of water tables in the basement complex area. They concentrate at a depth of about 30 m or more. There is a high possibility that most of these deep water tables represent a pressure head of an aquifer located at a deep position. The table below shows water table data in the Chad formation area.

Chad Formation Area

State	No. of Wells	>31m		11~30m		10m>	
		No.	ratio	No.	ratio	No.	ratio
Borno	365	40	11	136	37	189	52
Bauchi	88	14	16	40	45	34	39
Jigawa	856	272	32	431	50	153	18
Yobe	291	27	9	39	13	225	77
Total	1,600	353	22	646	40	601	38

The trend of wells grouped by depth of water table varies in each state. It is considered that the Chad Basin where the Chad formation is distributed has three distinct aquifers and that most water is extracted from the upper aquifer except for the densely-populated urban areas. Judging from this phenomenon, the water tables of 30 m deep or less represent that of upper aquifer. The following table shows well grouping according to their water tables in the sedimentary formation area and quaternary sediment area in the South Region.

Sedimentary Formation Area (South Region)

State	No. of Wells	>31m		11~30m		10m>	
		No.	ratio	No.	ratio	No.	ratio
Enugu	46	41	89	4	9	1	2
Anambra	94	81	86	10	11	3	3
Imo	78	71	91	6	8	1	1
Total	218	193	89	20	9	5	2

Quaternary Sediments Area

State	No. of Wells	>31m		11~30m		10m>	
		No.	ratio	No.	ratio	No.	ratio
Imo	53	20	38	31	58	2	4
Akwa-Ibom	142	44	31	66	46	32	23
Rivers	169	1	-	60	36	108	64
Delta	144	14	10	21	14	109	76
Total	508	79	16	178	35	251	49

Most of the borehole wells have water tables of a depth of 30 m or more in the sedimentary formation area of the South Region. This means that the aquifer is deep as mentioned in the preceding paragraphs. It is thought that these water tables represent a pressure head. The water tables are shallow in the Quaternary sediment area, especially in Rivers and Delta States where they are 10 m deep or less.

(d) Water Yield

The water yield here refers to the results obtained from pumping tests. Water yield data was obtained from various sources. Where no reported yields were available, information was obtained from water uses and from estimates of well discharge rates. The results of the inventory survey by geology are shown below:

Basement Complex Area

State	No. of Wells	>101 ℓ/min		51~100 ℓ/min		50 ℓ/min>	
		No.	ratio	No.	ratio	No.	ratio
Sokoto	444	93	21	75	17	276	62
Katsina	659	178	27	82	12	399	61
Osun	877	18	2	11	1	848	97
Ondo	511	3	1	14	3	494	97
Total	2,491	292	12	182	7	2,017	81

The water yield in the basement complex area is 50 ℓ/min or less and most yield values are difficult to obtain. The following table shows a distribution of wells according to yield in the sedimentary formation area of the North Region.

Sedimentary Formation Area (North Region)

State	No. of Wells	>101 ℓ/min		51~100 ℓ/min		50 ℓ/min>	
		No.	ratio	No.	ratio	No.	ratio
Sokoto	1,258	953	76	91	7	214	17
Katsina	310	88	28	46	15	176	57
Kebbi	816	804	99	2	0	10	1
Total	2,384	1,845	77	139	6	400	17

The North West area of Nigeria consists of a sedimentary basin extending to the Republic of Niger where several aquifer layers or strata are observed. The table above shows that the wells with a relatively large yield of 100 ℓ/min or more are installed in these aquifers. A distribution of wells according to yield in the Chad formation area distributed in the North East region is as follows:

Chad Formation Area

State	No. of Wells	>101 ℓ/min		51~100 ℓ/min		50 ℓ/min>	
		No.	ratio	No.	ratio	No.	ratio
Borno	527	414	79	70	13	43	8
Yobe	277	44	16	12	4	221	80
Jigawa	929	127	14	452	49	350	38
Total	1,733	585	34	534	31	614	35

The proportion of wells grouped by water yield varies from state to state and this yield result does not show a clear trend well yields in the sedimentary formation area of the Central Region as shown below. The majority of the wells have yields of 50 ℓ/min or less in any state and it is concluded that yields in this area are relatively small.

Sedimentary Formation Area (Central Region)

State	No. of Wells	>101 ℓ/min		51~100 ℓ/min		50 ℓ/min>	
		No.	ratio	No.	ratio	No.	ratio
Bauchi	895	266	30	90	10	539	60
Benue	277	-	-	-	-	227	100
Niger	283	86	30	37	13	160	57
Total	1,405	352	25	127	9	926	66

Well yields in the sedimentary formation area of the South Region are as follows:

Sedimentary Formation Area (South Region)

State	No. of Wells	>101 ℓ/min		51~100 ℓ/min		50 ℓ/min>	
		No.	ratio	No.	ratio	No.	ratio
Enugu	119	114	96	2	2	3	3
Anambra	72	72	100	-	-	-	-
Imo	77	75	97	2	3	-	-
Total	268	261	97	4	1	3	1

The majority of the wells have yields of 100 ℓ/min or more and the groundwater yield is generally considered to be large. Yields of the wells in the Quaternary sediment area are as follows;

Quaternary Sediments Area

State	No. of Wells	>101 ℓ/min		51~100 ℓ/min		50 ℓ/min>	
		No.	ratio	No.	ratio	No.	ratio
Imo	108	104	96	4	4	-	-
Akwa-Ibom	76	74	97	-	-	2	3
Rivers	105	105	100	-	-	-	-
Total	289	283	98	4	1	2	1

The majority of the wells have yields of at least 100 ℓ/min in the Quaternary sediment area and the groundwater yield is generally considered to be large.

3D.1.3 Database

The geological information is added to the results grouped according to LGAs obtained in NWRIS and is shown as the borehole condition on state and LGA basis in the Water Resources Inventory Survey. The well density is also presented according to LGAs as shown in the Water Resources Inventory Survey in the same way. Furthermore, the following maps have been prepared based on the NWRIS and the data obtained in the field survey and are incorporated in the Water Resources Database Maps.

- Hydrogeological Map (1/4 - 4/4)
- Well Depth and Water Level Map on LGA Basis (1/4 - 4/4)
- Well Density Map on LGA Basis (1/4 - 4/4)
- Groundwater Potential Map

3D. 2 HYDROGEOLOGICAL AREAS (HGAs)

3D. 2. 1 Division of Hydrogeological Areas

Nigerian geology can be roughly divided into two units; the basement complex area composed of crystalline rocks and the sedimentary formation area. The basement complex area is distributed in a block in the North Central area, South West area, and East area corresponding to the border with the Republic of Cameroon. The sedimentary formation area lies in the North West, North East and South Central Regions of Nigeria and form seven large basins. The sedimentary formation area is distributed in belts along the Niger and Benue rivers, thickly overlying the basement complex thereby separating adjacent regions of basement complex.

These geological distributions can be divided into the following eight regions as hydrogeological areas according to the geology, basin and aquifer occurrence and nature. Those results are shown in Figure 3D-1. Hydrological areas are also shown in Figure 3D-1.

Hydrogeological Areas

Region	Area (km^2)
1. Sokoto Basin Area (Sokoto Sedimentary Area)	63,700
2. Chad Basin Area (Chad Sedimentary Area)	120,400
3. Niger Basin Area (Upper Niger Sedimentary Area)	38,300
4. Benue Basin Area (Benue Sedimentary Area)	116,300
5. South Western Area (Ogun/Osun Sedimentary Area) 6. South Central Area (Lower Niger Sedimentary Area)	110,300
7. South Eastern Area (Cross River Sedimentary Area)	29,700
8. Basement Complex Area (Crystalline Rock Area)	445,100
Total	923,800

3D. 2. 2 Features of HGAs

(1) Sokoto Basin Area

The Sokoto Basin shows an exposed successions of sedimentary beds running from north to south with lower layers in the east and upper layers in the west. The sequence is composed of six main sedimentary formations; i) The lowermost Gundumi Formation is an unconfined aquifer in the North East area and receives recharge from rainfall and rivers. The specific capacity of existing boreholes averages 57 m^3/day/m, and represents a good aquifer, ii) The Illo Formation is inter fingered with the Gundumi Formation and is distributed in the southwest area of Sokoto State. The nature of this aquifer is the same as that of the Gundumi Formation, iii) The Rima Group is divided into three formations and sandy portions of the lowermost Taloka and the uppermost Wurno formation are aquifers. Aquifers in this group show low specific capacities of 3 to 20 m^3/day/m in the North area of Sokoto city but show a good specific capacity of 23 to 63 m^3/day/m in the South area. However, the water table is low and the water quality is poor in both areas, iv) The Dange Formation in the lower order of the Sokoto group is an aquiclude. The upper-order of Kalambaina Formation is an unconfined aquifer in this region and a lot of springs and lakes are distributed along hills composed of this formation, v) The Gwandu Formation is a sediment of Tertiary age and is divided into three layers. Sandy portions in the uppermost and lowermost order form unconfined and confined aquifers, respectively. The specific capacity of this formation is 50 to 100 m^3/day/m and it is a good aquifer, vi) The wetland of Sokoto and Rima rivers corresponds to the Quaternary sediment. The groundwater is utilized by means of shallow wells. In summary, the main aquifers of the Sokoto basin are classified into four groups which are, from top the upper portion of the Gwandu formation (first aquifer), the lower portion of the Gwandu Formation (second aquifer), the Wurno and Taloka Formations (Third aquifer), and the Gundumi and Illo Formations (fourth aquifer). The Sokoto groundwater basin composed of these aquifers forms a monocline structure toward northwest.

(2) Chad Basin Area

The Nigeria sector of the Chad Basin accounts for only 6.5 percent of the entire hydrographic Chad Basin. The Chad Formation occupies the uppermost order of the sequence of the formation composing the Chad Basin.

The Chad Formation consists of a succession of clays, sandy clays and silts in which beds and lenses of sand and gravel occur at various levels. There are three distinct aquiferous zones particularly in the Maiduguri area namely: the Upper, Middle and Lower aquifers. The Upper aquifer consists of quaternary deposits (alluvium) which overlie the entire basin except at the outcrop areas of the basement complex rocks. The thickness generally varies from about 30-100 m but locally may be up to 180 m. The yields from the upper aquifer vary between 0.2 to 5 ℓ/sec.

The Middle aquifer is composed of a mass of a few meter to 30 m thick sandy horizons and is located from about 150 m below the ground surface. It is the most extensively used aquifer in the basin and has suffered greater head decline than any other aquifer. Many of the boreholes penetrating this aquifer have been allowed to flow uncontrolled thereby adding to the wastage of the resource. The unit exhibits both artesian and subartesian conditions with artesian conditions particularly prevalent in the area east and north-east of Maiduguri. Free flow yield initially ranged from 21 ℓ/min with 5.5 m head to 204 ℓ/min with 15.2 m head.

The Lower aquifer is about 100 m thick and has been identified in the Maiduguri area with the horizon between 450 and 700 m below ground level. It was thought to be limited to this area but logs of boreholes drilled in recent years have shown that it extends eastwards of Maiduguri to New Mart. The artesian head is between three and six meter above the ground surface with yields of between 2 ℓ/sec and 25 ℓ/sec. Owing to the declining yield of the Middle aquifer in recent years, the Lower aquifer is now of increasing importance in groundwater exploration within Maiduguri metropolis. The trend in decline in abstraction rates and in the water table and piezometric surface in the Middle and Lower aquifers is not encouraging and appropriate steps should be taken to avoid irreversible damage to the aquifer.

(3) Niger Basin Area

The Niger Basin has three important water bearing zones namely Bida sandstone, Nupe sandstone and Alluvium. The Bida soundstone has a yield of 48 - 150 ℓ/min with specific capacity of 17 - 26 m^3/day/m. The Nupe sandstone has a yield of 42 - 300 ℓ/min with specific capacity of 120 - 860 m^3/day m. The Alluvium has a thickness which ranges from a few meters to 30 m. It is the most prolific aquifer with a yield of 450 - 2,200 ℓ/min.

(4) Benue Basin Area

The Benue Basin is popularly referred to as the Benue Trough in view of its tectonic evolution. The Benue Trough consists of a number of sub basins and could be subdivided into Upper and Lower Benue Basins. The Upper Benue Basin occupies the upper reaches of the Benue Trough. In the stratigraphical succession of this basin, the major aquiferous formations are Bima sandstone, Yolde and Gombe sandstone, but the yield is believed to vary considerably with the location. The yield ranges are estimated to be 60 - 480 ℓ/min, 114 - 300 ℓ/min, 90 - 408 ℓ/min, respectively.

The Lower Benue Basin is geologically related to the Upper Benue Basin described above. The multi-layer sandstone beds of the formation constitute good aquifers but are usually contaminated by brines from the interbedded shale. Potable water could be obtained from boreholes in this area if the saline horizons are properly identified by geophysical logging and consequently cased off. The most important aquifers in the lower Banue Basin are the Makurdi and Ezeaku formations and possibly the Keana sandstone. Borehole success in the Makurdi formation is a chance event and it is advisable that drilling should be preceded by systematic survey of the area of interest. In comparison with the other basins, there has been little groundwater exploration in this basin.

(5) South Western Basin Area

The South Western Basin consists of Cretaceous, Tertiary and Quaternary sediments deposited in a coastal basin. The major formations are Abeokuta, Ewekoro, Iloro and coastal plain sand. The Abeokuta formation is an extensive and prolific aquifer and is underlain by the basement complex. The groundwater is confined in the Lagos area where it reaches a target depth of 600 m below surface (Agagu 1994). On the other hand, in the unconfined area, depth to water table varies from 30 to over 100 m. The aquifer is heavily exploited at Ikeja area where one borehole has yielded over some eight years, a quantity of water in the region of 14 MCM without change of pressure head (Basil & Associates, 1980). The coastal plain sands and alluvium constitute the main aquifer and heavily exploited for domestic, industrial and institutional water needs particularly in the Ikeja area. The aquifer is essentially phreatic and depth to water table varies from a few meters to about 150 m.

(6) South Central Area

The South Central (lower Niger) area is sometimes referred to as the Niger Delta Basin and consists of Tertiary and Quaternary sediment. A very important aquifer in this basin is the Benin Formation which is thick and extensive and consists of coastal plain sands with a few clay layers. Another important aquifer is the Alluvium containing shallow occurrences of groundwater and consists of gravels, sand and clays. With the potential problem of saline intrusion near the surface, the wells need to be drilled to 300 m or more to reach fresh water. Boreholes tapping the aquifers of the Benin Formation have high yields with little drawdown and an average specific capacity of 650 cu.m/day/m.

(7) South Eastern Area

In the South Eastern area the Anambra Basin is underlain by Cretaceous sediments of which the false-bedded Ajali sandstone is the dominant formation. There also exist sandstone and coal seams of the Nsukka and Mamu Formations. The Ajali sandstone aquifer is overlain by the impervious shale of the Imo Shale Group and Nsukka Formation to the southwest where deep boreholes meet artesian and subartesian conditions. A borehole at Uzouwani, 24 km north of Umumbo (some 50 km west of Enugu), intercepted the Ajali Formation at about 180 m below ground level and produces a free flow of 33.7 ℓ/sec from an uncontrolled borehole (M.E. Offidile, 1992). A number of perennial springs issue from the base of the Ajali sandstone on the Enugu Escarpment at the contact with the Lower Coal Seam. Recharge of the aquifer is at its outcrop area around the Iclah-Nsukka-Enugu Escarpment.

The Cross River Basin on the other hand is underlain by dominant shale groups in straligraphical succession. There are Cretacious shale groups that outcrop in the eastern part of the basin.

Generally, groundwater potential is low in the Cross River Basin as obtaining exploitation is a chance even being limited to the sandstone lenses of the shale group particularly the Ezeaku and Nkporo which can best be mapped by geophysical surveys. Depth to water table is shallow, usually less than 25 m.

(8) Basement Complex Areas

In the basement complex rocks areas, groundwater occurrence is limited to fractured, fissured and brecciated zones. In the northern states, which is the approximate demarcation of the drought-prone areas of the country, reliance on groundwater for domestic and small scale irrigation is heavier in this region than in other parts of the country. Unfortunately, most of the area is covered by basement complex rocks and in spite of the poor hydrogeological characteristics of this formation it is still a major source of potable water supply. Many wells and boreholes penetrate the basement complex especially in Kano and Oyo States. The weathered mantle and the fracture zone have formed moderate to good aquifers in many localities which have been extensively exploited in these states. In the basalt of the Jos Plateau area, many productive boreholes have been drilled into ancient river valleys that have been covered by lava flows. The depth of burial and quality of the underlying rock and its degree of weathering are salient points in groundwater investigation in the basement complex. The average yield from basement complex aquifers ranges between 45 and 108 ℓ/min (David and Dewiest report, 1970), but very high yields of up to 240 ℓ/min can be attained in fractured and deeply weathered locations. Depth are usually a few meters or tens of meters but rarely reach 100 m.

3D. 2. 3 Groundwater Quality

Groundwater quality is generally good. In some areas iron, nitrate or fluoride concentrations exceed the WHO recommended standards for potability. Using pH as an index of corrosion potential, about 20 percent of the country is underlain by highly corrosive groundwater with pH less than 6.5, 40 percent by moderately corrosive groundwater with pH ranging from 6.5 to 6.8 and 40 percent by noncorrosive groundwater having pH exceeding 6.8. The corrosiveness is important for choosing appropriate materials for water supply equipment. Groundwater quality in the vicinity of mine is often degraded by the mining activity, resulting in low pH condition and abnormally high concentration of some metals. Water of very low pH, as with mine water, carry high concentrations of ferric and ferrous ions. Ferrous ions remain stable under this condition and will oxidise to ferric at high pH and be precipitated as ferric hydro-oxide. Above a pH of 5, abundant aluminum ions are absent in solution. Some mine waters with a pH below 4 are known to have several hundred to several thousand mg/litre of Aluminum. Magnesium ions are mostly precipitated above pH of 10.5.

At the Onyeama Coal mine, groundwater in contact with the Coal bearing Mamu Formation, has a pH of between 4 and 5, in contrast with a pH of 6 to 7 for water passing through the sandstone of the Ajali Formation only. The high acidity is attributed to the sulphide minerals associated with the coal. (Offodile 1992)

Furthermore, saline groundwater is observed in the Central and South regions. It is observed in the Lower Benue Trough in the Central Region and occurs when groundwaters encounter saline beds in the thick sedimentary formation. In many place of Benue and Plateau States saline groundwater occurs in deep wells. A lot of borehole wells are abandoned because of salinity problems. Another problem is saline groundwater obtained in coastal aquifers. It is evident that this is due to an intrusion of seawater penetrating deeply into the coastal aquifer as a result of an excessive pumping. Some shallow wells of the villages contain high concentrations of chloride and nitrate and it is clear that these wells are exposed to artificial contamination.

3D. 3 Potential Groundwater Resources

3D. 3. 1 Hydrogeological Mapping

The hydrogeological map at 1:2,000,000 scale as attached has been prepared in accordance with the mapping results of major geological structures based on Satellite image interpretation. The followings are the major objectives of the mapping work:

(1) Selection of a region which is assumed to have a high groundwater potential in the basement complex area.

i) It is assumed that faults and fractures have developed and weathering is observed deep inside the high potential area of groundwater. Judging from this assumption, a regions was selected where an observed lineament in the basement complex area of the geological structure map concentrates and indicated it as a high potential area.

ii) Generally, there is a heavy rainfall and both temperature and humidity are high in the South Region. Therefore, both depth and degree of weathering in the basement complex area are great compared to the North Region. From this fact the South Region can be expected to have a higher groundwater potential than North Region.

iii) The basement complex are can be divided into the following four major suites.

- Younger granites (Jurassic Age)
- Older granites (Pre Cambrian Age)
- Meta sediments including quartzite (Pre Cambrian Age): common in Eastern Nigeria
- Gneisse and migmatite (Pre Cambrian Age)

The hydrogeological correlation with these major suits is not clear, but according to certain data quartzite and granite are thought to have a higher groundwater potential than other major suites.

iv) Selection of the areas covered by volcanic rocks

River channels covered by alluvial sediments have been further overlain by volcanic rocks of later age in Jos Plateau. Those areas are limited in extent and are believed to be of high groundwater potential.

(2) Sedimentary Formation Area

In the terrain underlain by sedimentary rocks, target areas high in groundwater potential are selected on the basis of the results of past boreholes which encountered aquifers. The target areas are shown on the hydrogeological map.

3D. 3. 2 Evaluation of Groundwater Resource

The total amount of groundwater G is expressed by the following equation:

$$G = GO + GR - GD$$

Where,

GO: Initial groundwater resources,

GR: Total quantity of groundwater recharge including rainfall and recharge from surface water bodies,

GD: Total quantity of groundwater outflow and consumption.

In a stable groundwater region GR is equal to GD. GD, the outflow, is considered to be stable extractable groundwater reserve. Actually, the primary groundwater reserves corresponding to GO also exist. The estimation of groundwater resources is made based on the typical hydrogeological unit area divided in geological areas. The groundwater resources in each hydrogeological area was estimated on the basis of annual rainfall and permeability. The annual mean rainfall was obtained from the rainfall contour map prepared on the basis of an average annual rainfall in a 10 year period from 1980 to 1989.

Originally, the permeability differs depending on various conditions such as the climate (especially, different degree of weathering caused by a difference of rainfall and temperature), topographic features, kind of rocks, compaction, size of particles composing unconsolidated sediment, etc. Therefore, an adjustment ration is adopted taking those conditions into consideration. As a results, the groundwater resources are estimated as 51,900 MCM as shown below. The study results for each hydrogeological unit are shown in the Appendix.

Potential Groundwater Resources

Lithology	Area (km^2)	Rainfall (mm)	Permeability (%)	Adjustment (Ratio %)	Groundwater Reserves $\times 10^6 m^3$
Basement C.	442,900	1,087	10	35	17,230
Sedimentary F.	480,900	1,019	18	39	34,700
Total	923,800	1,051			51,930

In Niger two previous nationwide estimate of groundwater resources have been made so far in 1978 and 1987. Estimated annual groundwater resources are 87,000 MCM in the 1978 report and 49,400 MCM in the 1987 report compared with 51,900 MCM in this report. Table 3D-3 shows groundwater resources by HA.

As the mean annual rainfall of Nigeria with the land area of 923,800 km^2 is 1,051 mm, the groundwater resources of 51,900 MCM is equivalent to

5.3 percent of the mean annual rainfall, or a recharge rate of 56 mm. This amount of recharge is considerably lower than the amount of recharge obtained in the local water balance study conducted by JICA in Sokoto State. However, taking into consideration of: the steep mountainous topography of the central and eastern areas (in the basement complex area) of the Central Region; the high proportion of surface water runoff, predicted from the widely developed inselbergs; the thick widespread distribution of low-permeability silt and clay terrain along the Cross river from the lower Benue river basin, etc., it is thought that the amount of recharge obtained in this study is not an unreasonable value. Previous estimates of the amount of groundwater have produced a wide range of results. A better value ought to be obtained through repeated local water balance studies based on actual aquifer properties observed in many hydrogeological areas. It is expected that the hydrogeological data necessary for these studies will be improved and an estimation of higher accuracy can be made in the future.

3D. 3. 3 Groundwater Resources in Regional Areas

(1) North West Region (HA-I, Sokoto-Rima River Basin)

The total amount of groundwater is 4,300 MCM (33,000 m^3/km^2), which is rather small because the basement complex area of this river basin accounts for 50 percent of the catchment area, the rainfall is small, and the amount of recharge is also small. In the alluvium area near Sokoto City the amount of groundwater per unit area is 46,000 m^3/km^2, which is larger than the average of the basin.

(2) North East Region (HA-VIII, North East Region)

In this river basin the sedimentary formation account for 70 percent of the catchment area, but the rainfall is small and the total amount of groundwater is as small as 5,600 MCM (30,000 m^3/km^2).

(3) Central West Region (HA-II, Niger River Basin)

The basement complex area accounts for 75 percent of this region, the rainfall is large, and the alluvium along the Niger River has a large recharge

(93,000 m^3/km^2). Therefore, the groundwater volume is 8,200 MCM m^3 (52,000 m^3/km^2) in the entire river basin.

(4) Central East Region (HA-III, Upper Benue and Lower Benue River Basin)

The upper Benue river basin is occupied by the mountainous region along the Cameroon border. Both basement complex and sedimentary formation areas are composed of massive rocks. The weathering layer is thin and the groundwater volume is estimated as 7,000 MCM (44,000 m^3/km^2), which is relatively small.

In the lower Benue river basin the sedimentary formation is widely distributed and the alluvium is well developed. The unit groundwater volume is 60,000 m^3/km^2, which is larger than the upper river basin.

(5) South West Region (HA-VI, South West River Basin)

The basement complex areas account for about 60 percent of this region. In the south area an unconsolidated sedimentary formation of high permeability is present and its unit groundwater volume is 146,000 m^3/km^2, which is remarkably high. Therefore, the total amount of groundwater in the entire south west river basin is as high as 9,000 MCM.

(6) South East Region (HA-V and VII, Lower Niger and Cross River Basin)

The majority of this river basin is composed of sedimentary formations. Along the Niger River the Quaternary sediment and delta deposits of an unconsolidated sedimentary formation are widely distributed. The rainfall is heavy and the groundwater volume is as large as 13,400 MCM.

3D. 3. 4 Groundwater Potential Map

The results of groundwater resources estimations in the project area are shown in the Groundwater Potential Map at 1 to 4 million scale as attached in the separate volume "Database Maps". To use this potential map, it is necessary to fully understand that an occurrence of groundwater is locally variable even in the same aquifer so that groundwater does not necessarily exist uniformly in the entire hydrogeological area.

3D. 4 CURRENT STATUS OF GROUNDWATER EXPLOITATION

Many governmental agencies are currently involved in the drilling of water supply wells. The following is a list of the major agencies:

- Federal Ministry of Water Resource and Rural Development and their Field Offices
- Federal River Basin Authorities
- State Ministries of Agriculture and Natural Resources or Water Resources
- State Water Agencies
- Directorate of Food, Road and Rural Infrastructure (DFRRI)
- United Nations International Children's Emergency Fund (UNICEF)
- Japan International Cooperation Agency (JICA)

Table 3D-4 shows the breakdown of information in 1990 of the total number of boreholes operated by the respective agencies in the respective states. The National Borehole Programme (NBP) has been conducted by the FMWR since 1981. According to the 1992 report 860 boreholes were drilled. However, in most of these boreholes the installation of the equipment such as generating sets, submersible pumps, elevated storage tanks, etc., necessary for the borehole well function made slow progress. In the 1991 programme an emphasis was placed on the installation of these facilities and an effect was made to speed up the completion including rehabilitation of broken down/vandalized sites. The 1991 completion/rehabilitation of NBP summarization is shown below:

Rehabilitation of NBP

S/No.	Item of Works	Quantity Supplied
1	Generators	85
2	Submersible Pumps	57
3	Elevated Tanks	44
4	New Boreholes Drilled	2

In 1986 the DFRRI was established to energetically install rural water supplies. Table 3D-5 shows the number of sites by state in Phase I and II. This number includes handdug wells at 7,347 sites. Various types of wells are adopted depending on the number of persons who will use the water, the situation of occurrence of groundwater, etc. An example of Benue State is shown below:

Types of Wells and Their Percentage in Benue State

No. of Site in Phase I and II	Man-power Operated Well	Man-powered Hand Pump	Borehole Drilled Hand Pump	Motorized Minischeme	Rain Harvest
541 Sites	247	2	159	132	1
100 %	45.7	0.4	29.4	24.4	0.2

The man-powerd wells are manually operated with diameters of three to four feet and depth generally less than 50 feet. The type of hand pump in operation is mostly the India Mark II model.

3D. 5 PRESENT PROBLEMS AND NEEDS

3D. 5. 1 Lack of Investigation before Drilling

Groundwater can be secured throughout the year even in dry areas of the North Region and can be used as potable water without special treatment. Since it is obtained relatively easily, groundwater development is extensive and has long history in the North Region. However, because rainfall is small in this region and the amount of recharge is also small, there are often dry wells. It is reported that the success rate of borehole drilling in the basement complex area is 63 percent in Adamawa State, 74 percent in Jigawa State, and 63 percent in Taraba State. The success rate obtained from the DFRRI is almost the same value. Furthermore, shallow wells may dry up in the dry season. For this reason, some places need deeper wells. It is necessary to abstract groundwater from a prolific aquifer in order to secure a stable groundwater supply in the sedimentary formation area. For this reason, in addition to a geological survey, effective investigations such as geophysical surveys are required to determine borehole drilling sites with a high success rate.

Furthermore, it is essential to conduct pumping tests without fail after drilling to clarify aquifer properties. This will provide important data not only to determine the capacity of the submersible pumps to be installed but also to promote subsequent groundwater development.

3D. 5. 2 Deterioration of Groundwater Quality

In the South-Western and South-Central Hydrogeological areas large amounts of groundwater are extracted because the coastal plain sand and alluvium form a very good aquifer and the domestic, industrial and institutional water demand is high. For this reason, in a region where groundwater is pumped up in large quantities problems of saline groundwater have arisen due to an intrusion of seawater. In Ikeja and Apapa areas where this problem is prevalent, deeper drilling is conducted to obtain fresh water. Even in coastal areas of Lagos State the groundwater abstraction is thought to be nearly critical in terms of quantity. An intrusion of saline water into the delta formation is also observed in coastal areas of Delta and River States. The continuation of such overexploitation will trigger a serious contamination problem of saline water in wells from which large amounts of water for domestic use are obtained. As a result of water quality analysis of a Nigerian well now in use, ammonium nitrate was found. There is no room for doubt that this is due to contamination of groundwater caused by an infiltration of surface water. It is possible to prevent this contamination of groundwater to a great extent through residents efforts to properly treat wastewater around a well and to maintain cleanliness, install a watering place for livestock, etc.

In addition, it is reported that nitrate nitrogen and nitrite nitrogen are detected in well water extracted from shallow aquifers in parts of southeastern Nigeria including Anambra, Imo, Akwa Ibom and River States (Egboka and Ezeonu 1990, Ojiegbe 1990). It is assumed that these substances originate from chemical fertilizers. the factors leading to such contamination, which are though to be caused by man, should be analyzed at an early stage of the NWRMP study and appropriate countermeasures should be taken at the earliest.

3D. 5. 3 Lack of Monitoring Wells and System

It is believed that the groundwater table is lowering in the Chad and Sokoto basins and the following three reasons are given:

- Decrease in the amount of rainfall.
- Groundwater exploitation.
- Decrease in the amount of recharge from surface water due to the extraction of upstream water including the water storage, irrigation and so forth.

Data on the change of groundwater level give important clues to understand the condition and behavior of the aquifer system. Recharge of aquifers in the Sokoto basin is restricted and significant drawdown accompanies increased pumping rates. Further, in Chad basin, irrigation development is in progress along the Hadejia-Jama'are river and decreased groundwater recharge is feared. In this situation, the measurement of water table fluctuations over long periods is considered to be an important factor in deciding the future course of groundwater exploitation. Even though monitoring wells exist in this area, data are not collected regularly. Data collected from these wells in the past has already been lost.

At present, the North East Arid Zone Development Programme is in progress in cooperation with European Economic Community. This programme includes groundwater exploitation and irrigation development as well as the construction of schools and medical clinics. As it is necessary to obtain records of the change in water table for the above purpose, monitoring wells have been installed, and observations have been made for several years.

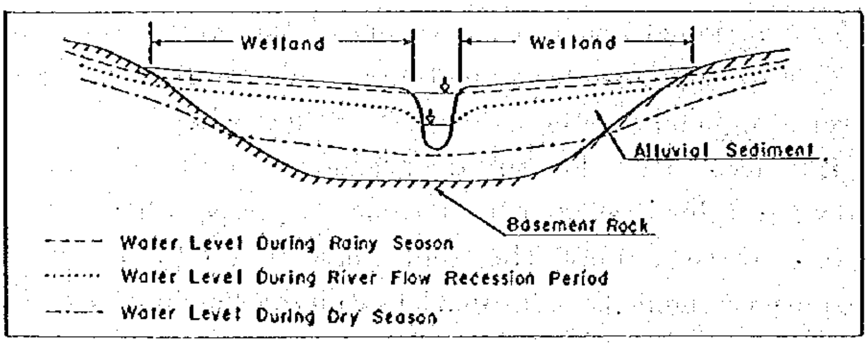
As mentioned above, observation of the water table condition is indispensable for groundwater exploitation, and installation of a monitoring system over a regional area is required. In Sokoto where there are numerous aquifers, it is necessary to identify the productive aquifer and to measure the change in water table in each. Also in Chad, respective water levels should be obtained in all three aquifers. The number of wells and their depths needed for the above purpose should be identified based on the distribution of the aquifers.

3D. 5. 4 Need for Well and Shallow Groundwater Behavior Observation

Fadama is seasonally water-logged or completely flooded land. Often called a stream-side Fadama or flood plain Fadama (Turner 1985). Fadama is in a river terrace in the Quaternary sediment area. Therefore, Fadama, especially flood plain Fadama is important for irrigation.

This Quaternary sediment is composed of gravel, sand and clay. The groundwater exists in the gaps between sediment particles and it is unconfined. Since this sediment is unconsolidated and has excellent permeability, it absorbs rainfall and flood waters of swollen rivers in a short time during the wet season so that the water table in the deposit rises sharply and the sediment is completely saturated with groundwater when it is flooded. Then, when the dry season sets in, the water level of the river drops and at the same time the groundwater disappears or decreases. The groundwater level in the dry season is almost the same as the water level of the river in the area surrounding the river. When the river dries up, the groundwater level along the river is completely below the riverbed. As a result the groundwater level of Fadama has a heavy seasonal fluctuation. The groundwater level in the direction at right angles with the direction of the stream drops slowly from the mountain toward the river. The subterranean water also runs from mountain toward the river and groundwater is always gushing out into the river.

On the contrary, if, for example, the water is discharged from an upstream dam in a dried up river and the water level of the river is higher than that along the river in Fadama, the river water ends up by infiltrating and flowing into the quaternary sediment and recharges the Fadama. The following figure shows the results above.



The development of shallow groundwater for small scale irrigation was initiated within the scope of the Agricultural Development Programme (ADPs) in the 1980s in many parts of the Northern States of Nigeria where rainfed agriculture is subject to periodic drought. A trial and error method was adopted and the flood plains of some the major rivers were found to be most promising. However, full scale Fadama agriculture was hampered by lack of reliable estimate of the areas with potential for exploitation of shallow groundwater. There were also no guideline establishing the quantity of water that could be safely extracted by suitable tubewells. In an effort to solve these problems, the World Bank founded studies on shallow groundwater potential of the Famada area in many states of Northern Nigeria which include Sokoto, Katsina, Kaduna, Bauchi and Kano. The studies were executed between 1985 and 1986 by the respective State ADP, under the contract with reputable consulting firms. As explained above, the data on the shallow groundwater potential and hydraulic properties of aquifers in Fadama areas was collected and greatly contributes to the development of Fadama.

However, the development did not have the intended effect due to lack of a basic investigations in many key areas that are required in selecting a drilling site. For instance, geophysical surveys should be conducted extensively to delineate the boundaries of potential Fadama areas and to assess specific sites within the areas. Exploratory drilling should also be undertaken where feasible. Groundwater hydrology and water balance and recharge estimates should be evaluated. Understanding of these aspects is fundamental to correct management of groundwater resources for intensive small-scale irrigation.

3D. 6 NWRMP TOWARDS THE YEAR 2020

3D. 6. 1 General Strategies and Priority

Nigeria is favored with abundant groundwater resources of high quality. The resources, estimated at about 52,000 MCM in total, are fully utilized in the country because groundwater has various advantages over other types of water resources. Groundwater is unevenly distributed depending on topographic and geologic factors. For the purpose of exploitation, it is necessary to locate places where abundant groundwater is expected in shallow prolific aquifers and then to determine favorable drilling sites. A balance between human activities and natural conditions must be taken into account for optimizing benefit of groundwater resource. Therefore careful management will be required in exploitation of the resources to avoid less of the balance between abstraction and natural recharge by limiting yield to a necessary amount. However in reality some problems arise, including a sharp drop of groundwater levels, infiltration of saline water, and deterioration of water quality. Problems in managing and preserving groundwater in Nigeria are as follows:

- Lack of a uniform policy for groundwater development.
- Inadequate investigation for determining drilling sites.
- Drop of groundwater levels and increasing salinity due to over exploitation.
- Lack of adequate monitoring systems for measuring fluctuation of water tables.
- Inadequate research and development for measures to increase the amount of recharge in dry areas.
- Inadequate data collection systems and lack of comprehensive databases.
- Lake of comprehensive studies of behavior of shallow groundwater in wetland (Fadama)

It is desired that immediate action against these problems be taken. The following three measures have the highest priority:

i) To activate the monitoring systems for measuring fluctuation of groundwater levels in the Chad and Sokoto-Rima river basins

ii) Installation of monitoring wells for measuring salinity of groundwater in Lagos and the rest of the coastal areas.

iii) Installation of monitoring wells for wetland irrigation.

3D. 6. 2 Groundwater Exploitation in Response to the Demand

Groundwater occurs in aquifers formed in strata or bed rocks and is limited in its yield for a unit time length. Therefore, maximum scales of groundwater development are dependent on geology of straits or bed rocks in which aquifers are formed. Yield generally range from 120 to 180 ℓ/min in the basement complex terrains and from 150 to 300ℓ/min in the sedimentary terrains excluding the Niger Delta and coastal plains of the South Region with exceptionally large yields. These yields are equivalent to demands of rural water supply with limiting uses of groundwater to domestic water.

Excluding the South Region, therefore, subjects of groundwater development should be confined to those related to rural water supplies including semi-urban water supplies in places. Besides, it is one of the essential subjects for management how to exploit groundwater in strata or bed rocks keeping abstractions in suitable levels for yields of relevant aquifers. For groundwater management, the following points must be taken into consideration.

i) Conducting effective investigation to improve success rates of drilling, ii) Carrying out a pumping test for every completed drillhole to determine and optimum yield. The pumping test particular, is essential in case that is abstracted from non-renewable confined aquifers in sedimentary terrains.

Groundwater supplies were often hampered in some places in Nigeria due to over exploitation. It is reported that a special emphasis has been placed on the importance of accurate estimation of available amounts of groundwater suitable for capacities of aquifers, and regulation and protection for groundwater supplies in Nigeria. This is apparently remarkable advances in the groundwater development policy of the country.

3D. 6. 3 Regional Groundwater Balance and Conservation

The 3D. 6 shows the comparison between supply and demand for groundwater resources at present and towards the year 2020 by SHA.

HA	Groundwater Resources (MCM)	Present		Toward Year 2020	
		Demand (MCM)	Water Use Rate (%)	Demand (MCM)	Water Use Rate (%)
I	4,340	20	0.4	290	7
II	8,180	20	0.2	260	3
III	6,990	15	0.2	300	4
IV	4,390	5	0.1	180	4
V	7,150	30	0.4	730	10
VI	9,020	70	0.8	830	9
VII	6,280	40	0.7	710	12
VIII	5,680	60	1.0	620	11
Total	51,930	260	0.5	3,920	8

The estimated demand for groundwater is about eight percent or 3,900 MCM against the total resources of 51,930 MCM.

The total groundwater resources are well above the demands toward the year 2020. Those with higher ratio of water use are in HA-V,VI and VII in the South Region and HA-VIII in the Lake Chad Basin. It must be, however, noted that the resources of HA-VIII are relatively small for its sizable demand.

Some SHAs in the Basement Complex terrains in the Northern Region indicate high water use rates for their relatively small resources. It may become difficult to maintain sufficient water supplies if their demands grow considerably.

Future prospects of groundwater supplies and demands may be anticipated as follows; as mentioned above, it will become difficult to maintain high water supplies in the Basement Complex terrains in the North Region.

- The Central Region indicates low groundwater use rates in general and has a good possibility for further exploitation. Hydrogeological investigation of this Region has been still very limited and should be accelerated as groundwater development advances.
- Groundwater use rates vary considerably from one SHA to another in the South Region, which suggests that a large amount of water is being abstracted in areas with prolific aquifers. However, careful groundwater management will be required in coastal areas where groundwater use rates are high and aquifers are vulnerable to sea water contamination.
- The table 3D-6 predicts the future groundwater demands and resources in each SHA and provides useful data for future groundwater development.

3D. 6. 4 Groundwater Exploitation by Region

(1) North-West Region (HA-I)

In this river basin, 5,320 borehole wells (Water Supply Sector) have been constructed. The number is the second largest next to that in the Lake Chad Basin. More than fifty percent or 2,760 of them are in the alluvial plain in Sokoto State. Annual groundwater supply capacity of entire wells in the region is only 20 MCM. This is because about 90 percent of wells are operated by hand pumps with pumping capacity of each well of 1.2 m^3/hour.

As mentioned above there are a great number of wells along the Rima river in Sokoto State and their water levels are beginning to drop due to overpumping. It is necessary to control groundwater utilization called for in this area. Goronyo dam may have caused decrease in river water that recharge groundwater in Sokoto City area. Changes in groundwater levels in this area should be watched by setting up a monitoring well.

Wetland is developed along rivers in Sokoto-Rima. In this area private irrigation is anticipated to expand, which will results in increase of shallow groundwater uses. Investigation of shallow groundwater is required.

(2) North-East Region (HA-VIII)

This region has been most extensively exploited for groundwater in the country because available surface water is scarce. The number of water wells is 6,760 accounting for 30 percent of wells in the country. Thirty percent of the wells are operated with mechanical pumps, and 70 percent with hand pump. While the capacities of wells in Kano State in the Basement Complex terrains operated with mechanical pumps, average at only about 12 m^3/hour for one well, average capacities for those in the alluvial plains of other states are estimated at around 22 m^3/hour for one well.

In Yobe State where many moderate wetlands are developed, an average capacity is as high as 40 m^3/hour for one well. Borno State, which has been best exploited for groundwater in the region, has 1,630 wells with an annual supply capacity of 21 MCM, which accounts for 35 percent of annual supply capacity of 58 MCM in the entire Region. Of these, 400 to 500 wells have been constructed to supply water for urban and rural water uses in Maiduguri. Those wells which have been constructed to deep aquifers to supply water to the Maiduguri Metropolis, are suffering from decrease in their capacities and drop in their water tables and pressure heads due to overabstraction. Accordingly, operation control for existing wells is required by setting up monitoring wells to monitor groundwater reservoir.

Since this region has few surface water sources as mentioned above, further exploitation of groundwater will be required. A careful study is needed because the groundwater yield is as small as 30,000 m^3/km^2 in the sedimentary formation area. Particularly in areas far from rivers, a careful investigation is required for location of wells and pumping plan since these areas are recharged only by rain water.

In wetlands along rivers, part of rain water and runoff from rivers recharge groundwater. Investigation of sub-surface groundwater is required in wetlands where sub-surface water is used for farming and private irrigation systems are increasing.

(3) Central West Region (HA-II)

There are 3,340 borehole wells in this river basin, 1,790 wells of which (53 percent) are in Niger State. Only a few borehole wells are in the other states. This river basin consists of basement complexes and, therefore, many of these borehole wells are operated by hand-pumps with lifting capacity of 1.2 m^3/hour each. The amount of exploited groundwater in this basin is 20 MCM, which is one of the smallest in the country and similar to that in the Sokoto-Rima basin.

Since further development of groundwater in this basin will be done mainly in the Basement Complex area, careful investigation is required for the occurrences of groundwater and their potential resources in the Basement Complex areas in order to attain effective utilization of groundwater.

(4) Central East Region (HA-III and IV)

Exploitation of groundwater in this basin is slow in progress and there are only 2,640 borehole wells. Many of them are operated by hand pumps with small lifting capacities. Annual supply of groundwater is as low as 13 MCM.

This basin, consisting mostly of the Basement Complex, is situated in the plateau centering Jos and the mountains near the Cameroon border. Recharge by rainfall is considered to be very small. A part of the basin consists of sedimentary formations comprising consolidated sedimentary rocks partly or silt and clay, which are low in permeability. The Basement Complex and the sedimentary formations occupy 84 percent of the total area of the basin, whose groundwater resource for a unit area is estimated at 45,000 m^3/km^2 and small. Groundwater exploitation by borehole well appears to be of economically infeasible. But the area has abundant surface flow, which will be of the first choice for domestic water supply.

(5) South West Region (HA-VI)

This region is provided with 4,080 borehole wells, of which 75 percent are operated with mechanical pumps, 25 percent with hand pumps. Mechanical pump wells supply mainly urban water and hand pumps supply rural water with annual abstraction quantities of 78 MCM and 6 MCM, respectively.

Lifting capacities of mechanical pump well range between 40 and 70 m^3/hour with exceptionally high capacities in the suburbs of Lagos exceeding 100 m^3/hour. Because of this high abstractionate groundwater near Lagos is polluted by the ingression of seawater. Abstraction of groundwater should be controlled by setting up a monitoring well. Rural areas in the region, extending over the middle stream basins are underlain by Basement Complex, with and have a small potential groundwater yield of 50,000 m^3/km^2. It is often economical to use surface water in hard and fresh rock area having thin weathering layers. For future water supply in rural area, therefore, the use of surface water and groundwater should be studied for each LGA.

(6) South East Region

This region is provided with 1,090 borehole wells, 90 percent of which are operated by hand pumps. Most of mechanical pump wells are in urban area of Anambra and Akwa-Ibom States. Their pumping capacities range between 70 and 100 m^3/hour.

Although the number of wells in the region is the smallest in the country, groundwater yield and capacity of each pump in the sedimentary formation areas far exceed those in other regions. The annual groundwater abstraction is as large as 61 MCM in urban area, but is as small as 5 MCM in rural area.

Both urban and rural areas are facing an extremely short supply of water now. Further exploitation of groundwater will be needed in future. Eastern parts of Enugu and Anambra States and upper Cross river basin are located in hilly country. Urban and rural areas are mostly developed near hill tops and require wells more than 100 m deep for groundwater exploitation.

Costs of drilling and operation-maintenance for such deep borehole wells are anticipated to be considerably high in comparison with those for shallow wells in other regions. A study must be made on the use of surface water and groundwater for each LGA from economical point of view.

3D. 6. 5 Installation and Operation of Monitoring Wells Network

In the North Region water is mainly extracted from non-renewable semi-confined and confined aquifers when large quantities of water are required. It is important to maintain a safe yield in extracting water from such an aquifer. The safe yield can be obtained from a pumping test, but long-term observation of water table though monitoring wells is required to obtain a more reliable value. It is believed that in the Chad basin the recharge to an aquifer decreased and the water table and pressure head of the entire aquifer dropped appreciably. The decrease in recharge was due to a decrease in rainfall and a dam development in the upstream reaches of rivers following into the basin. However, there are no monitoring wells to correctly understand these phenomena. Where monitor wells exist, their operation is not now being performed adequately. In addition, it is reported that the water table dropped in the Sokoto-Rima river basin for the same reasons. Furthermore, contamination of groundwater caused by seawater intrusion is reported in coastal areas of the South Region. Installation of monitor wells is also required in these areas.

At present in Nigeria the wetland development of shallow groundwater for small scale irrigation has been enthusiastically promoted. This shallow groundwater development involves the pumping of groundwater from shallow boreholes called tube wells or wash bores. In many cases a pumping test is not performed after a borehole is installed so that there is some doubt as to whether the required amount of groundwater can be obtained. For this reason, it is necessary to clarify the drawdown effects associated with these shallow extractions in wetland area and to understand the seasonal aquifer fluctuation and their relationship to groundwater exploitation. Furthermore, the amount of groundwater available can be obtained from the difference between the upper and lower levels of this seasonal water level fluctuation. Accordingly, it is essential that a monitoring well network be established in each region. The following plans should be carried out.

(1) Monitoring Wells Network in Maiduguri Areas (HA-VIII)

A large amount of groundwater is extracted from the middle and lower aquifers to supply water to the Maiduguri metropolis and its neighboring areas. For this reason, the pressure head of these confined aquifers has dropped. The

State Water Board recorded a drop of 6 m/year in 1982. At present, the monitoring is not functioning in spite of such a sharp decline. The Monitoring Wells Network Plan was made to immediately determine the current groundwater condition as well as to monitor future changes. Three borehole wells will be installed in each aquifer in five sites centered on the water supply wells.

(2) Monitoring Wells Network in Chad Basin (HA-VIII)

As mentioned above, monitoring wells are installed in the upper and middle aquifers to determine the long-term fluctuation of water table and pressure head in the entire Chad basin. They are installed in four sites around Hadejia, the center of Chad basin. In each site two borehole wells are installed for each aquifer.

(3) Monitoring Wells Network in Sokoto-Rima Basin (HA-I)

Development of groundwater resources in this region is mainly for rural and semi-urban water supplies, and there is no intensive pumping in large quantities for urban requirements. However, the number of wells is the largest next to the Chad basin. Like the Chad basin, it is believed that the groundwater level is dropping due to a decrease in rainfall and a decrease in the amount of recharge caused by water supply, dam construction, etc. There are three main aquifers and monitoring wells are installed for the aquifers, although wells are installed separately in the Basement Complex Area.

(4) Monitoring Wells Network in Lagos Areas (HA-VI)

As a result of an intrusion of seawater due to excessive pumping of industrial water in Lagos Area, especially, around Ikeja, groundwater contamination has been highlighted. For this reason, monitoring wells will be installed to observe a fluctuation of the water table as well as to collect and analyze samples. In this region installation of four, wells is planned.

(5) Monitoring wells Network in South East Region (HA-V and VII)

Contamination of groundwater caused by seawater intrusion has occurred due to excessive pumping in coastal areas in Ondo, Rivers, Delta and other states. Installation of monitoring wells is planned at 30 sites to collect samples of groundwater in this area.

(6) Monitoring Wells Network in Wetland Areas

Pumping tests can be used to define safe yields in shallow boreholes in wetland area. On the other hand, monitoring wells are required to observe long-term fluctuations of groundwater to help determine the available groundwater potential, and to establish appropriate pump discharge rates. Measurement of the seasonal fluctuations of groundwater in wetland area is indispensable for the future wetland development. Plans are being drawn up throughout the country for the development of irrigation in wetlands. Monitoring Wells Network should be set up to investigate shallow groundwater resources for the development. The number of monitoring wells needed for each area of development as one well in 25 km^2 are shown in the following table.

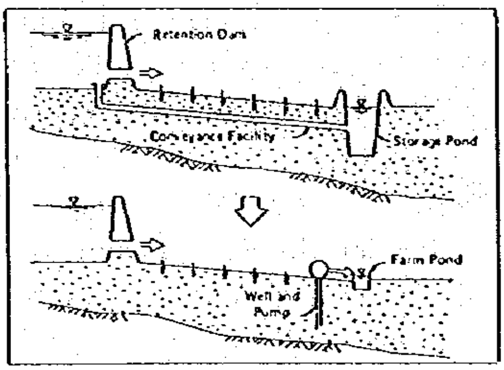
	HA	Present Service Area (1,000ha)	New Development (1,000ha)	Total Areas (1,000ha)	No. of Monitoring Wells
North West	I	35	68	103	40
North East	VIII	98	94	192	80
Central West	II	10	147	157	60
Central East	III	0	90	90	35
	IV	3	74	77	30
South West	VI	0	42	42	20
South East	V	1	32	33	10
	VII	3	53	56	25
Total		150	600	750	300

3D. 6. 6 Remark on Flood Retention Dams for Groundwater Recharge

The north region of Nigeria is a dry area but it has an annual rainfall between 500 and 600 mm. In dry area, various efforts have been taken to store rainwater as long and as much as possible. The basic method is to minimize rainwater runoff and to have it permeate into the ground to minimize evaporation. Some of the methods are described in the following paragraphs.

(i) Flood Retention Dam

Rain water runs off rapidly over the surface and dries up in a short period of time. The surface water during the rainy season is stored in a retention dam. A sketch of retention dam is shown in the figure below.



This dam has two functions: one is to retain water and another is to disperse the flow. A retention dam has a function for collecting groundwater and then allowing the retained water flow out through pipes constructed downstream. Runoff is also retained as groundwater for long periods. If the geophysical condition permits, a retention dam supplies surface water to other dispersion routes accelerating recharge of groundwater.

Water in a retention dam is used directly. Water in retention dam is used by connecting the retention dam to a storage pond, constructed in an area where the water is used, with pipe lines. The capacity of a storage pond must be sufficient to store water required during the dry season. Another method is to use water of the dam or groundwater recharged by water from the dam by constructing a well downstream of the dam. Water may be used after storage in a farm pond or by pumping directly from the well.

(ii) In gently inclined areas that become a lakes or ponds during the rainy season, a large and shallow body of water is created which caused a large amount of water to evaporate. It will be wise to reduce evaporation by minimizing the surface area to retain water for long periods. One method is to dig holes in part of the lake or pond created during the rainy season, or deeply excavate the entire area of lake or pond.

(iii) Another method used in the area described in (ii) above, is to accelerate recharge during the rainy season and use the water during the dry season. This is done by digging shallow wells to accelerate recharge during the rainy season. After the rain when a lake or pond dries up and water level of wells fall below the ground level, recharged groundwater seeps out, and can be used for long periods. This method is defective in area where these are weathered and cracks layers.

(iv) In the vicinity of seasonal rivers, river water may be stored during the rainy season. In this method a number of ponds are dug along rivers and ponds and rivers are connected with a channel.

(v) In gently inclined areas where pond are created during the rainy season, storage ponds are constructed. In this method holes are dug and earth is piled up around the holes in circular or rectangular shapes.

(vi) In areas where there are rivers, rivers are dammed up. The size and number of dams are determined by the size and inclination of a river and by the amount of rainfall. It is suited for rocky regions.

(vii) In areas where gravel layers are developed and water is not retained, for long periods, barrier walls should be constructed in gravel layers, which is called an underground dam. Barrier walls need not be a perfect barrier. It would be sufficient if barrier walls can control the flow rate of groundwaters. The shape of barrier walls is determined by the configuration of the ground and the shape of foundation. Unlike other methods, the construction of an underground dams requires a careful study and a large scale investigation in planning and execution of works. Since stored surface water is likely to deteriorate in quality, borehole and dug wells are recommended. It would be even more effective if the above methods that accelerate recharge and borehole drilling are combined in the basement complex areas.

3D. 6. 7 Inter- Government Coordination

Main programs and agencies in Nigeria related to the groundwater development are as follows:

- Consecutive implementation of National Borehole Program by FMWRRD.
- Establishment of wells and boreholes for rural water supply by DFFRI.
- Establishment of borehole wells by Rural Water Supply Project, a part of Agricultural Development Project.
- Establishment of wells and boreholes by UNICEF and JICA.
- Establishment of boreholes by State Water Boards, State Ministries of Water Resources, River Basin Development Authorities and private individuals and Organizations.

Two problems are pointed out concerning execution of these rural water supply projects.

(i) It seems that each of these agencies and organizations is executing the groundwater supply development separately and independently. Consequently, unnecessary repetition and confusion is caused in executing the programs. As for the rural water supply project, the type of pumps to be installed, scale, priority, etc. of the water supply development should be studied on both LGA and state levels. The data should then be gathered by the FMWRRD and finally put together into one plan. Afterwards, this project will be executed at the state and LGA levels based on that unified plan. Responsibilities for executing this plan will be allotted to other agencies.

(ii) Valuable hydrogeological data can be obtained though the execution of a project. The executing agencies keep to themselves the obtained data such as depth of wells, water table, yield obtained from an aquifer test, aquifer properties, etc., and in some cases the data has been scattered and lost.

This problem has been already pointed out and a par of this data collection has been executed. However, the coordination of data collection among the executing agencies is still poor. A more through and nation-wide data collection system including all agencies and organizations related to groundwater development should be made to establish a databank.

3D. 6. 8 Groundwater Management and Administration

As an example, foreign countries have the following legislation which regulates the management and administration of groundwater. Many countries have laws called Water Acts or Groundwater Acts. The groundwater can be classified into two types from the legal point of view; One with a public nature, which is regarded as "public water" and personal possession is not allowed so that "in principle its use is prohibited" and the other with a private nature, which is generally regarded as a form of land ownership so that "in principle its use is free".

Nigeria promulgated Water Resources Decree 1993, Decree No.101 in Federal Republic of Nigeria Official Gazette No.27, Vol.80, prescribing groundwater as a water resource. According to this law, although water resources are regarded as "public water" and personal possession is not allowed, it does allow groundwater to be taken freely based on the provision that "Who has a statutory or customary right of occupancy to any land may take and use water from the underground water resources". Furthermore, a secretary is authorized to control groundwater extraction and the following is provided in the law.

- Proper intake of groundwater during water shortage
- Suspension of use of groundwater when it is recognized as harmful to health
- Revocation of a right to use or take water when such a right is likely to override the public interest.

This water resource decree give strong support to the master plan related to water resources and it is expected that this law will be strictly observed.

3D. 6. 9 Plan Implementation Program

Programs until the year 2020 are described in 3D.6.5. The periods and estimated costs of there are shown in the table. The estimated costs include costs for charges in equipment and maintenance up to 2020 as required.

3D. 7 NATIONAL WATER MASTER ACTION PLAN TOWARDS THE YEAR 2000

3D. 7. 1 General

The plan for groundwater for the year 2000 involves high priority problems and measures to solve the problems. The problems are described in the following sections.

3D. 7. 2 Installation and Operation of Priority Monitoring Wells Network

(1) Maiduguri Area

The purpose is to monitor the drop in the water table and/or pressure head in the Maiduguri area as described in 3D. 6. 5. The network shall be installed at five sites, a central site is located next to the water supply wells and the other four sites are arranged at equal distance to the north, south, east and west. Three monitor wells at each site will measure water levels in the Upper, Middle and Lower aquifers, 15 wells in all. The well depths shall be 50 meters for the Upper aquifer, 250 m for the Middle aquifer, and 500 m for the Lower aquifer. The diameter of wells shall be six inches. A 4-inch casing shall be inserted after drilling. A water pressure-type level meter shall be used and wells shall be installed in a monitoring shelter. Pumping tests shall be conducted after the completion of drilling, geological logging and the insertion of the casing. An accurate leveling survey shall be conducted for each well. Maintenance of wells and water level data collection shall be the responsibility of NWRI.

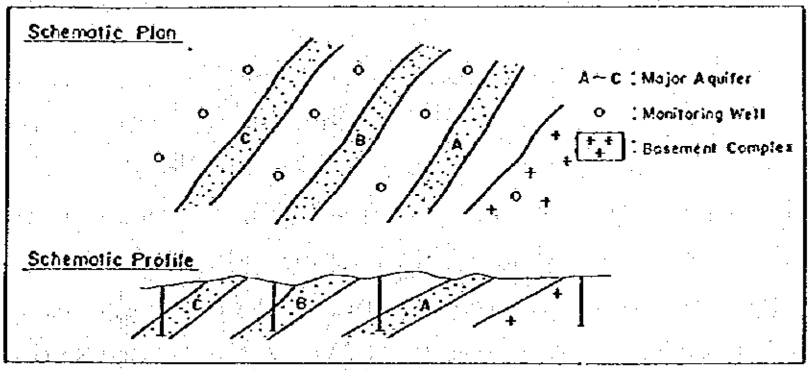
(2) Chad Basin

Monitoring well shall be set up to check long term variations in the water table of the Upper aquifers and the pressure head of Middle aquifers. Wells shall be installed in four sites near the center of the Chad Basin and the vicinity of Hadejia. Each site shall have two wells. The depth of wells shall be 40 m for Upper aquifer and 200 m for Middle aquifer. Pressure-type water level meters shall be installed in monitoring huts. After drilling, tests shall be conducted and maintenance shall be done by NWRI as in the case of Maduguri.

(3) Sokoto-Rima River Basin

As in the case of the Chad Basin, groundwater levels are believed to be low because of the decrease in recharge due to the decrease of rain, the construction of dams, and excessive pumping.

Strata of the Sokoto Basin run in the direction north-east to south-west in the north of Sokoto and Kebbi States. Monitoring wells shall be drilled into the three major aquifers, three borehole wells for one aquifer, nine borehole wells in all. Each borehole well shall be 150 meters in depth. One monitoring well shall be set up in the Basement Complex Area. Positions of monitoring wells are shown in the following figure.



(4) Lagos Area

The purpose is to monitor the contamination of groundwater. A pressure-type water level meter shall be installed to monitor the change in the water table and to collect samples to observe changes in salt content with time. The depth of wells shall be 100 m. This area has a high yield of fresh groundwater but the portion near the surface contains salt. Before determining the site of the monitoring wells, the changes and extent of salt content and depth shall be investigated using existing wells.

(5) Monitoring Wells Network in Wetland Area

Monitoring wells network for small scale irrigation are essential. Forty wells in the Sokoto-Rima river basin of HA-I and 60 wells in the Lake Chad basin, 100 wells in all, are needed by the year 2000. The depth of wells shall be 15 m.

3D. 7. 3 Guideline and Criteria for Groundwater Investigation, Exploitation and Monitoring

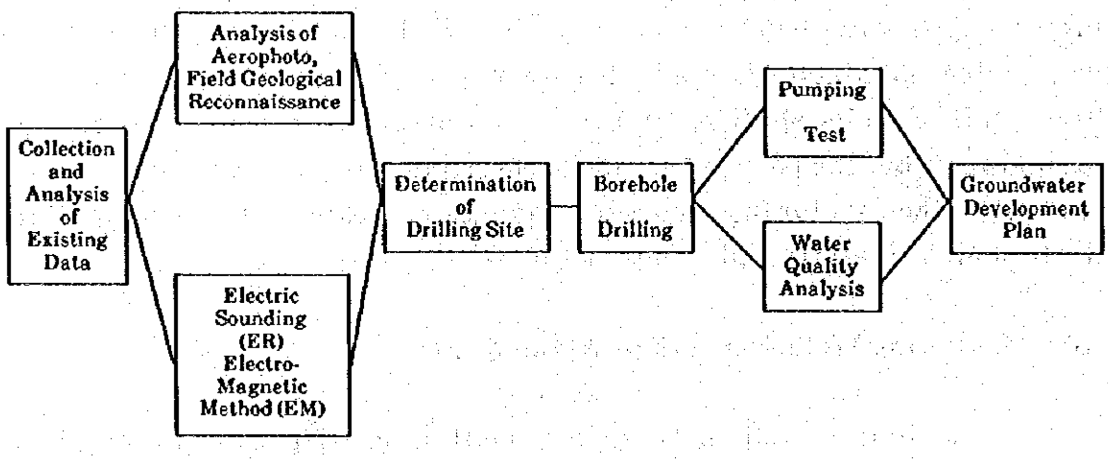
(1) Pre-drilling Investigation

A large number of borehole wells have been dug and, according to some reports, the success rate of borehole drilling is between 63 and 74 percent due to probably to inadequate pre-drilling investigation.

Groundwater is sought in shallow prolific aquifers in sedimentary rock areas. A large amount of groundwater is likely to exist in weathering layers that extend down due to the development of fracture zones in the basement complex areas.

Drilling sites should be selected from the above areas, which calls for effective investigations. Recently, various investigation technique have been employed in the country. A very promising and feasible one is the electrical resistivity (ER) method. This technique has been effective in determining the continuity of aquifers and depth of weathering layers in the basement complex. It is reported that a JICA program has been effectively carried out in north-western Nigeria. Electro-magnetic (EM) method is also said to be effective in the basement complex area.

Flow of a groundwater investigation is as follows:



Analysis of aerialphotos is also an effective and necessary means for determining drilling sites in the basement complex area.

(2) Pumping Tests

Pumping tests are essential to estimating yield and acquiring various aquifers properties. Most of the pumping test records in Nigeria are incomplete. According to one report, "in most of the data analyzed, only one-stage test pumping was done, which lasted only a few hours. This did not allow for qualitative analysis and appraisal of well/aquifer characteristics". Pumping test analysis questionnaire and standard pumping test data format sheets from the "Borehole data inventory and pumping test analysis for groundwater development in drought-prone areas of Nigeria" carried out by FMWR in 1991, are described in the appendix. From now on the presentation of pumping test results should be requested so that each column of the above questionnaire is filled out.

(3) Training of Investigation Engineers

Trained personnel are required for the analysis of aerialphotos, ER and EM used in pre-drilling investigations and pumping tests. The training should be done by instructions who teach the method of the investigation and an organization well-versed with investigation equipment. At present, NWRI in Nigeria is the most proficient organization. A crew of trained engineer may conduct investigations under contract and in cooperation with local groundwater development agencies. Or the crew may train personnel from agencies under contract. An organization for training should be established.

3D. 7. 4 Plan Implementation Program

Programs for the year 2000 are as described in 3D. 7. 2. The projected starting and estimated cost, location of the works are shown in Table 3D.9 and 10, and Figure 3D.2.

TABLE 3D-1 STATUS OF EXISTING BOREHOLE WELLS BY STATE

State	No. of	Ratio	Depth of Wells (m)					Water Level (m)				Water Yield (l/min)				Pump	
Name	Wells	%	>151	101~150	51~100	50>	un-known	>31	11~30	10>	un-known	>101	51~100	50>	un-known	Hand	Mecha-nical
1 SoKoTo	2765		85	358	826	1140	356	755	984	565	461	1144	202	686	733	1819	93
2 Kebbi	1292		17	73	432	642	128	235	436	451	170	1109	5	17	161	976	31
3 Katsina	1265		-	108	609	502	46	149	740	224	152	281	158	670	156	189	212
Sub Total	5322	22.9	102	539	1867	2284	530	1139	2160	1240	783	2534	365	1373	1050	2984	336
4 Kwara	543		10	11	131	301	90	7	15	93	428	122	82	37	302	260	134
5 Niger	1789		13	15	343	943	475	65	156	773	795	226	127	438	998	1364	150
6 Kaduna	886		-	-	170	542	174	99	162	452	173	516	98	270	2	692	114
7 Kogi	113		24	22	36	17	14	4	5	18	86	51	22	5	35	* 116	14
8 F.C.T.	10		2	1	7	-	-	2	2	6	-	1	9	-	-	-	-
Sub Total	3341	14.4	49	49	687	1803	753	177	340	1342	1482	916	338	750	1337	2432	412
9 Kano	1375		1	35	408	922	9	15	725	299	336	88	322	558	407	851	476
10 Jigawa	1438		2	49	670	681	36	278	531	283	346	177	523	504	234	839	311
11 Yobe	886		51	46	362	249	178	33	61	545	247	101	19	544	222	390	157
12 Borno	1627		633	47	212	201	534	49	176	422	980	440	94	269	824	447	161
13 Bauchi	1438		50	76	423	782	107	125	416	716	181	494	210	706	28	237	331
Sub Total	6764	29.1	737	253	2075	2835	864	500	1909	2265	2090	1300	1168	2581	1715	2764	1436
14 Adamawa	534		11	45	164	221	93	-	70	370	94	3	1	436	94	284	25
15 Plateaw	1307		-	-	5	1302	-	-	58	1249	-	-	-	1307	-	1045	-
16 Taraba	190		-	-	25	164	1	-	5	185	-	-	-	190	-	168	22
17 Benue	610		3	21	103	483	-	6	92	512	-	-	-	610	-	* 468	
Sub Total	2641	11.4	14	66	297	2170	94	6	225	2316	94	3	1	2543	94	1965	47
18 Cross River	51		1	15	9	-	26	4	11	20	16	14	5	2	30	* 277	-
19 Enugu	140		102	11	11	1	15	41	4	1	94	114	2	3	21	* 78	-
20 Anambra	107		88	10	3	1	5	81	10	3	13	72	-	-	35	* 42	2
21 Imo	191		52	71	64	4	-	147	37	3	4	179	6	-	6	* 368	73
22 Abia	74		9	5	8	16	36	4	8	2	60	36	2	-	36	* 366	-
23 Akwa-Ibom	215		23	67	70	35	20	65	67	32	51	84	-	2	129	171	14
24 Rivers	307		58	38	180	20	11	1	60	108	138	105	-	-	202	80	61
Sub Total	1085	4.7	333	217	345	77	113	343	197	169	376	604	15	7	459	1382	150
25 Oyo	820		-	9	79	732	-	-	-	-	820	4	12	803	1	703	67
26 Ogun	204		27	53	82	38	4	33	28	34	109	125	43	18	18	38	143
27 Lagos	1288		161	43	110	905	69	135	331	656	166	280	70	333	605	691	461
28 Delta	170		24	26	120	-	-	21	21	122	6	-	41	129	-	78	92
29 Edo	103		54	43	6	-	-	74	22	6	1	-	84	19	-	7	96
30 Osun	970		-	2	38	813	117	-	2	827	141	19	11	845	95	823	57
31 Ondo	526		17	-	-	509	-	12	-	509	5	3	14	502	7	513	13
Sub Total	4081	17.5	283	176	435	2997	190	275	404	2154	1248	431	275	2649	726	2853	929
Total	23234	100	1518	1300	5706	12166	2544	2440	5235	9486	6073	5788	2162	9903	5381	14380	3310

* including dug wells with hand pump

TABLE 3D-2 WELL SITE DISTRIBUTION DENSITY

No.	State	Area (sq. km)	Population (x10^3)	Borehole Wells	Density (No. of wells/sq. km)
1	Sokoto	68,090	4,393	2,765	0.041
2	Kebbi	37,250	2,059	1,292	0.035
3	Katsina	23,950	3,879	1,265	0.053
4	Kwara	34,700	1,568	543	0.016
5	Niger	72,340	2,481	1,789	0.025
6	Kaduna	44,390	3,968	886	0.020
7	Kogi	28,810	2,100	113	0.004
8	F.C.T.	6,960	379	10	0.001
9	Kano	21,680	5,638	1,375	0.063
10	Jigawa	24,210	2,732	1,438	0.059
11	Yobe	45,240	1,411	886	0.020
12	Borno	76,050	2,595	1,627	0.021
13	Bauchi	66,310	4,291	1,438	0.022
14	Adamawa	38,220	2,123	534	0.014
15	Plateau	53,870	3,285	1,307	0.024
16	Taraba	56,860	1,480	190	0.003
17	Benue	32,410	2,779	610	0.019
18	Cross River	21,990	1,866	51	0.002
19	Enugu	12,510	3,162	140	0.011
20	Anambra	4,690	2,768	107	0.023
21	Imo	5,430	2,488	191	0.035
22	Abia	6,380	2,298	74	0.012
23	Akwa-Ibom	6,780	2,360	215	0.032
24	Rivers	19,600	3,984	307	0.016
25	Oyo	27,140	3,489	820	0.030
26	Ogum	17,030	2,339	204	0.012
27	Lagos	3,730	5,687	1,288	0.345
28	Delta	17,280	2,569	170	0.010
29	Edo	19,700	2,159	103	0.005
30	Osum	9,390	2,203	970	0.103
31	Ondo	20,810	3,884	526	0.025
	Total	923,800	88,417	23,234	0.025

Area and Amount			Basement Complex Area	Sedimentary Formation Area	Total
HA I	Area	sq.km	66.500	65.100	131.600
	Groundwater	$\times 10^6$ cu.m	1,660	2,680	4,340
HA II	Area	sq.km	121,900	36,200	158,100
	Groundwater	$\times 10^6$ cu.m	5,130	3,050	8,180
HA III	Area	sq.km	89,500	69,400	158,900
	Groundwater	$\times 10^6$ cu.m	3,590	3,400	6,990
HA IV	Area	sq.km	35,200	37.800	73,000
	Groundwater	$\times 10^6$ cu.m	1,640	2,750	4,390
HA V	Area	sq.km	5,300	48,600	53,900
	Groundwater	$\times 10^6$ cu.m	270	6,880	7,150
HA VI	Area	sq.km	59,700	40,800	100,500
	Groundwater	$\times 10^6$ cu.m	3,080	5,940	9,020
HA VII	Area	sq.km	11,100	48,700	59,800
	Groundwater	$\times 10^6$ cu.m	650	5,630	6,280
HA VIII	Area	sq.km	53,700	134,300	188,000
	Groundwater	$\times 10^6$ cu.m	1,210	4,370	5,580
Total	Area	sq.km	442,900	480,900	923,800
	Groundwater	$\times 10^6$ cu.m	17,230	34,700	51,930

TABLE 3D-4 NUMBER OF EXISTING BOREHOLE WELLS BY EXECUTING AGENCY

State	FMWR		RBDA	STATE	UNICEF	LGA	DFRRI	OTHERS	TOTAL
	* NBP	* DRP							
Katsina	19	25	-	464	-	-	-	-	508
Sokoto	40	25	4,688	450	-	-	-	-	5,203
Abuja	10		-	-	-	-	-	-	10
Kaduna	24	15	-	377	-	-	15	-	431
Niger	46	15	-	-	-	-	-	-	61
Kwara	54	-	-	174	407	-	-	23	658
Bauchi	41	15	255	64	-	-	-	10	385
Gongola	31	15	13	325	-	-	73	5	462
Plateau	49	-	-	-	-	-	-	-	49
Benue	38	-	50	89	-	-	73	-	250
Oyo	68	-	12	3	-	-	38	44	165
Ogun	47	-	-	-	-	-	-	-	47
Ondo	55	-	13	13	-	-	-	6	87
Bendel	48	-	23	-	-	-	-	-	71
Lagos	58	-	-	-	-	-	-	-	58
Anambra	49	-	10	14	-	45	-	-	118
Imo	52	-	9	-	-	-	-	-	61
River	55	-	49	146	-	-	48	30	328
Akwa-Ibom	29	-	-	51	57	10	152	5	304
Cross River	19	-	3	-	-	2	-	1	25
Kano	44	25	694	-	-	-	-	-	763
Borno	40	25	558	-	1	374	2	2	1,002
Total	916	160	6,377	2,170	465	431	401	126	11,046

(The Journey so far 1985-1991)

*NBP: National Borehole Programme

DRP: Drought Relief Programme

TABLE 3D-5 SUMMARY OF DFRRI ACHIEVEMENT IN RURAL WATER SUPPLY AS OF 14/1/93

State	PHASE-I No. B/Hs completed passed FCI*	PHASE-II No. B/Hs completed passed FCI*	Remark
1 Akwa-Idom	165	673	
2 Anambra	312	277	
3 Enugu			
4 Bauchi	399	572	
5 Edo	89	–	
6 Delta			Phase III is in progress
7 Borno	250	325	
8 Yobe		285	
9 Cross River	73	–	
10 Adamawa	250	387	
11 Taraba		115	
12 Imo	250	168	
13 Abia		169	
14 Kaduna	153	696	
15 Kano	252	627	
16 Jigawa		739	
17 Katsina	177	517	
18 Benue	268	273	
19 Kogi	566	681	
20 Kwara			
21 Lagos	252	252	
22 Niger	250	282	
23 Ogun	250	416	
24 Ondo	296	526	
25 Oyo	293	796	
26 Osun			
27 Plateau	359	545	
28 Rivers	258	603	
29 Sokoto	276	267	
30 Kebbi			
31 F. C. T.	251	–	
Total	5,689	10,191	

*FCI: Federal Comprehensive Inspection

TABLE 3D-6 GROUNDWATER BALANCE BY HA IN THE YEAR 2020

SHA	Rivers	Catchment Area A (km^2)	Average Water Resources B (cu.m per km^2)	Ground Water Resources C=AxB (MCM)	Water Supply Demand D (MCM)	Water Balance E=C-D (MCM)	Water Use Rate F=D/C (%)
I-1	Gada	4,030	23,825	96	5	91	6
I-2	Bunshur	8,490	27,065	230	34	196	15
I-3	Gagere	8,660	26,200	227	23	203	10
I-4	Sokoto	12,220	32,520	397	28	369	7
I-5	Rima	9,240	40,383	373	29	345	8
I-6	Gawon Gubli	8,690	40,396	351	32	319	9
I-7	along Sokoto River	8,480	41,150	349	18	331	5
I-8	Zamfara	17,130	34,942	599	46	553	8
I-9	Gulbinka	11,380	28,551	325	14	311	4
I-10	Damzaki	8,130	29,999	244	12	232	5
I-11	Malendo	11,780	27,473	324	29	295	9
I-12	Along Border River	8,880	41,150	365	5	361	1
I-13	Ouara and Maiel	10,000	34,445	344	9	336	3
I-14	Swashi and Dole	4,490	25,719	115	3	112	3
	SUB TOTAL	131,600		4,340	286	4,053	7
II-1	Oli and Wuruma	9,930	25,830	256	—	—	—
II-2	Moshi	10,210	48,028	490	7	483	1
II-3	Kontagora	8,970	79,348	712	8	704	1
II-4	Oshun and Awun	7,150	46,209	330	21	309	6
II-5	Oshin,Oi and Ove	10,800	51,450	556	45	511	8
II-6	Kojin Maringo	17,800	46,220	823	6	817	1
II-7	Eba	7,730	88,641	685	6	679	1
II-8	Kampe	12,310	56,613	697	8	689	1

SHA	Rivers	Catchment Area A (km²)	Average Water Resources B (cu.m per km²)	Ground Water Resources C=AxB (MCM)	Water Supply Demand D (MCM)	Water Balance E=C-D (MCM)	Water Use Rate F=D/C (%)
II-9	Tubo	7,470	47,421	354	33	321	9
II-10	Koringa	5,350	45,602	244	7	237	3
II-11	Galma	11,630	42,554	495	32	463	6
II-12	Upper Kaduna	9,420	42,251	398	24	374	6
II-13	Sarikin powa	7,550	44,693	337	8	329	2
II-14	Gbako	12,120	67,246	815	19	796	2
II-15	Small Tributaries	2,580	88,641	229	3	225	1
II-16	Gurara	17,080	44,389	758	35	723	5
	SUB TOTAL	158,100		8,180	263	7,917	3
III-1	Kirange and Others	9,450	30,640	290	23	267	8
III-2	Mayo,Ine and Others	10,700	49,964	535	14	520	3
III-3	Hawal and Others	16,140	23,593	381	41	340	11
III-4	Upper Congola	31,550	40,366	1,274	41	1,232	3
III-5	Middle Gongola	6,110	47,400	290	31	258	11
III-6	Small Tributaries	4,230	45,451	192	6	187	3
III-7	Mayo Belwa	7,560	53,382	404	24	380	6
III-8	Pai	16,350	46,659	763	36	727	5
III-9	Fan	5,750	54,360	313	15	297	5
III-10	Duchi	10,810	46,130	499	19	479	4
III-11	Taraba and Lower Dong	10,100	51,703	522	23	499	4
III-12	Suntai	5,350	56,590	303	10	293	3
III-13	Upper Taraba	12,730	46,970	598	3	595	0
III-14	Upper Donga	12,070	52,086	629	12	616	2
	SUB TOTAL	158,900		6,990	298	6,692	4

SHA	Rivers	Catchment Area A (km²)	Average Water Resources B (cu.m per km²)	Ground Water Resources C=AxB (MCM)	Water Supply Demand D (MCM)	Water Balance E=C-D (MCM)	Water Use Rate F=D/C (%)
IV-1	Shemankar	6,000	57,087	343	17	326	5
IV-2	Rity and Fiyu	4,530	68,835	312	21	291	7
IV-3	Ankwe and Others	11,550	53,243	615	34	581	6
IV-4	Asku and Guma	6,520	67,378	439	9	431	2
IV-5	Katsina-Ala	12,820	61,246	785	27	758	3
IV-6	Small Tributaries	6,490	70,703	459	30	429	6
IV-7	Mada	8,730	48,085	420	15	405	4
IV-8	Akini	11,430	48,649	556	24	532	4
IV-9	Small Tributaries	4,930	93,646	462	12	450	3
	SUB TOTAL	73,000		4,390	188	4,202	4
V-1	Osordo,Ubo and Oril	8,810	73,256	645	58	587	9
V-2	Anambra	11,490	115,482	1,327	81	1,246	6
V-3	Asa and Others	6,340	143,938	913	52	861	6
V-4	Along Niger River	8,530	136,769	1,167	220	946	19
V-5	Forcados	18,730	165,447	3,099	317	2,782	10
	SUB TOTAL	53,900		7,150	729	6,422	10
VI-1	Wuru,Kobo and Ove	4,800	51,715	248	5	243	2
VI-2	Ogun and Oyan	22,060	63,918	1,410	104	1,306	7
VI-3	Yewa	5,670	125,719	713	93	620	13
VI-4	Ondo	5,640	84,529	477	95	382	20
VI-5	Oshun	10,130	59,095	599	121	477	20
VI-6	Shasha and Omi	10,900	65,565	715	62	653	9
VI-7	Silko	5,750	80,078	460	57	403	12
VI-8	Osse	13,730	74,860	1,028	81	947	8

SHA	Rivers	Catchment Area A (km²)	Average Water Resources B (cu.m per km²)	Ground Water Resources C=AxB (MCM)	Water Supply Demand D (MCM)	Water Balance E=C-D (MCM)	Water Use Rate F=D/C (%)
VI-9	Lagoon	11,520	154,482	1,780	78	1,702	4
VI-10	Ossimo	10,300	154,482	1,591	131	1,461	8
	SUB TOTAL	100,500		9,020	827	8,193	9
VII-1	Upper Cross	7,490	94,289	706	47	660	7
VII-2	Okpanku	8,660	82,512	715	30	684	4
VII-3	Middle Cross	9,490	94,289	895	126	769	14
VII-4	Middle Cross	8,470	69,712	590	48	543	8
VII-5	Lower Cross and Imo	13,370	163,022	2,180	373	1,807	17
VII-6	Lower Cross	5,590	105,846	592	53	539	9
VII-7	Small Tributaries	6,730	89,491	602	38	564	6
	SUB TOTAL	59,800		6,280	714	5,566	11
VIII-1	Tagwai	8,070	31,631	255	73	182	29
VIII-2	Gari	10,080	27,930	282	68	214	24
VIII-3	Challawa and Wataries	6,650	23,415	156	66	89	43
VIII-4	Kano	7,660	23,281	178	40	139	22
VIII-5	Bunga and Jama'are	13,780	23,280	321	40	281	13
VIII-6	Iggi	6,430	24,849	160	13	147	8
VIII-7	Gaya and Hadejia	15,680	31,680	497	105	392	21
VIII-8	Along Border	12,820	30,549	392	20	371	5
VIII-9	Katagun	9,910	32,623	323	26	298	8
VIII-10	Misau and Dingaiya	28,610	32,997	944	63	881	7
VIII-11	Yobe	4,710	31,115	147	6	141	4
VIII-12	Along Lake Chad	19,270	30,361	585	14	571	2
VIII-13	Ngadde	23,490	32,655	767	42	725	5

SHA	Rivers	Catchment Area A (km²)	Average Water Resources B (cu.m per km²)	Ground Water Resources C=AxB (MCM)	Water Supply Demand D (MCM)	Water Balance E=C-D (MCM)	Water Use Rate F=D/C (%)
VIII-14	Yedseram	9,530	26,208	250	29	221	11
VIII-15	Komadugu Gama	11,310	28,714	325	25	300	8
	SUB TOTAL	188,000		5,580	629	4,952	11
TOTAL		923,800		51,930	3933	47,997	8

TABLE 3D-7 DEEP BOREHOLE WELLS FOR MONITORING SYSTEM

Region	HA	Name of Areas	No. of Wells	Cost Estimation N.×10⁶						
				TOTAL		1996~2000	2001~2005	2006~2010	2011~2015	2016~2020
North West	I	Sokoto Rima River Basin	10	Term						
				Installation	13.0	11.0	0	1.0	0	1.0
				Monitorring	4.4	0.4	1.0	1.0	1.0	1.0
				Sub Total	17.4	11.4	1.0	2.0	1.0	2.0
North East	Ⅷ	Maiduguai	15	Term						
				Installation	23.7	21.5	0	1.1	0	1.1
				Monitorring	4.6	0.6	1.0	1.0	1.0	1.0
				Sub Total	28.3	22.1	1.0	2.1	1.0	2.1
		Lake Chad Basin	8	Term						
				Installation	7.8	6.6	0	0.6	0	0.6
				Monitorring	2.8	0.4	0.6	0.6	0.6	0.6
				Sub Total	10.6	7.0	0.6	1.2	0.6	1.2
South West	Ⅵ	Lagos	5	Term						
				Installation	4.8	3.8	0	0.5	0	0.5
				Monitorring	2.2	0.2	0.5	0.5	0.5	0.5
				Sub Total	7.0	4.0	0.5	1.0	0.5	1.0
		Ogun	5	Term						
				Installation	4.3	0	3.8	0	0.5	0
				Monitorring	1.8	0	0.3	0.5	0.5	0.5
				Sub Total	6.1	0.0	4.1	0.5	1.0	0.5
		Ondo	5	Term						
				Installation	4.3	0	3.8	0	0.5	0
				Monitorring	1.8	0	0.3	0.5	0.5	0.5
				Sub Total	6.1	0.0	4.1	0.5	1.0	0.5
		Delta	5	Term						
				Installation	4.3	0	0	3.8	0	0.5
				Monitorring	1.3	0	0	0.3	0.5	0.5
				Sub Total	5.6	0.0	0.0	4.1	0.5	1.0
South East	V	Rivers	5	Term						
				Installation	4.3	0	0	3.8	0	0.5
				Monitorring	1.3	0	0	0.3	0.5	0.5
				Sub Total	5.6	0.0	0.0	4.1	0.5	1.0
	Ⅵ	Akwa-Ibom	5	Term						
				Installation	3.8	0	0	0	3.8	0
				Monitorring	0.8	0	0	0	0.3	0.5
				Sub Total	4.6	0.0	0.0	0.0	4.1	0.5
		Gross Rivwe	5	Term						
				Installation	3.8	0	0	0	3.8	0
				Monitorring	0.8	0	0	0	0.3	0.5
				Sub Total	4.6	0.0	0.0	0.0	4.1	0.5
TOTAL			68	Term						
				Installation	74.1	42.9	7.6	10.8	8.6	4.2
				Monitorring	21.8	1.6	3.7	4.7	5.7	6.1
				TOTAL	95.9	44.5	11.3	15.5	14.3	10.3

TABLE 3D-8 MONITORING WELLS FOR WETLAND IRRIGATION

Region	HA	No. of Wells	Cost Estimation N × 10⁶						
			Total		~2000	2001~2005	2206~2010	2011~2015	2016~2020
North West	I	40	Term		40				
			Installation	6.9	6.9	0	0.0	0	0.0
			Monitoring	5.4	0.6	1.2	1.2	1.2	1.2
			Sub-Total	12.3	7.5	1.2	1.2	1.2	1.2
North East	VIII	80	Term		60				
			Installation	13.8	10.3	3.5	0	0	0
			Monitoring	7.2	0.8	1.6	1.6	1.6	1.6
			Sub-Total	21.0	11.1	5.1	1.6	1.6	1.6
Central West	II	60	Term			40			
			Installation	10.3	0	6.8	3.5	0	0
			Monitoring	4.9	0	0.5	1.2	1.6	1.6
			Sub-Total	15.2	0.0	7.3	4.7	1.6	1.6
Central East	III	35	Term					15	
			Installation	6.1	0	0	0	2.6	3.5
			Monitoring	0.8	0	0	0.0	0.1	0.7
			Sub-Total	6.9	0.0	0.0	0.0	2.7	4.2
	IV	30	Term				30		
			Installation	5.1	0	0	5.1	0	0
			Monitoring	2.6	0	0.0	0.6	1.0	1.0
			Sub-Total	7.7	0.0	0.0	5,7	1.0	1.0
South West	VI	20	Term					10	
			Installation	3.4	0	0	0	1.7	1.7
			Monitoring	0.5	0.0	0.0	0.0	0.1	0.4
			Sub-Total	3.9	0.0	0.0	0.0	1.8	2.1
South East	V	10	Term				10		
			Installation	1.7	0	0	1.7	0	0
			Monitoring	1.3	0.0	0.0	0.3	0.5	0.5
			Sub-Total	3.0	0.0	0.0	2.0	0.5	0.5
	VII	25	Term					15	
			Installation	4.3	0	0	0	2.6	1.7
			Monitoring	0.5	0.0	0.0	0	0.1	0.4
			Sub-Total	4.8	0.0	0.0	0.0	2.7	2.1
Total		300	Term						
			Installation	51.6	17.2	10.3	10.3	6.9	6.9
			Monitoring	23.2	1.4	3.3	4.9	6.2	7.4
			Total	74.8	18.6	13.6	15.2	13.1	14.3

TABLE 3D-9 IMPLEMENTATION SCHEDULE OF DEEP MONITORING WELLS

Region	HA	Name of areas	No. of Well	Estimated Cost $N.\times 10^6$		1996	1997	1998	1999	2000
North West	I	Sokoto Rima River Basin	10	Installation	11.0					
				Monitorring	0.4					
				Sub Total	11.4					
North East	VII	Maiduguai	15	Installation	21.5					
				Monitorring	0.6					
				Sub Total	22.1					
	VIII	Lake Chad Basin	8	Installation	6.6					
				Monitorring	0.4					
				Sub Total	7.0					
South West	VI	Lagos	5	Installation	3.8					
				Monitorring	0.2					
				Sub Total	4.0					
TOTAL			38	Installation	42.9					
				Monitorring	1.6					
				Total	44.5					

TABLE 3D-10 IMPLEMENTATION SCHEDULE OF MONITORING WELLS FOR WETLAND IRRIGATION

Region	HA	Name of Areas	No. of Wells	Estimated Cost N.×10^6		1996	1997	1998	1999	2000
North West	I	Sokoto Rima River Basin	40	Installation	6.9					
				Monitorring	0.6					
				Sub Total	7.5					
North East	VIII	Lake Chad Basin	60	Installation	10.3					
				Monitorring	0.8					
				Sub Total	11.1					
TOTAL			100	Installation	17.2					
				Monitorring	1.4					
				Total	18.6					

FIGURE 3D-1 SKETCH MAP OF HYDROGEOLOGICAN AREAS OF NIGERIA

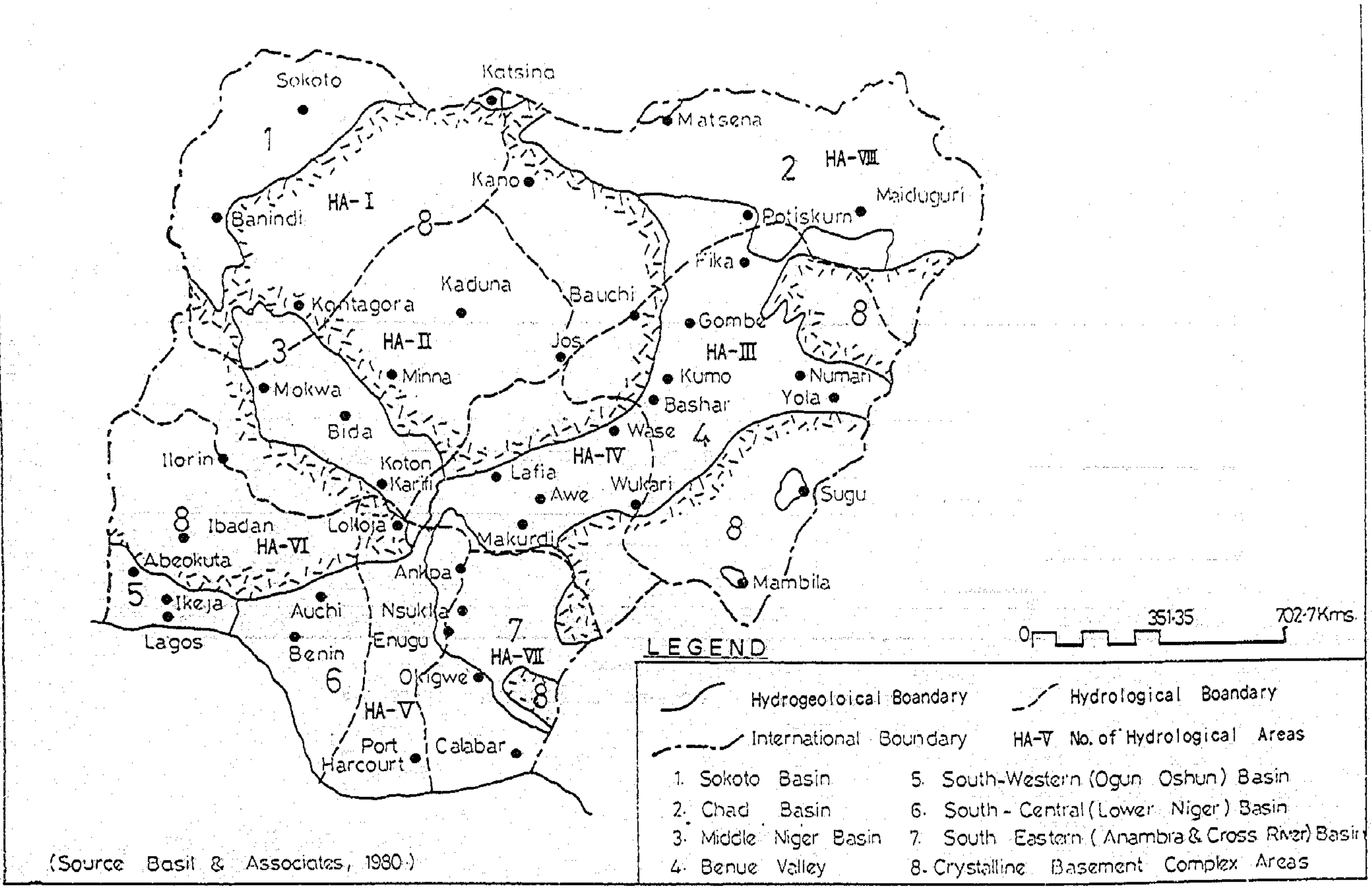
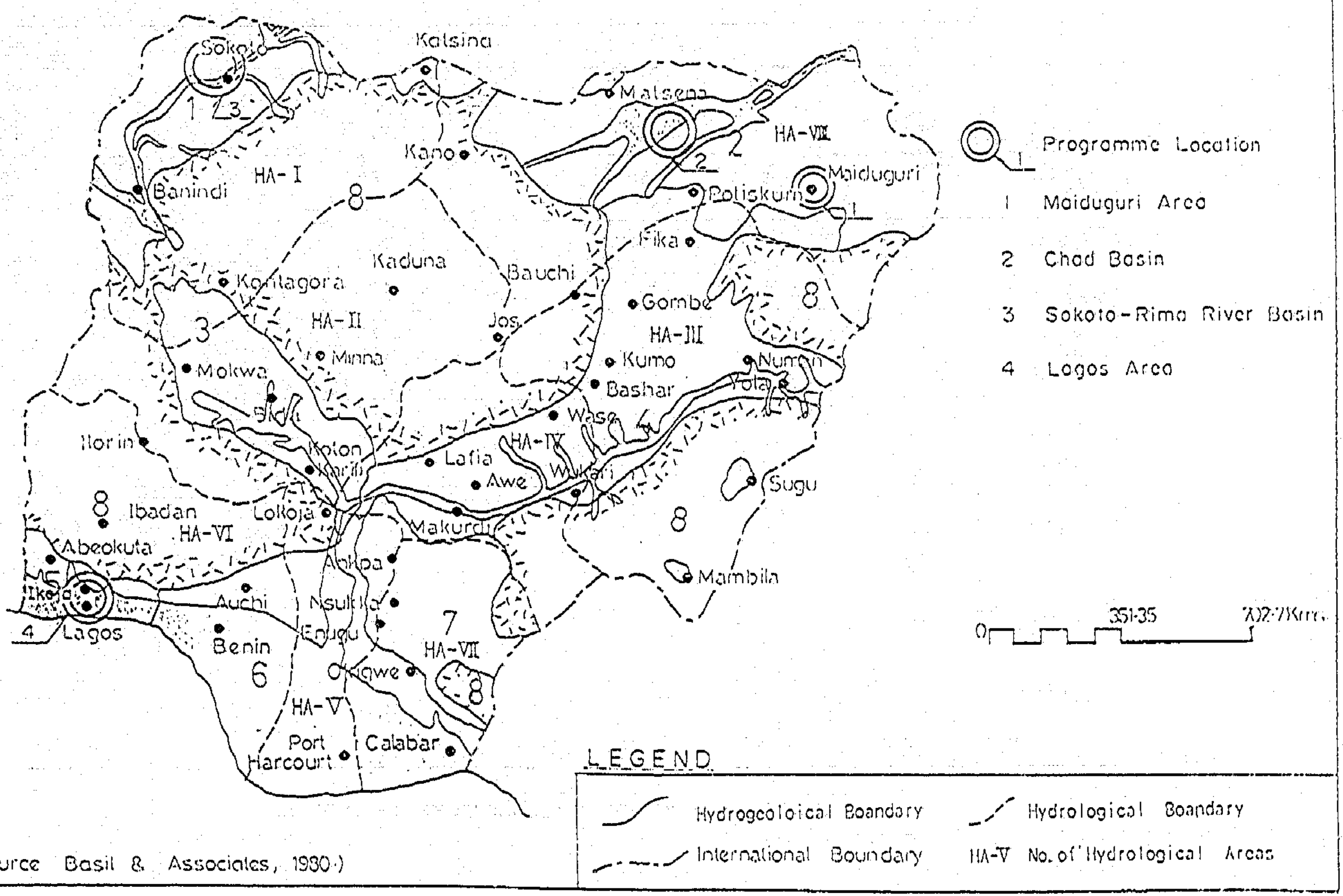


FIGURE 3D. 2 PROGRAM LOCATION FOR MONITORING WELLS NETWORK



(Source Basil & Associates, 1980)