those plants.

Table B.1-17 Costs Comparison among Three Water Alternative Sources

Water Sources	Accounting Cost a	Opportunity Cost of Capital b	Economic Cost c=a+d	Pipeline Transmission d	Grand Total C+d
Riyadh's New Wells Project	0.36	0.18	0.54	*-	0.54
Sharjah's New Desalination Plant	0.35	0.17	0.52	1.32	1.84
Average 30 Desalination Plants (1998)	0.67	0.38	1.05	1.32	**2.37

* Included in accounting cost
** Including the value of electricity generated
Source: Household water and sanitation services in Saudi Arabia: an analysis of economic, political and ecological issues

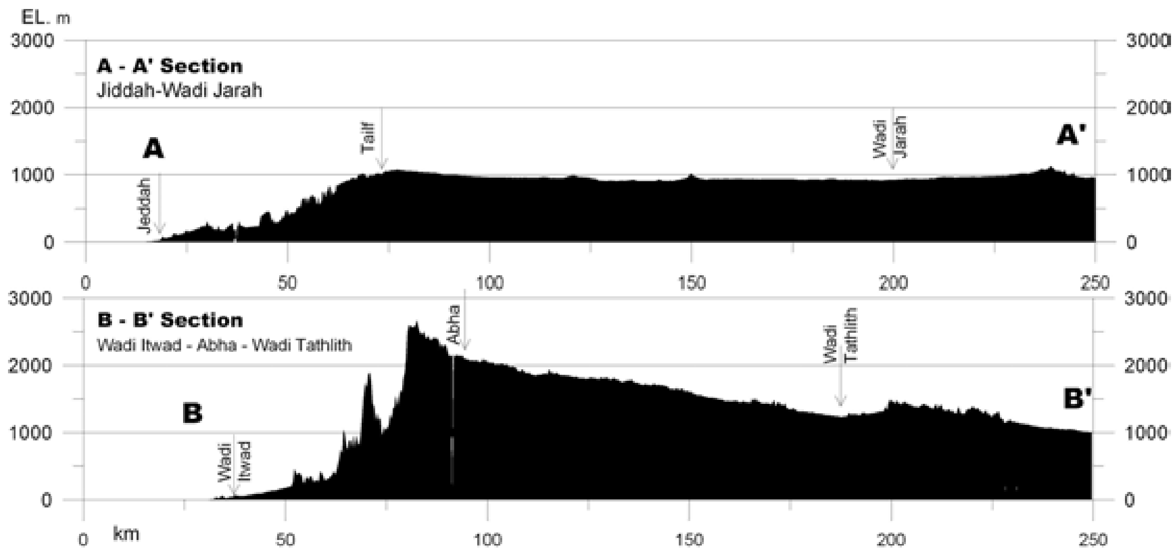
1.2 Natural Condition

1.2.1 Geography

The study area lies on the south-western part of the Kingdom that rises abruptly from the Red Sea in the west and dips gently towards the Najd in the east. In the trunk of the study area, Hijaz Asir highlands rises up to about 3,000 meters in the south near Abha, while at northern boundary of the area near Taif, the elevation is about 1,500 meters (refer to Figure B.1-6 and Figure B.1-7).

There is a distinct coastal plain, locally known as Tihama, separated from the hills by an imposing scarp wall that runs parallel to the Red Sea along 700 km in the study area.

Toward the east forms the peak of Hijaz Asir highlands, hills peter out further east to the interior, and give way to an extensive plateau covered with lava flow (Harrat) of the area, and very thin veneer rock debris and alluvium over a basalt and crystalline basement, which is frequency outcrop as knolls and low hills. In large scale geographic view, the study area is divided into three geographic regions, as follows.(veneer rock debris: weathered and scoring debris , then debris cover; laying on older rock formation)



Note: Section line is shown in Figure B. 1-14

Figure B.1-6 Topographical Section

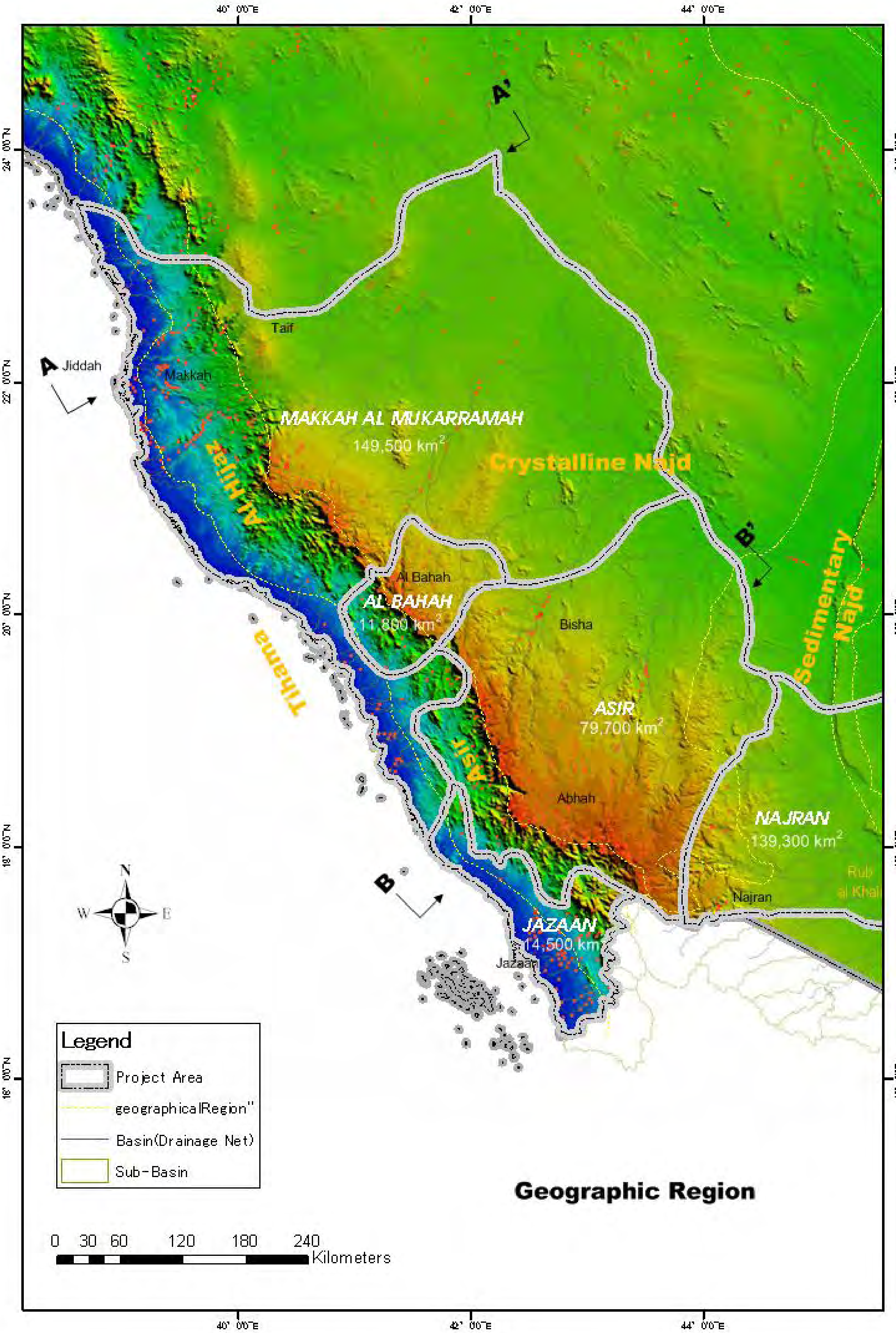


Figure B.1-7 Geography of Study Area

Western Coastal Lowland – Tihama

This region, locally called as 'Tihama' forms narrow strips along the Red Sea coast. In the north in the area it starts as a plain near Jeddah to gradually widen to over 40 kilometers near Jazan in the south.

This plain is low depositional surface mostly on a coral plain that grades upward to the east to form a pediment on hard crystalline rock of geologic basement.

Al Hijaz Asir Plateau

The Hijaz Asir plateau forms the tops of the southern half of the Red Sea escarpment, extending from Taif into Yemen. In the study area, it occupies 700 km along with the Red Sea. The plateau slopes gently to east and north.

Crystalline Najd

The crystalline Najd is the part of the Najd region that is underlain mainly by resistant rocks of igneous and metamorphic origin. The plain is a rocky expanse of coalescing pediments and desert, as large as 500 km wide, and is dotted with prominent, isolated rock knobs or spires.

1.2.2 Geology

Study area is underlain by tightly folded, regionally metamorphosed volcanic-clastic, and epi-clastic rocks and many mafic to felsic plutonic[3] all of late Proterozoic age. It is called as 'Arabian Shield-Nubian Shield' and is exposed with concealed by the sedimentary cover rock that dips gently toward the east. As covered rock, in the study area, Paleozoic sandstones, comprising the Cambrian-Ordovician Wajid sandstone, are found on the southeastern range of the study area and overlie Proterozoic rocks.

In the study area, several episodes of volcanism are recognized in the geologic age. Of those events, older volcanic activity occurred in Precambrian age and formed a volcano-clastics and subordinate flow rocks, complexly inter-layered with volcanically delivered and epi-clastic sedimentary rocks. While the younger rocks, Tertiary and Quaternary basalt-flows and gabbro-dikes are found in particular the north of the study area. Both are associated with Red Sea rifting: the basalt is part of a large area of a flow rocks and volcanic cones resulting from volcanic activity, whereas the gabbro dikes were intruded into tension fractures.

Overlying the bedrock are unconsidered Quaternary deposit that included wadi alluvium, fanglomerate delivered from the Red Sea escarpment, terrace gravels, coastal-plain silt and eolian sand. These formed during the period of active erosion following the uplift of the region and the opening the Red Sea, which caused the development of wadi system draining to the east and west and the erosional retreat of the Red Sea escarpment.

Typical litho-stratigraphy and geologic map of the study area is shown in Figure B.1-8 and Figure B.1-9.

[3] Note:
Plutonic rock: Type of igneous rock formed by solidification depth beneath the earth surface
Felsic rock: Igneous rock dominated by aluminum-rich minerals.
Mafic rock: Igneous rock dominated by magnesium and ferrous iron.

Era	Lithostratigraphy	Intrusive Rock	Age	Orogenic Events
Quaternary				
	Alluvium			Red Sea rifting
	Basalt Cones			
	Basalt necks and dikes			
Tertiary	Basalt flows		27	
	Laterite			
Ordovician–Cambrian, Permian	Wajid Sandstone		570?	Local uplift
Upper Precambrian				
	Muradama group		600?	Najd faulting (south strand)
		Granite Suite / Diorite and gabbroic rocks		
	Atura formation		640	Extension and uplift
			660	
		Granodiorite and granite suite	690 735	Crustal shortening (continental collision)
	Halaban group		760 780	Andean–type island arc
		Tonalite and granodiorite suite		Shortening (collision)
	Ablah group		800	Andean–type island arc
		Diorite suite	900	Ensimatic
	Baish, Bahah, and Jiddah groups	?		
Lower Precambrian			110	island arc

Figure B.1-8 Litho-stratigraphy (Central Part of Study Area: Abha Region)

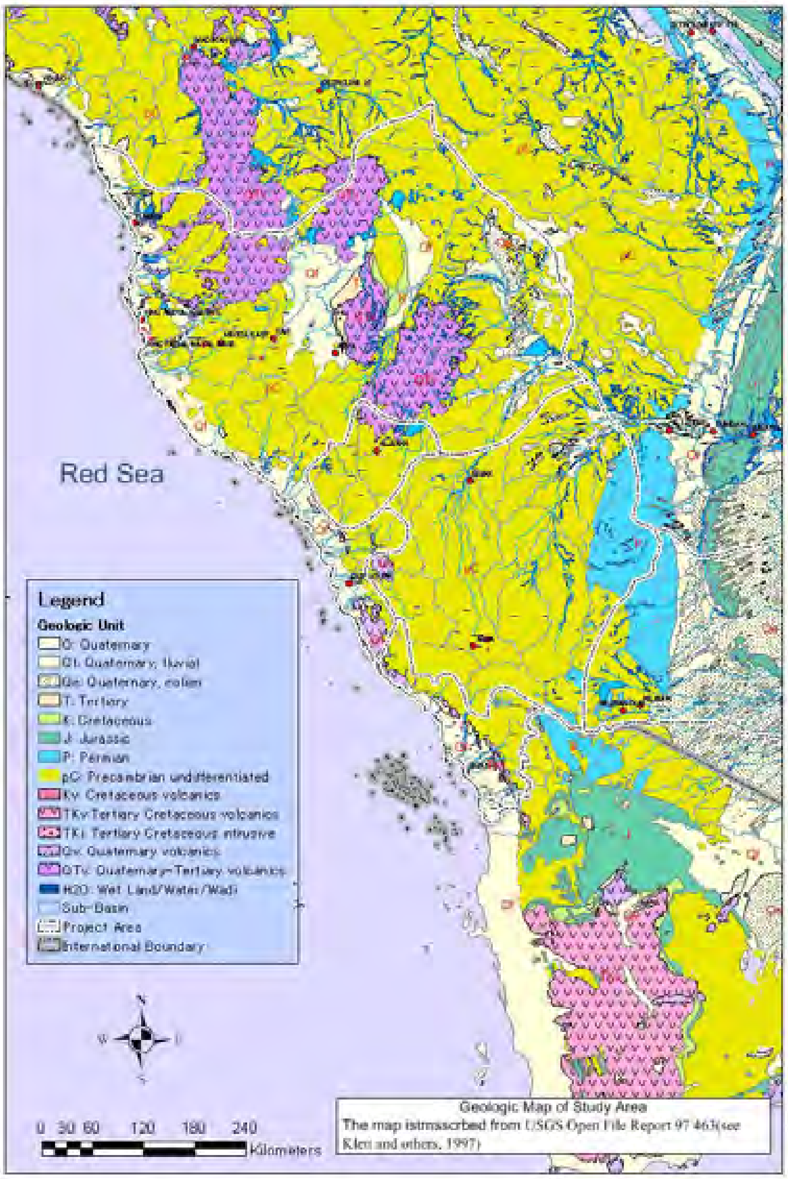


Figure B.1-9 Geologic Map of the Study Area

1.2.3 Meteorology (Meteorological Stations)

The study area has 10 Meteorological Stations under the control of Presidency of Meteorological and Environment (hereinafter referred to as P.M.E) and 56 of them under the control of MOWE as shown in Table B.1-18 and Table B.1-19 respectively.

Table B.1-18 Meteorological Stations under the Control of P.M.E and Available Data

Station Name	Station No.	Longitude	Latitude	Available Data
ABHA	41112	42°39´39˝	18°13´59˝	1978 - 2007.10
AL BAHA	41055	41°38´35˝	20°17´41˝	1985 - 2007.10
BISHA	41084	42°37´09˝	19°59´28˝	1970 - 1974,1977 - 2003.2
JEDDAH	41024	39°12´00˝	21°30´00˝	1970 - 1975,1977 - 2002.2
JIZAN	41140	42°35´05˝	16°53´49˝	1970 - 1974,1977 - 2003.2
KHAMIS MUSHAYT	41114	42°48´23˝	18°17´58˝	1970 - 1974,1977 - 2003.6
MAKKAH	41030	39°46´08˝	21°26´16˝	1985 - 2007.10
MEDINA	40430	39°48´06˝	22°21´36˝	1970 - 1974,1977 - 1983.10
NAJRAN	41128	44°24´49˝	17°36´41˝	1978 - 2007.09
TAIF	41036	40°24´00˝	21°16´48˝	1970 - 1970.10

Source:P.M.E

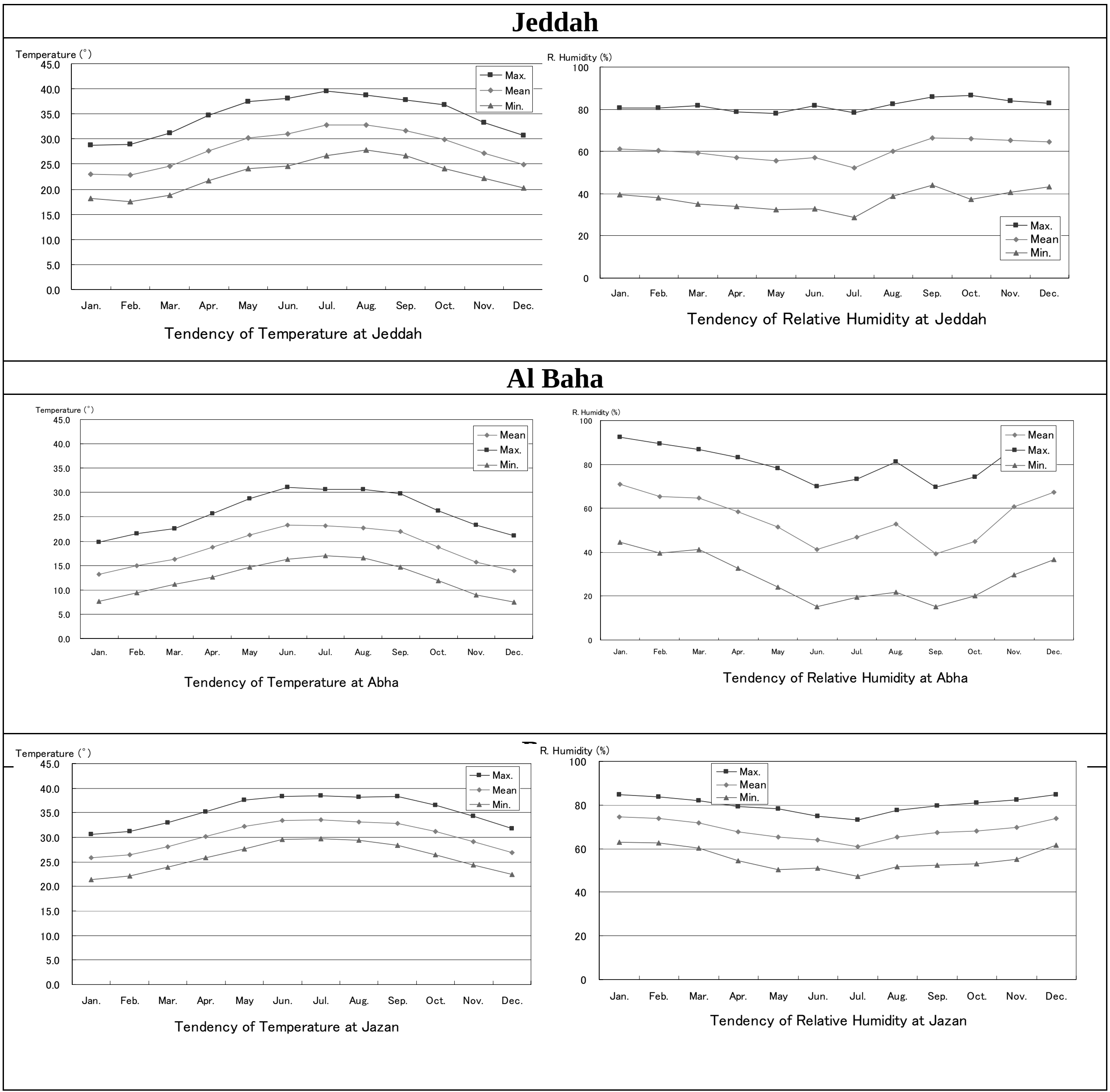
Table B.1-19 Meteorological Stations under the Control of MOWE and Available Data

No.	Station Name	Elevation (EL.m)	Longitude	Latitude	Available Data
1	A004	2400	43°06′00″	18°10′00″	1975 - 2002
2	A005	2200	42°29′00″	18°12′00″	1975 - 2003
3	A006	2100	42°36′00″	18°15′00″	1975 - 2000
4	A007	2600	42°09′00″	19°06′00″	1975 - 2003
5	B001	2400	41°17′00″	20°06′00″	1975 - 2003
6	B004	1020	42°36′00″	20°01′00″	1975 - 2003
7	B005	1090	42°32′00″	19°52′00″	1975 - 2003
8	B006	975	43°31′00″	19°32′00″	1975 - 2003
9	B007	2400	41°33′00″	19°52′00″	1975 - 2002
10	B008	1230	42°22′30″	19°59′10″	1975 - 2001
11	D001	940	44°22′00″	24°29′00″	1970 - 1990
12	EP002	4.7	50°00′00″	26°30′00″	1975 - 2002
13	EP003	75	48°23′00″	26°59′00″	1975 - 2002
14	HU002	300	49°01′00″	24°04′00″	1975 - 2002
15	HU003	160	49°34′00″	25°30′00″	1969 - 2004
16	HU005	430	48°08′00″	25°05′00″	1975 - 2001
17	HU006	450	47°22′00″	26°22′00″	1975 - 2001
18	H001	1010	41°38′00″	27°28′00″	1975 - 2001
19	H002	985	41°34′00″	27°22′00″	1975 - 1992
20	H005	878	42°30′00″	27°16′00″	1975 - 1987
21	J001	53	41°03′00″	19°32′00″	1975 - 2001
22	J002	60	39°20′00″	22°09′00″	1975 - 2000
23	J003	90	40°26′40″	20°19′00″	1984 - 2002
24	M001	590	39°35′00″	24°31′00″	1975 - 2002
25	M002	840	40°30′00″	24°51′00″	1975 - 1981
26	M004	849	40°31′00″	24°50′00″	1982 - 2003
27	N001	1272	44°15′39″	17°34′00″	1975 - 1999
28	R001	564	46°43′00″	24°34′00″	1964 - 2003
29	R002	430	47°24′00″	24°10′00″	1975 - 2001
30	R003	539	46°44′00″	22°17′00″	1975 - 2002
31	R004	670	44°48′00″	26°17′00″	1980 - 2003
32	R005	665	45°37′00″	25°32′00″	1975 - 2003
33	R006	730	45°15′00″	25°15′00″	1975 - 2003
34	R007	600	46°34′00″	24°25′00″	1975 - 2001
35	R008	550	46°28′00″	22°33′00″	1975 - 2003
36	SA001	190	42°57′00″	17°03′00″	1975 - 2003
37	SA002	40	42°37′00″	17°10′00″	1975 - 2003
38	SA003	350	41°53′00″	19°00′00″	1975 - 2003
39	SA004	30	41°24′00″	18°44′00″	1975 - 2002
40	SA005	410	41°48′08″	19°13′34″	1975 - 2001
41	SK001	574	40°12′00″	29°58′00″	1975 - 2002
42	SK002	549	37°21′00″	31°20′00″	1975 - 2002
43	SK003	566	38°17′00″	30°31′00″	1975 - 2002
44	SU001	600	45°34′00″	20°28′00″	1970 - 1993
45	TA002	1500	40°30′00″	21°18′00″	1975 - 2000
46	TA003	1230	40°25′00″	21°37′00″	1975 - 2000
47	TA004	1530	40°27′00″	21°24′00″	1980 - 2003
48	TA005	1126	41°40′00″	21°11′00″	1975 - 1997
49	TA006	1450	41°17′00″	20°37′00″	1982 - 2001
50	TB001	737	36°35′00″	28°22′00″	1975 - 2003
51	TB002	820	38°29′00″	27°38′00″	1975 - 1995
52	U001	724	43°59′00″	26°04′00″	1980 - 2003
53	U002	740	42°11′00″	25°50′00″	1982 - 2003
54	W001	240	35°01′00″	28°28′00″	1975 - 2003
55	TA007	2200	41°28′00″	19°59′00″	1975 - 1992
56	B009	2011	41°54′00″	19°32′00″	1975 - 2003

Source:MOWE

Figure B.1-10 Location Map of Meteorological Stations by P.M.E and MOWE

Meteorological characteristics on temperature and humidity in Jeddah, Al Baha and Jazan are shown in following Figure B.1-11.



Source:P.M.E

Figure B.1-11 Tendency of Temperature and Relative Humidity in the Study Area

1.2.4 Hydrology (Rainfall, Runoff)

(1) Rainfall

There are 105 Rainfall Stations under the control of MOWE as shown in Table B.1-20. Location of the rainfall stations in each region are shown in Supporting Report.

Table B.1-20 Rainfall Stations under the Control of MOWE in the Study Area

No.	Region	Station Name	Elevation (EL.m)	Longitude	Latitude	Available Data
1	Makkah	J111	55	38°50′00″	23°06′00″	1966 - 1988、1991 - 2006
2		J140	8	39°02′00″	22°49′00″	1966、1969 - 1979、1982 - 1998、2000 - 2003、2005 - 2006
3		J116	317	39°38′00″	22°35′00″	1966 - 1979、1985 - 1986、1988 - 2006
4		J220	470	39°49′00″	22°22′00″	1966 - 1995、1997 - 2004
5		J002	60	39°20′00″	22°09′00″	1972、1994 - 2001、2004
6		J106	60	39°20′00″	22°09′00″	1994 - 2001、2005 - 2006
7		J219	125	39°26′00″	22°12′00″	1970 - 1995、1997 - 2006
8		J221	90	39°21′00″	21°55′00″	1971 - 1995、1997 - 2004
9		J239	350	39°41′00″	21°58′00″	1976 - 2002、2004
10		J214	710	39°59′00″	21°59′00″	1966 - 2006

No.	Region	Station Name	Elevation (EL.m)	Longitude	Latitude	Available Data
11		J134	11	39°12´00˝	21°30´00˝	1970 - 1979、1984 - 2005
12		J102	116	39°42´00˝	21°26´00˝	1966 - 2003、2005 - 2006
13		J114	280	39°49´00˝	21°26´00˝	1964 - 1965、1969 - 1970、1972、1975 - 1976、1979、1981、1995 - 1998
14		TA250	1465	40°27´00˝	21°40´00˝	1982 - 1992, 2001
15		J113	520	40°07´00˝	21°22´00˝	1966 - 1976、1979 - 1997、1999 - 2005
16		J204	720	40°12´00˝	21°21´00˝	1966 - 2005
17		J205	910	40°13´00˝	21°21´00˝	1966 - 2005
18		TA251	1900	40°22´00˝	21°22´00˝	1982 - 1992, 2001
19		TA206	1680	40°24´00˝	21°17´00˝	1966 - 2004
20		TA233	1650	40°39´00˝	21°08´00˝	1971 - 2005
21		J003	90	40°26´00˝	20°19´00˝	1994 - 1996、2004 - 2005
22		J107	84	40°27´00˝	20°19´00˝	1966 - 1977、1981 - 1982、1986 - 1987、1989 - 1992、1994 - 2005
23		J108	6	40°17´00˝	20°09´00˝	1966 - 1975、1977 - 1985、1987 - 2003、2005
24		J001	53	41°03´00˝	19°32´00˝	1970 - 1988、1994 - 1995、1997 - 1998
25		J131	370	41°37´00˝	19°28´00˝	1970 - 1988、1990 - 1998、2000 - 2006
26		SA120	580	41°50´00˝	19°26´00˝	1968 - 2005
27		SA005	410	41°48´00˝	19°13´34˝	1990 - 1999
28		SA122	450	41°50´00˝	19°07´00˝	1969 - 1996、1999、2001、2002、2004、2006
29		SA147	85	41°28´00˝	19°02´00˝	1970 - 1976、1978 - 1983、1995- 2000、2003 - 2005
30		SA142	90	41°35´00˝	18°46´00˝	1966、1970 - 2005
31		SA004	30	41°24´00˝	18°44´00˝	1973 - 1987、1997 - 1998
32		B111	810	42°51´00˝	21°15´00˝	1965 - 1971, 1974, 1976, 1982, 1985 - 1986, 1991 - 1997, 2001 - 2002, 2004
33		B001	2400	41°17´00˝	20°06´00˝	1975 - 2003
34		B103	1470	41°39´00˝	20°15´00˝	1975 - 1976, 1978 - 1996, 2005
35		J139	80	41°02´00˝	19°44´00˝	1967 - 1987、1992 - 1995、1997 - 1999
36	Al Baha	J126	350	41°26´00˝	19°46´00˝	1966 - 1988、1990 - 1997
37		B007	2400	41°33´00˝	19°52´00˝	1965 - 1981, 1983 - 2005
38		B101	2330	41°35´00˝	19°54´00˝	1960 - 1980, 1982 - 2005
39		J127	440	41°32´00˝	19°40´00˝	1970 - 2001、2005
40	Asir	J137	398	41°58´00˝	19°58´00˝	1966、1968、1972 - 2002、2004 - 2005
41		B114	1305	42°14´00˝	20°01´00˝	1966 - 1978, 1980 - 1997, 2001
42		B008	1230	42°22´30˝	19°59´10˝	1990 - 1997, 2000
43		B004	1020	42°36´00˝	20°01´00˝	1975 - 2003
44		B217	1715	41°56´00˝	19°45´00˝	1971 - 1976, 1985 - 1996, 2000 - 2002
45		B005	1090	42°32´00˝	19°52´00˝	1973 - 1999
46		B216	2000	41°59´00˝	19°28´00˝	1970 - 1998, 2002
47		SA003	350	41°53´00˝	19°00´00˝	1968 - 1988、1991 - 1993、2000 - 2006
48		SA105	390	41°58´00˝	18°56´00˝	1965 - 1988、1991、1993、1998 - 2003
49		SA139	450	42°02´00˝	19°03´00˝	1970 - 2006
50		SA120	580	41°50´00˝	19°26´00˝	1968 - 2005
51		A127	2250	42°15´00˝	18°47´00˝	1966 - 1979、1981 - 2006
52		B208	1650	42°44´00˝	19°01´00˝	1967 - 1976, 1985 - 1996
53		A103	2100	42°47´00˝	18°06´00˝	1965 - 2006
54		B219	1480	42°48´00˝	19°20´00˝	1971 - 1997, 1999 - 2002, 2004 - 2005
55		B006	975	43°31´00˝	19°32´00˝	1983 - 1996, 1999 - 2002
56		SA138	570	42°01´00˝	18°38´00˝	1966、1970 - 2005
57		SA113	450	42°02´00˝	18°32´00˝	1965 - 1999
58		A206	2480	42°15´00˝	18°41´00˝	1967 - 1995、2002 - 2006
59		A117	2200	42°16´00˝	18°37´00˝	1966 - 1995、1997 - 2006
60		A108	2300	42°23´00˝	18°31´00˝	1967 - 1983、1985 - 2006
61		A107	2150	42°34´00˝	18°36´00˝	1968 - 1982、1984 - 1994、1998 - 2006
62		A113	1700	42°41´00˝	18°38´00˝	1966 - 2002、2004 - 2006
63		B110	1650	42°53´00˝	18°48´00˝	1965, 1968, 1970 - 1976, 1978 - 1997, 2000 - 2005
64		A110	1880	42°59´00˝	18°41´00˝	1966 - 1983、1985、1990 - 1997、2001 - 2005
65		SA108	420	41°55´00˝	18°20´00˝	1965 - 1966、1968 - 2005
66		A130	2440	42°19´00˝	18°20´00˝	1982 - 2006
67		A124	2400	42°20´00˝	18°25´00˝	1965 - 1981、1983 - 2006
68		A201	2030	42°31´00˝	18°25´00˝	1966 - 1996
69		A112	1980	42°34´00˝	18°22´00˝	1965 - 2006
70		A128	1800	42°42´00˝	18°28´00˝	1974 - 1993、1996 - 2001
71		SA116	700	42°12´00˝	18°15´00˝	1968 - 1988、1993 - 1994、1998 - 2002、2004 - 2006
72		SA144	408	42°15´00˝	18°10´00˝	1971 - 2000、2004 - 2006
73		A118	2820	42°22´00˝	18°15´00˝	1965 - 2002、2004 - 2006
74		A005	2200	42°29´00˝	18°12´00˝	1982 - 2003
75		A006	2100	42°36´00˝	18°15´00˝	1973 - 1976、1978 - 1996
76		A123	1900	42°52´00˝	18°19´00˝	1965 - 1993、1995 - 2001
77		SA115	20	41°40´00˝	18°00´00˝	1965 - 1979、1982、1987、1990、2000、2005
78		A121	2300	42°45´00˝	18°02´00˝	1965 - 2006
79		A004	2400	43°06´00˝	18°10´00˝	1981 - 1999、2003 - 2006
80		A105	2060	43°11´00˝	18°14´00˝	1968、1970 - 2002、2004 - 2006

No.	Region	Station Name	Elevation (EL.m)	Longitude	Latitude	Available Data
81		A004	2400	43°06′00″	18°10′00″	1981 - 1999、2003 - 2006
82		A104	2350	43°22′00″	17°56′00″	1966 - 2002
83	Jazan	SA102	65	42°14′00″	17°42′00″	1966 - 2005
84		SA204	200	42°36′00″	17°34′00″	1979 - 1985、1998 - 2006
85		SA145	600	42°48′00″	17°37′00″	1966、1968 - 1969、1972 - 1976、1980 - 1993、1997 - 2006
86		SA106	70	42°32′00″	17°22′00″	1967 - 1994、1997 - 2004
87		SA126	540	42°53′00″	17°27′00″	1966 - 2006
88		SA125	200	42°27′00″	17°08′00″	1967 - 1968、1970 - 1977、1979 - 2006
89		SA002	40	42°37′00″	17°10′00″	1965 - 1993、1995、1999 - 2002、2005 - 2006
90		SA107	70	42°47′00″	17°07′00″	1966 - 2005
91		SA129	150	42°54′00″	17°10′00″	1967、1969 - 1987、1992 - 1999、2005 - 2006
92		SA140	305	43°02′00″	17°19′00″	1967、1970 - 1990、1993、1995、1998 - 2006
93		SA110	860	43°08′00″	17°16′00″	1960 - 1984、1988 - 2006
94		SA148	4	42°32′00″	16°55′00″	1984 - 1997、2003 - 2005
95		SA132	73	42°47′00″	17°01′00″	1963、1990 - 2006
96		SA101	69	42°50′00″	16°58′00″	1960 - 1976、1978、1980 - 1995、1998 - 2005
97		SA001	190	42°57′00″	17°03′00″	1976 - 1993、2000 - 2005
98		SA104	223	43°05′00″	17°03′00″	1960 - 2006
99		SA111	900	43°07′00″	17°03′00″	1960 - 2006
100		SA143	340	43°08′00″	16°54′00″	1971 - 1996、2002 - 2005
101		SA135	240	43°14′00″	16°48′00″	1967 - 1974、1982 - 1984、1988、1990 - 2006
102		SA136	90	43°08′00″	16°41′00″	1967 - 2006
103		SA137	40	42°57′00″	16°36′00″	1967 - 1979、1982 - 1997、2000 - 2002、2004 - 2005
104	Najran	N001	1272	44°14′00″	17°33′00″	1969 - 1975、1977 - 1978、1980 - 2001
105		N103	2020	43°38′00″	17°40′00″	1966 - 2002、2004 - 2006

Sources: MOW.E

The tendency of areal rainfall characteristics is shown in Figure B.1-12. Regarding tendency on areal rainfall, in the north areas (representing by monitoring station J140 located in north of Jeddah) in the study area, annual rainfall is 100mm or less at the maximum.

In the mountain land area (representing by A107 monitoring station) of the central part in the study area, there is comparatively much annual rainfall and it reaches from 50 mm to 250 mm.

The Jazan Region located in the south area representing by SA137 station shows largest annual rainfall from 50mm in minimum to 400mm in maximum.

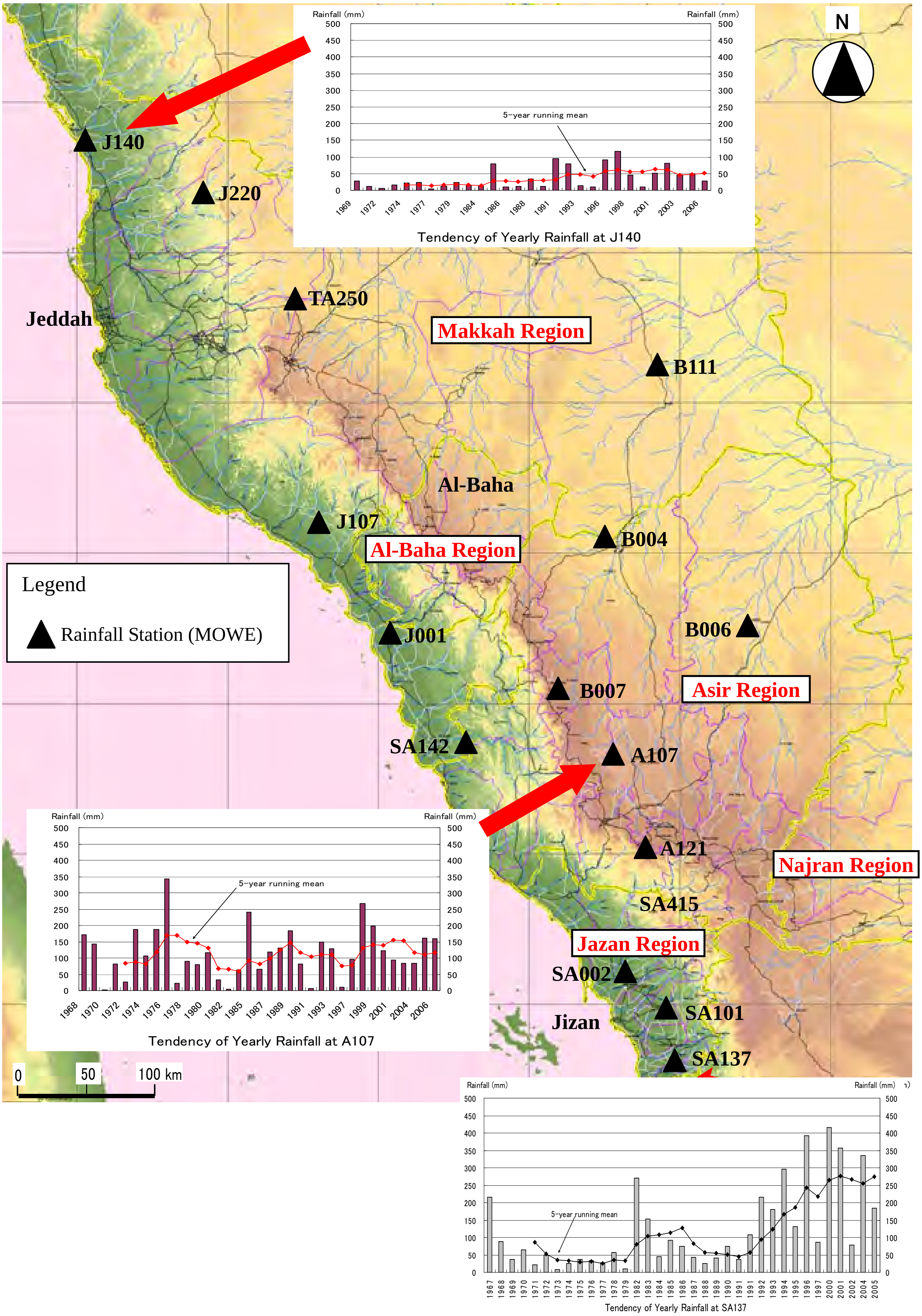


Figure B.1-12 Tendency of Annual Rainfall in the Study Area

(2) Tendency of Rainfall from 1968-2004

Based on the database of MOWE, the annual rainfall in 1968 - 2004 was arranged, and the amount of areal annual rainfall in 5 regions was calculated by the Thiessen dividing method.

These calculation results are shown in Figure B.1-13.

The tendency for annual rainfall to decrease is remarkable in recent years. According to these figures, Jazan Region has the most rain in the five regions, and annual average rain shows 400mm or more.

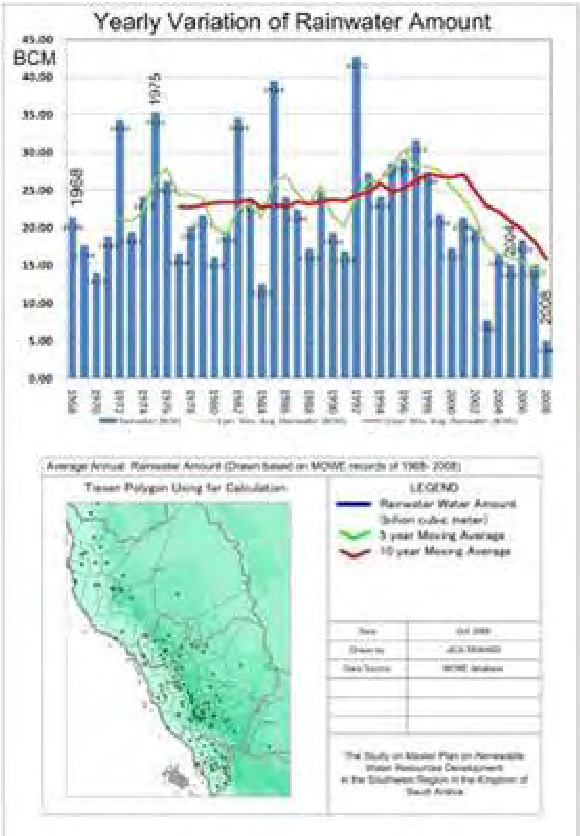


Figure B.1-13 Tendency of Annual Rainfall and Areal Distribution

(3) Runoff Stations

MOWE has 40 Runoff Stations in the study area shown in Table B.1-21, an observation of discharge has continued until around 1985. Location of the runoff stations in each region are shown in Supporting Report.

Table B.1-21 Runoff Stations under the Control of MOWE in the Study Area

N0.	Region	Station Name	Station No.	Catchment Area (km^2)	Altitude (EL.m)	Latitude	Longitude	Data Arrangement
1	Makkah	WADI RANYAH (LOWER)	B407	8,830	820	21°14′0″	42°47′0″	1973～1976, 1979～1981
2		WADI KHULAYS NR UM ADDAR	J401	2,671	100	22°11′10″	39°27′10″	1966～1981
3		WADI NAAMAN	J402	383	390	21°21′0″	40°7′0″	1967～1981
4		WADI RABIGH AT RABIGH	J403	4,500	8	22°48′25″	39°2′0″	1969～1981
5		WADI QUDAYD AT HAMMAMAH	J405	100		22°24′0″	39°23′0″	1969～1972
6		WADI SADIYAH AT SADIYAH	J407	1600		20°44′0″	39°55′0″	1970～1977
7		WADI SAFRA AT DAGHABIJ	J408	895.7	495	22°51′0″	38°54′0″	1967～1981
8		WADI GHORAN	J410	1405.6	100	21°57′20″	39°25′10″	1966～1981
9		WADI YIBA AT SUQ THULUTH	SA401	784	420	19°16′0″	41°48′0″	1970～1981
10		WADI YIBA AT SUQ JUMA	SA402	2722	80	19°2′30″	41°27′30″	1972～1978

N0.	Region	Station Name	Station No.	Catchment Area (km^2)	Altitude (EL.m)	Latitude	Longitude	Data Arrangement
11		WADI BISSEL	TA401	236	1525	21°12′0″	40°43′0″	1966～1981
12		WADI LIYYAH NR AT TAIF	TA402	182	1640	21°13′0″	40°27′0″	1966～1975
13		WADI TURABAH NEAR TURABAH	TA403	3720	1270	20°54′0″	41°37′0″	1966～1981
14		WADI WAJJ NR AT TAIF	TA404	120	1750	21°12′30″	40°20′20″	1966～1981
15		WADI WAJJ AT AKRAMAH DAM	TA405	230	1700	21°15′0″	40°21′0″	1966～1969
16		WADI ARDAH	TA407	1100	1450	20°32′0″	41°17′0″	1981
17		WADI SHUQUB	TA408	300	1500	20°40′0″	41°16′0″	1981
18		WADI SHUQUB	TA409	700	1500	20°45′1″	41°12′0″	1981
19	Al Baha	WADI RANYAH (UPPER)	B408	3,290	1,360	20°18′0″	42°6′0″	1972～1981
20		WADI DOQAH NR USHAYLAH	J404	970	80	19°45′0″	41°2′0″	1968～1981
21	Asir	WADI ABHA AT ABHA	A401	59	2,160	18°12′0″	42°29′0″	1966～1974
22		WADI ASHRAN AT MAZMA	A402	80	2,150	18°17′0″	42°28′0″	1966～1981
23		WADI BIN HASHBAL	A403	2285	1800	18°28′0″	42°42′0″	1966～1978, 1981
24		WADI HANI	A404	146	2,030	18°24′0″	42°31′0″	1966～1978, 1980～1981
25		WADI TINDAHA	A405	440	1,880	18°18′0″	42°51′0″	1967～1981
26		WADI ITWED AT KHAMIS MUSHATY	A406	500	1,950	18°18′30″	42°43′18″	1970～1973
27		WADI KHAMIS MUSHAYT AT KHAMIS MUSHAYT	A407	599	1,950	18°18′0″	42°44′0″	1970～1973
28		WADI BISHA NR HEIFA	B402	500	1,140	19°52′0″	42°32′0″	1967～1977, 1979～1981
29		WADI TATHLITH AT TATHLITH	B404	12,700	1,080	19°31′0″	43°30′0″	1967～1978, 1980～1981
30		WADI TUBALAH	B405	1,090	1,290	20°2′0″	42°13′0″	1969, 1971～1981
31		WADI BISHA AT SADA	B406	16,920	1,090	20°9′0″	42°42′0″	1967～1981
32		WADI HARJAB	B410	2,875	1,170	19°48′0″	42°35′0″	1979～1981
33		WADI SHERRI NR KWASH	SA404	119	410	18°58′38″	41°53′40″	1970～1977
34		WADI HALI AT AL HUSSAN	SA411	4575.6	298	18°46′0″	41°35′0″	1967～1981
35		WADI ITWAD (MAIN STATION)	SA414	1350	150	17°48′0″	42°21′0″	1967, 1969～1980
36	Jazan	WADI BAYSH AT FATIYAH	SA415	4713	200	17°34′0″	42°37′0″	1959～1963, 1968～1981
37		WADI DAMAD NEAR DAMAD	SA417	1000	130	17°9′0″	42°53′0″	1958～1964, 1966～1981
38		WADI JIZAN AT MALAKI	SA418	1200	42	17°3′0″	42°57′0″	1967～1981
39		WADI KHULAB NR SUQ AL AHAD MASARHA	SA421	900	99	16°43′0″	43°1′0″	1969～1981
40	Najran	WADI NAJRAN AT AS SAFA	N401	5,600	1,270	17°27′0″	44°4′0″	1967～1978

Sources: MOW.E

Looking on the areal tendency of annual runoff representing by station J410 located in north of Jeddah of the Makkah Region, there is runoff of 40 MCM in 1975, however, there is little runoff for other years in the north area. In the mountain land area representing by A403 monitoring station in the central area of the Study Area, although year change of runoff is large comparatively and there is a year showing runoff with 80MCM, small runoff have been continued in 1977 and afterwards.

In the Jazan Region representing by station SA421 located in south of the study area, it shows continuous runoff, and shows the runoff of 15 MCM in minimum or more 80 MCM in maximum. (refer to Figure B.1 -14)

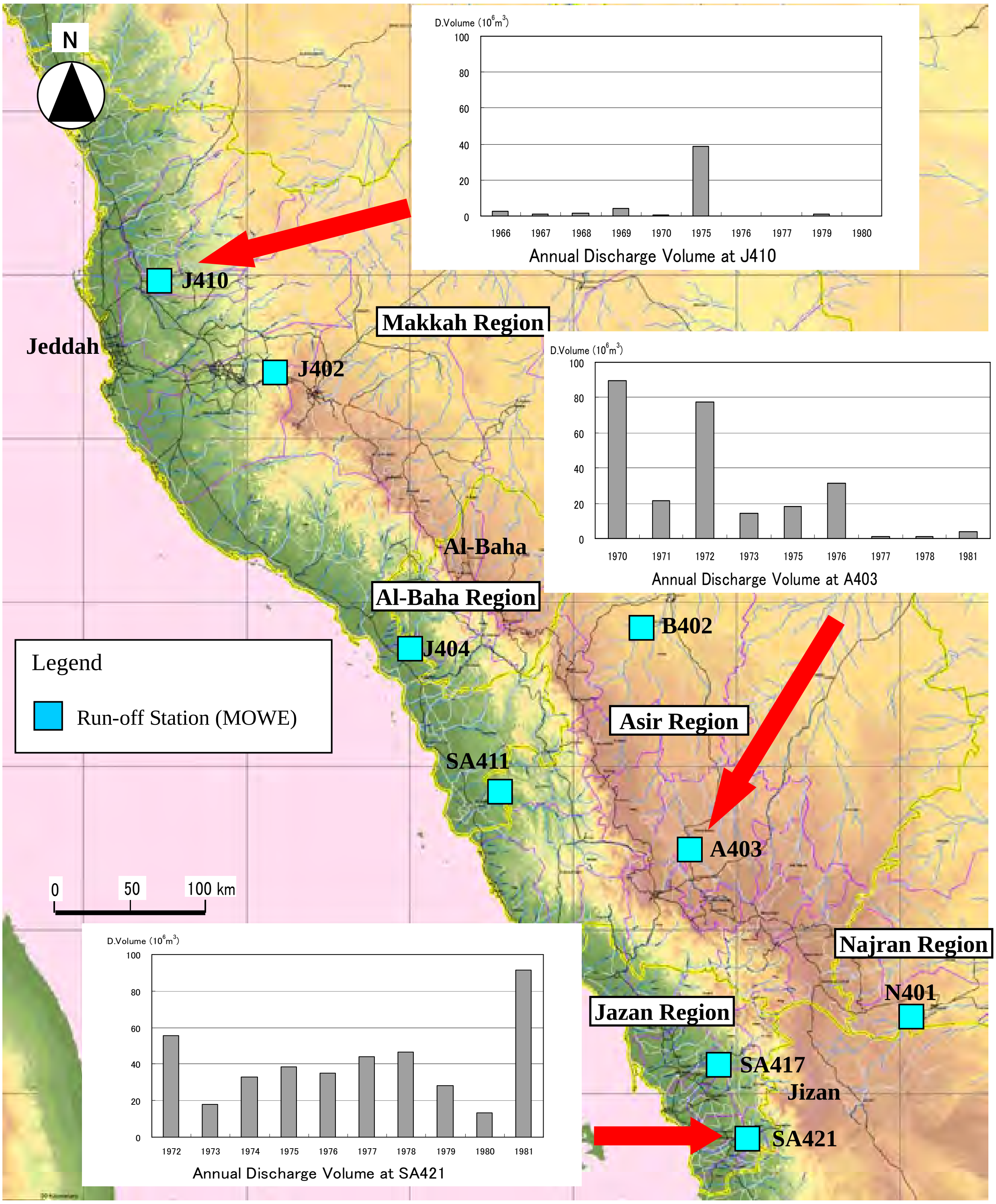


Figure B.1-14 Tendency on Annual Runoff in the Study Area

1.2.5 Hydrogeology

In the study area, the natural groundwater storage systems include aquifers from both the oldest and the youngest of he geologic ages. These are Precambrian crystalline rocks from the former age and others are of Recent alluvial deposits and eolian sands from the later age. The aquifer occurs within the sedimentary strata and volcanics overlying the Precambrian basement of the study area. The lithology sequence of these strata has been divided into eight major aquifers based on the lithology adjacent to the area as shown in Table B.1-22.

Table B.1-22 Lithology Sequence and Major Aquifers

Lithology Sequence	Principal Aquifers	Secondary Aquifers
1 Quaternary Sediments	-	**Alluvium**
2 Quaternary and Tertiary Volcanics	Neogene	**Basalt**
3 Eocene Carbonate to Upper Cretaceous Rocks	Damman Umm er Radhuma	Aruma
4 Middle and Lower Cretaceous Clastic Rocks	Wasia-Biyadh	Sakaka
5 Lower and Upper Jurassic Cretaceous Carbonate	-	Buwaib Yamama Sulay Arab Juballa Hanifah
6 Middle and Lower Jurassic Clastic and Carbonate Rocks	-	Dhruma
7 Jurassic, Triassic, and Permian Clastic Rocks	Minjur **Minjur/Dhruma**	Jilh Jauf
8 Lower Paleozoic Clastic Rocks	Tabuk **Wajid** Saq	

Note: Aquifer name shown in **bold** is being recognized in the Study area.

The distinction between principal aquifers and secondary aquifers occurring in the sequence is based on their hydrologic properties and aerial extent. The principal aquifers have greater permeability and larger yields than the secondary aquifer, and the amount of water in storage are observed to be of larger amounts in the principal aquifers. The layer primary consists of sandstone, limestone, and dolomites, compose the aquifer which has large aerial extent and great volumes of stored water. The sedimentary section consists of sandstone and interspersed with less permeable strata which act as confining beds.

The principal sandstone aquifers are widely distributed in the southeastern of the study area and locally possess excellent water-bearing properties varying greatly from place to place and can differ considerably within relatively short distances.

Water-bearing sandstone and limestone beds of the Mesozoic age, being correlative to Wajid and Minjur/Dhruma Aquifer in the south eastern part of the Asir and Najran Region, are good aquifers.

Important also, but of less water storage and lower yields, are the secondary aquifers. These aquifers are located throughout all the study areas and generally have minor sources of water, especially for local use. Some, however, are hydraulically connected with underlying principal aquifers and provide large quantities of water to wells.

In the study area, two principal aquifers: Minjur/Dhruma, Wajid: and two secondary aquifers: Alluvium and Basalt: are of principal groundwater resources.

1. Lower Paleozoic Clastic Rocks (Wajid Aquifer)
2. Jurassic, Triassic, and Permian Clastic Rocks (Minjur/Dhruma Aquifer)
3. Quaternary and Tertiary Volcanics (Basalt Aquifer)
4. Quaternary Sediments (Alluvium)

Four aquifers cropping out in the study area are shown in Figure B.1-30.

The principal aquifers are distributed in the southeast of the study area and locally possess excellent water-bearing properties (1 and 2 aquifer of the above). They comprise of Paleozoic to Mesozoic sandstone and limestone beds. Others, however less water storage and lower yields, are the Basalt and Tertiary to Quaternary Sediments. These aquifers are located throughout the study area and are generally used for local demands as minor sources (3, 4 aquifer of the above). General characteristics of aquifer are described as follows.

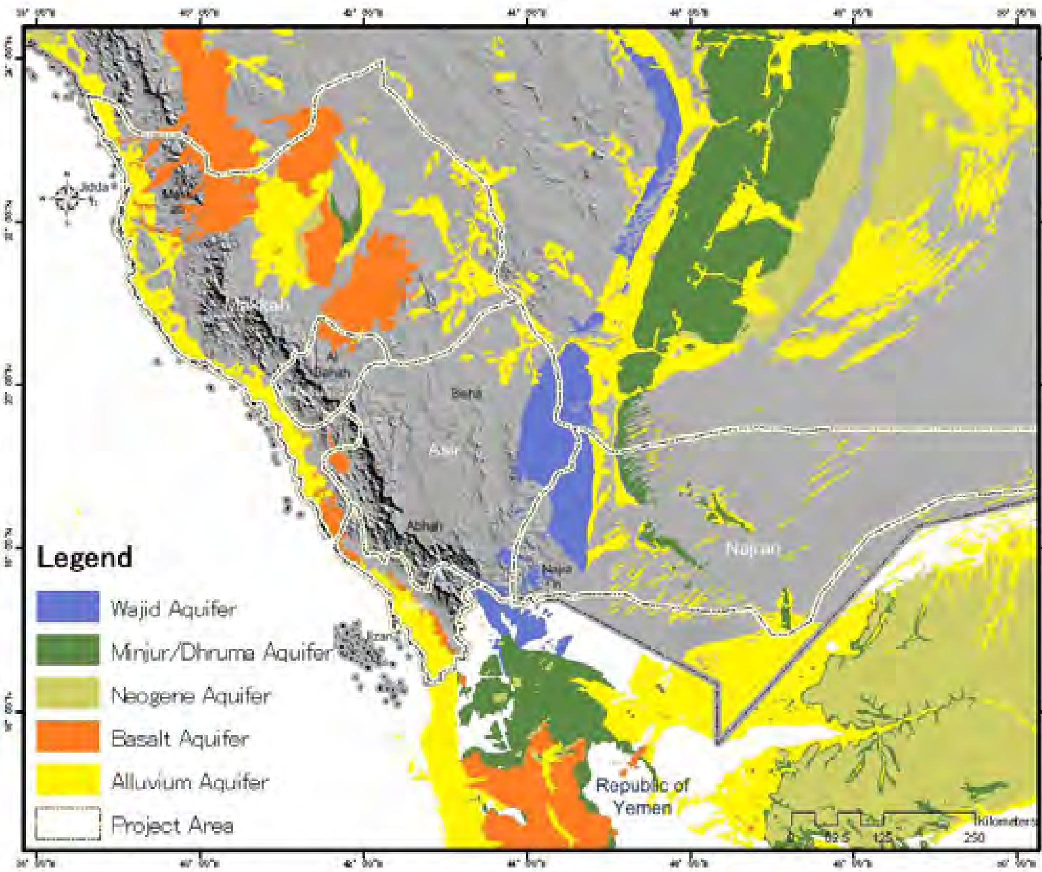


Figure B.1-15 Aquifers in Study area

<u>Lower Paleozoic Clastic Rocks (Wajid Aquifer)</u>

The Wadi Sandstone, named for the Jabal Wadi at latitude 19°06' N and longitude 44°27' E, overlaps the southeast edge of the Arabian Shield located on the border of the area. The age of sandstone, of which is considered to be Permian (USGS 1997) or Cambrian to Ordovician (Water Atlas of Saudi Arabia 1985) was determined by the stratigraphic position of the formation.

The rock is predominantly a fine to coarse-grained sandstone. The rocks are generally homogeneous, very porous, poorly cemented and interbeded with shale horizons. Large planar cross bedding is displayed throughout the sandstone horizons.

Location of Wadi Sandstone outcrop is exposed for about 300 kilometers south of the Wadi Dawasir to Wadi Habawnah and for about 100 kilometers to the west, dipping beneath the land surface near the escarpment of Jabal Tuwayq. The formation dips to the east and to the north beneath the Jabal Tuwayq. Although the limit of the subsurface extent is uncertain, data from test holes indicate that the Wadi Sandstone extends for at least 200 kilometers eastward beneath the Rub al khali.

Groundwater flows from the recharge area in the southern part of the Wadi Sandstone extent to the natural discharge areas in the northeast, where groundwater from the Wajid Aquifer seeps into the alluvium of the Wadi Dawasir.

The water quality is generally good and the dissolved-solids concentration of water in the aquifer is generally less than 1,000 milligrams per liter. The best quality of the water is found in the south near the recharge area. However, mineralization increases toward the north and the east.

<u>Jurassic, Triassic, and Permian Clastic Rocks (Minjur and Minjur/Dhruma Aquifer)</u>

The Minjur Sandstone is located in the east of Najran at latitude with a coordinates of 18°30' N and longitude 45°00' E. The geologic age of Minjur Sandstone is dated as Late Triassic. The Minjur Sandstone, which is originally of continental origin, is a massive bed with course to very coarse quartzitic sandstone with thin layers of limestone, shale, conglomerate and gypsum.

While Dhruma Formation is correlated to the Middle Jurassic age and is predominantly sandstone and shale, the maximum thickness of Dhruma Formation itself is about 100 meters. Dhruma Formation overlies Minjur Sandstone and may hydrologically act as a single complex.

<u>Quaternary and Tertiary (Basalt Aquifer)</u>

Lava fields (Harrat), along with numerous spatter or cinder cones and small flows or ash fields are scattered over an areas of Makkah of high lands and the Red Sea coastal area of Asir and Jazan Region. The basalt flows resulted from a series of eruptions during the Tertiary and Quaternary ages. The basalt generally overlies Quaternary ages. The basalt generally overlies sedimentary deposits. In places, basalts cover ancient alluvial deposits. These rocks display different properties within the sequence of flows; that is, some are vesicular with highly fissured and cavernous sections, and some are massive and impermeable. The Basalt aquifer exists where crevices, joints, and fractures have developed in the rocks. Direct recharge from rainfall makes these aquifers locally significant. Rainfall, however, is low over many of the outcrops and additionally the relatively impermeable rocks prevent infiltration. The most important aquifers were formed where the overlying Recent alluvium, basalt, and underlying sub-basalt alluvium are hydraulically connected and act as a single aquifer system.

<u>Quaternary and Tertiary (Alluvium)</u>

Alluvial aquifer lies on Eastern Slope and Red Sea Coastal Plain in the study area.

＜Eastern Slope＞
The area has wadis that radiate outward from the crystalline rocks of the Arabian Shield eastward to the sedimentary strata. In these areas, the valleys are widely irregular in shape and contain buried ridged and relict stream channels. In the relict channels, the lowermost part of the alluvium consists of coarse sand and silt.

The Alluvial Aquifers in many of the drainage areas including the volume of water in storage was sufficient to meet only local demands. Nevertheless, it is evident that problems related to groundwater development are shown to be the small aquifer size, the nature of the recharge, the rapid development of soil salinity when used for irrigation and the low permeability due to high silt content. In the study area, the most promising aquifers are in the Wadi Dawasir, of which the drainage is partly located in the eastern area of the Najran and Jizan areas. Other areas thought to be worth considering are the Wadi Bisha.

<Red Sea Coastal Plain>
Wadis that drain westward from the crystalline rocks to the Red Sea coastal plain are short and steep. In the headwaters, the wadis have cut deeply dissected narrow valleys. Deposits of alluvium are rarely more than 100 meters and are generally less than 10 meters thick.

Alluvial deposits fill many drainage areas on the costal plain. The deposits are laid down by flood waters as superficial material on the wadi floors and in the terraces above the wadi floors, deposited when the streams flowed at a high elevation.

Alluvium is made up of material that ranges various particle size from clay, silt, and sand to gravel and boulders. This material is laid down in the streambed as a series of fine to coarse deposits. Streambeds that are filled with coarse material serve as the best water-bearing deposits because of their ability to serve as a storage reservoir and to easily transmit water. The aquifer is generally unconfined but may be semi-confined or confined where silt and clay are interbeded with sand layers.

Aquifers in these deposits are mainly used for domestic and livestock supply but, locally, some are used for irrigation. The aquifers have often been tapped by galleries and wells. Yields to wells are small to moderate. The he specific conductance of this water was found to vary greatly, ranging from freshwater to saline water.

1.2.6 Groundwater and Water Quality

In the study area, four layers are regarded as the productive aquifers which have enough permeability and storage to effective extraction for bulk water use. Their general hydrologic characteristics and groundwater quality are described as follows:

Wajid Aquifer (Lower Paleozoic Clastic Rocks)

Wajid Aquifer lies on eastern area of Asir region and Najran region which occupy a part of Wadi Dawasir basin. The water quality is generally good and the dissolved-solids concentration of water in the aquifer is generally less than 1,000 milligrams per liter. They quality of the water improves eastward toward the Rub al Khali basin, but eventually the trend reverses and mineralization increases.

Minjur/Dhruma Aquifer (Jurassic, Triassic, and Permian Clastic Rocks)

Minjur/Dhruma Aquifer is limitedly found in Makkah Region as remnant, and Najran Region overlaid by recent eolian sand in Rub al Khali. Water quality data has indicated that the saline increase down-gradient and with depth. The dissolved solids ranged from freshwater to saline water.

Basalt Aquifer (Quaternary and Tertiary)

Basalt Aquifer covers extensive area in the Makkah region. Mineral concentration of the water from the Basalt Aquifer was shown to be generally low. The specific concentration was reported as a range from freshwater to brackish water and Sodium and chloride were the dominant ions.

Alluvium (Quaternary and Tertiary)

Alluvium aquifer is located everywhere in extensive areas: the Red Sea coastal strip, along with wadi courses, mountainous basins and even in eolian sands in the study area. The specific conductance of this water was found to vary greatly, ranging from freshwater to saline water. The percentages of sodium and chloride were slightly higher than the other dissolved minerals. As total mineralization increased, however, the sodium and chloride concentrations became increasingly dominant.

The record of Eclectic Conductivity (EC) had been collected since the 1980's to evaluate potable water quality. Figure B.1-16 shows EC distribution of the area delineated with maximum values from a survey well (Water Atlas of Saudi Arabia, 1984).

EC of less than 2,000 micro S/cm (indicated in blue and light blue in Figure B.1-16) would require no treatment for drinking purpose in the local use except possibly for chlorination to ensure that it was bacteriological safe. Water with EC of 2,000 to 6,000 micro S / cm can be used for livestock watering and some crops in irrigation. Water with EC in excess of 6000 micro S /cm has only limited use without extensive treatment.

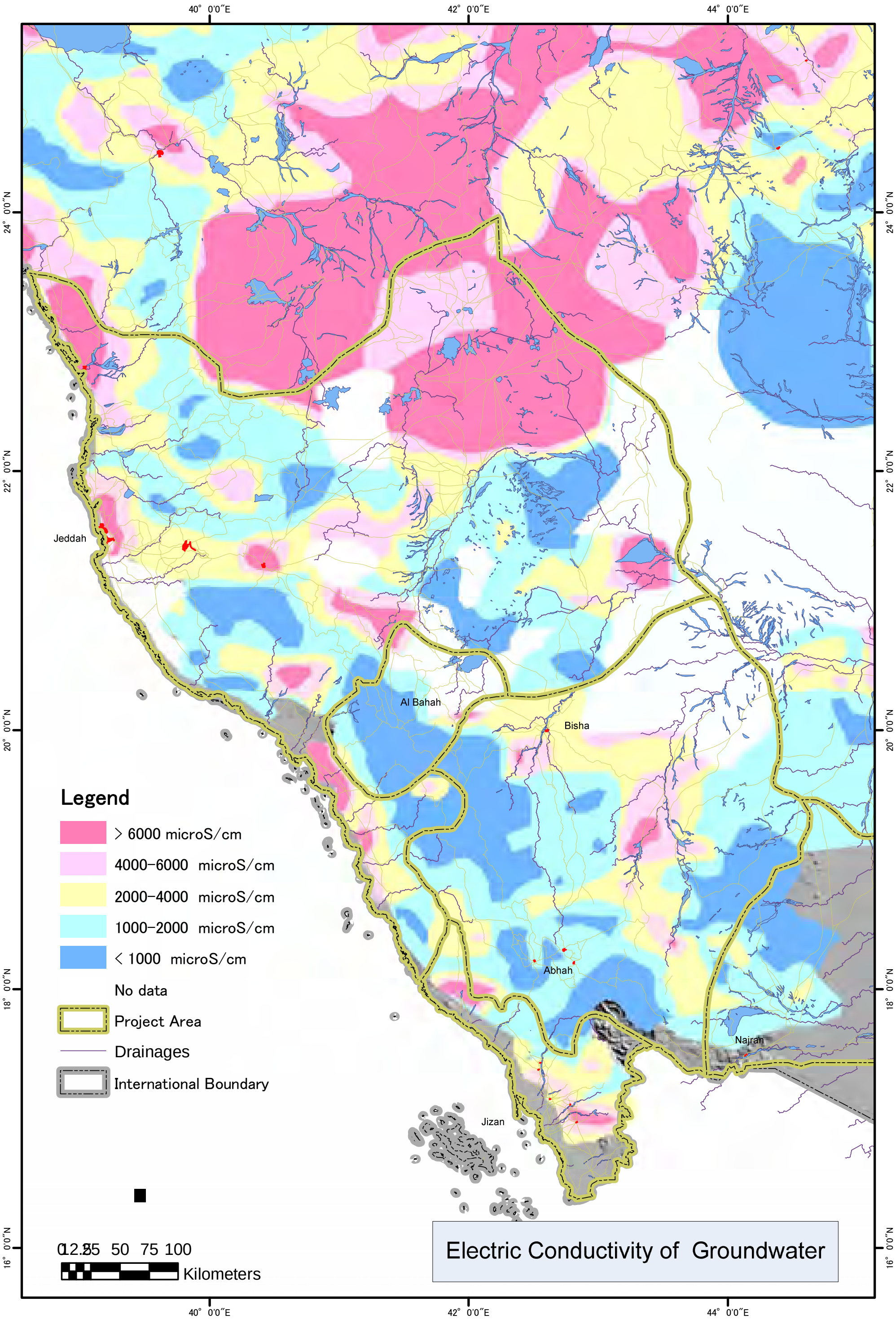


Figure B.1-16 Electric Conductivity of Groundwater in the Study area

1.2.7 Land Use

Land use map was collected from International Steering Committee of Global Mapping (ISCGM) product covering the study area at 1 km resolution in a consistent manner and its content is equivalent to conventional maps at scales of 1:1,000,000. These geographic data sets are composed of not only land-use but also elevation, vegetation, land-cover, transportation drainage systems, boundaries and population centers and the data will be updated at approximately five-year intervals to facilitate the monitoring of changes occurring in the global environment. Figure B.1-17 shows the land use map dated Nov. 2006 prepared by General Directorate of Military Survey KSA and Geographical Survey Institute JAPAN.

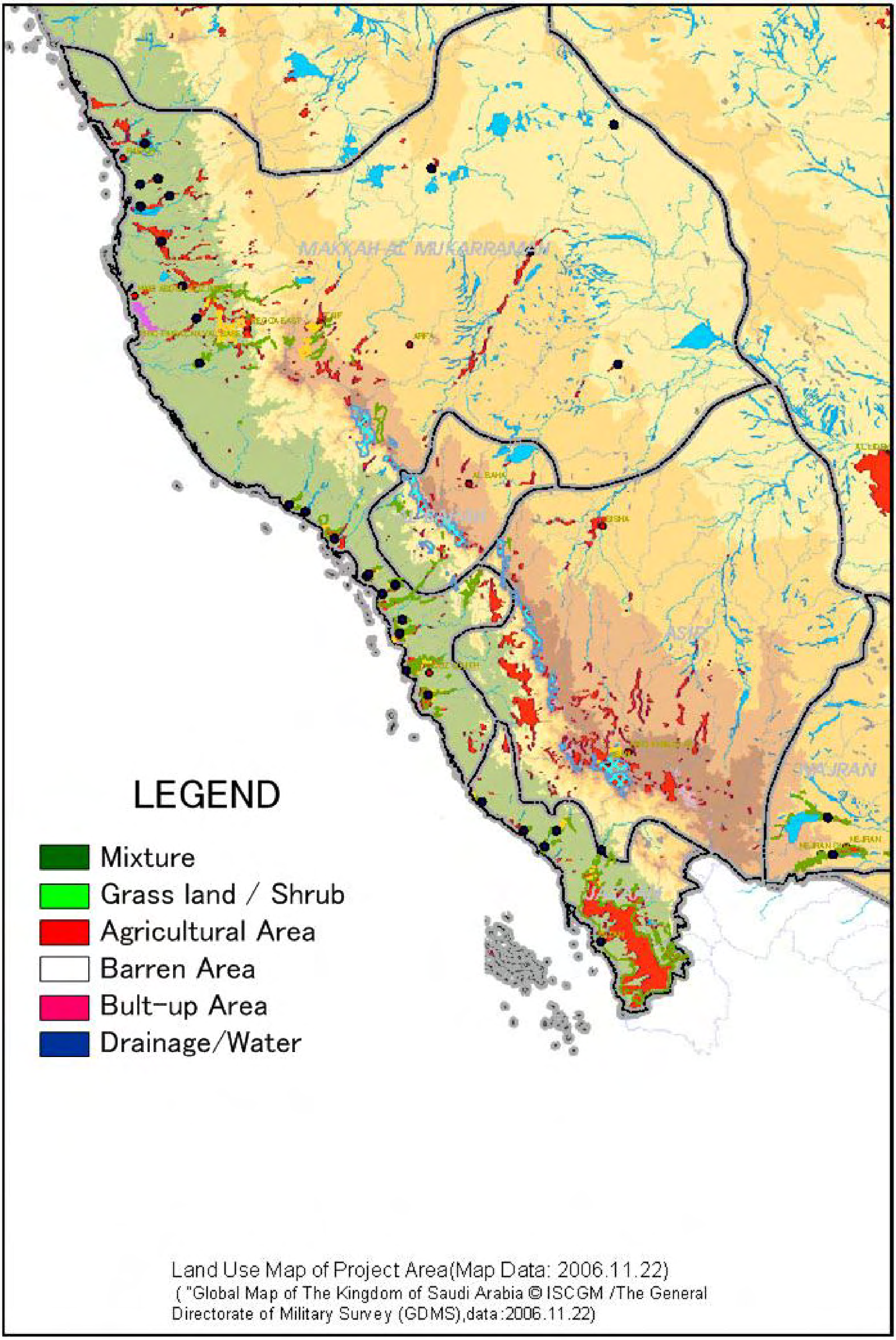


Figure B.1-17 Land Use Map in the Study area

1.2.8 Fauna and Flora

Characteristics of Habitats

The majority of the study areas are covered with the artificial environments such as agricultural land and residential land, and desert areas or wastelands. Therefore, these areas are not suitable for development of ecosystem. On the other hand, the average annual rainfall in the Al Hijaz Asir highland, which runs through the center of the study area, amounts to 300-500 mm. Such relatively high rainfall brings rich biodiversity in the area. According to the First Saudi Arabian Report on the Convention of Biodiversity, the kingdom has 10 "large" and 11 "small" areas of juniper forest, most of which fall inside the study area. These areas are some of the few forested areas in the country, and as well as being important as areas of soil formation and desertification barriers, they also host a comparatively high diversity of other plants and animals.

Endemic or Endangered Species

Saudi Arabia became a signatory to the Convention on Biodiversity (CBD) in 2001, demonstrating its continued commitment to maintaining biodiversity.

Saudi Arabia is home to a number of endemic and / or endangered species of animal, some of which, such as the Houbara Bustard (Chlamydotis (undulata) macqueenii) and the Arabian Oryx (Oryx leucoryx), have received worldwide attention.

Less global attention is given to Saudi Arabia's floral biodiversity, despite it being home to a number of species of international importance, such as the Nubian Dragon Tree (Dracaena ombet), classified in the IUCN Red List of Threatened Species as endangered and the East African Juniper (Juniperus procera), classified as near-threatened.

Due to the local conditions already described, the study area is estimated to hold around 70% of the kingdom's 3000 or so plant species, indicating that a considerable proportion of the faunal species are likely to be present in the same area. Further clarifications are needed in order to identify precisely which species of note are to be found within the study area; however the following are already identified as being important species present in the area, either due to their endemicity, rarity or as a "flagship species."

Flora:	• *Juniperus* sp. Reasonably widespread at higher elevations; • *Ziziphus* sp. Christi (Christ's Thorn Jujube) Common in wadi beds and rangeland, and has many uses in Arabian culture from shade to fruit and forage, soap, timber, and honey production; • *Acacia* sp. This community is generally confined to gravelly wadi-beds and slopes of the study area; • *Olea europaea* (Olive). Generally found on slopes below Juniper communities.
Fauna:	• *Chlamydotis (undulata) macqueenii* (Houbara Bustard) ; • *Oryx leucoryx* (Arabian Oryx); • *Dendrocopos dorae* (Arabian woodpecker) – Listed by IUCN as vulnerable, and endemic to Saudi Arabia and the Yemen; • *Caracal caracal* (Caracal Lynx)

Protected Areas

A long tradition of protected or managed areas exists within the Arabian Peninsula, based on the Hima system. Hima are traditionally managed grazing, woodcutting and / or hunting areas, many of which have been destroyed by modern agriculture practices or neglect.

One of the most comprehensive Hima systems in Saudi Arabia existed in the Al Baha region in the present study area. This, like all Hima, had its own unique formula for conservation; a blend of traditional agricultural methods, environmental conditions, and social factors, which allowed for the sustainable use of natural resources. Attempts to revive certain elements of the system are now underway, mainly as part of the management program for Saudi Arabia's growing number of protected areas.

Theoretically, Saudi Arabia has 5 different types of national protected areas, which have been compared by the IUCN categories (the accepted benchmark) and assigned the equivalencies shown in Table B.1-23 below.

Table B.1-23 Saudi Arabian Protected Area Categories and their IUCN Equivalents

Saudi Arabian Designation	Equivalent IUCN Categories	
Special Nature Reserve (SNR)	Ia	Strict Nature Reserve: protected area managed mainly for science
	IV	Nature conservation reserve or managed reserve / wildlife sanctuary
Natural Reserve (NR)	II	National Park: protected area managed mainly for ecosystem protection and recreation
	IV	Habitat/Species Management Area: protected area managed mainly for conservation through management intervention
Biological Reserve (BR)	Ia	see above
	V	Habitat/Species Management Area: protected area managed mainly for conservation through management intervention
Resource Use Reserve (RUR)	V	Protected landscape or seascape
	VI	Managed Resource Protected Area: protected area managed mainly for the sustainable use of natural ecosystems
	VIII	Multiple use management area
	IX	Biosphere reserve
Controlled Hunting Reserve	VIII	Multiple use management area

Source: First Saudi Arabian National Report on the Convention on Biological Diversity

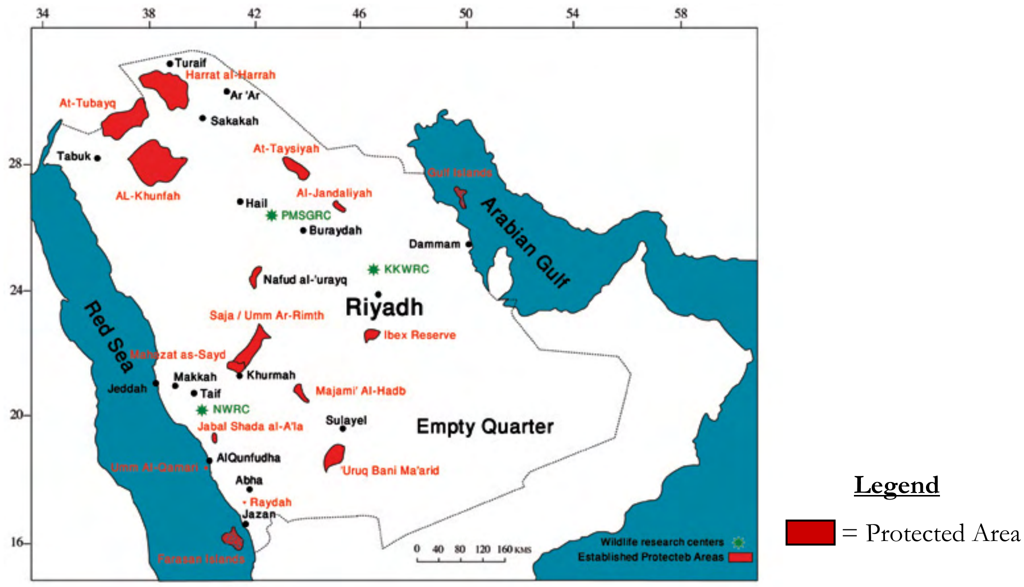
To date, 15 protected areas, covering almost 4% of the country's surface conserve all the major physiographic regions, half the country's biotopes, key wetlands, marine and mountain habitats and protect viable populations of endemic, endangered and key plant and animal species.

Table B.1-24 Protected Areas within the Study Area

Name of Protected Area	Region	Year Created	Category	Size of Area (km^2)
JABAL SHADA AL-A'LA	Asir	2002	SNR	67
Raydah	Asir	1989	SNR	9

Source: Based on information found on NCWCD website (www.ncwcd.gov.sa)

Two further protected areas; Uruq Bani Ma'arid and Saja/Um Ar Rimth lie very close to the study area (in the Empty Quarter and Al Riyadh districts respectively) but are thought not to straddle the district borders of the study area. The precise location of these protected areas is to be confirmed with the GIS department of the National Commission for Wildlife Conservation and Development (NCWCD).



Source: Created using base map from www.fitfortravel.scot.nhs.uk

Figure B.1-18 Protected Areas in the Study Area

1.2.9 Vegetation

The vegetation (land cover) map illustrates important valuables in estimating water demand and understanding water balance. The map was collected from Global Land Cover Facility (GLCF) products. It was processed with satellite images from 1981 to 1992 and composed of 1 km spatial resolution (grids) with 14 classifications, as shown in Figure B.1-19.

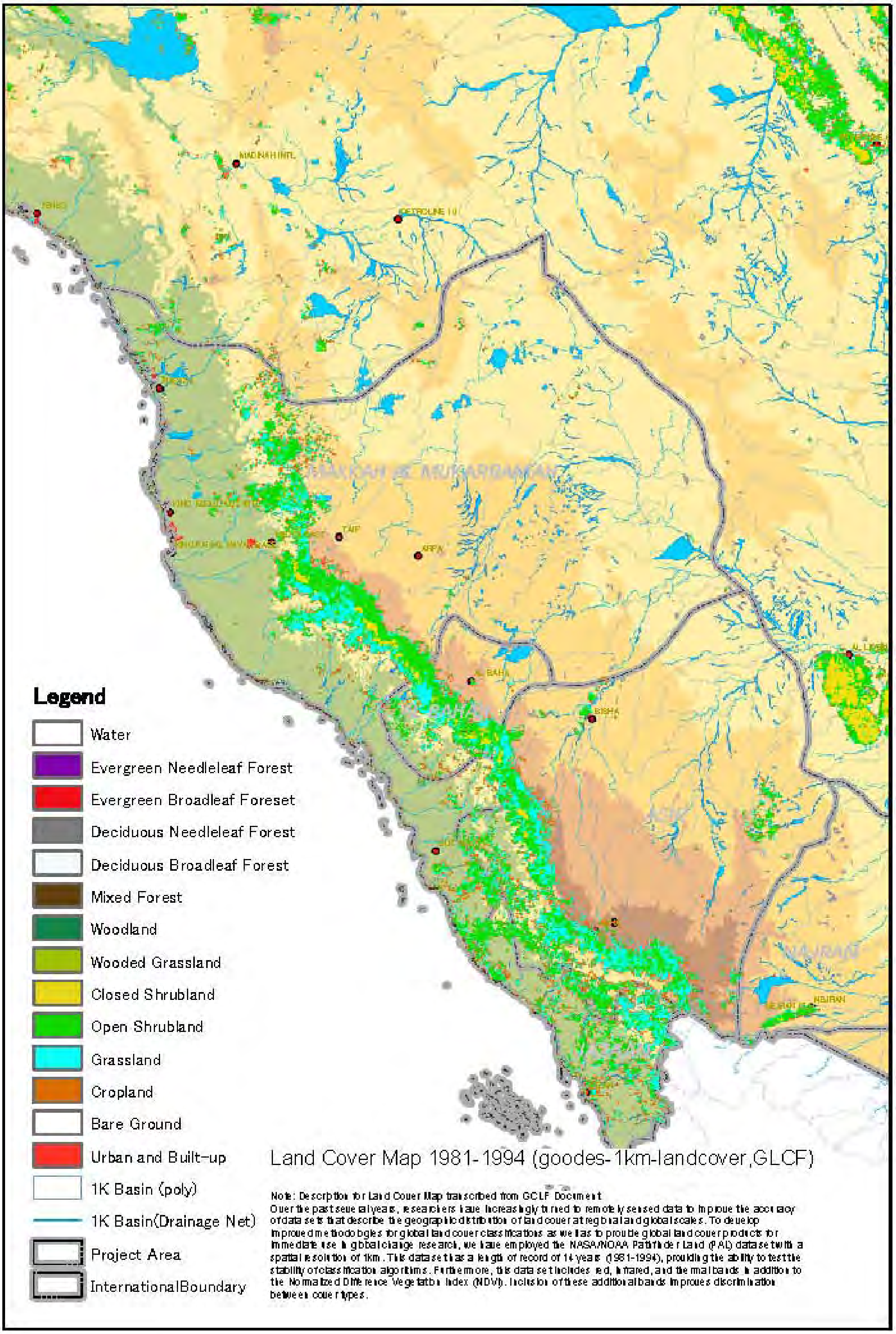


Figure B.1-19　Landover Map in the Study area

1.3 Previous Studies and Plans for Conventional Water

1.3.1 General

Conventional water resources in KSA classified as runoff water, shallow groundwater and fossil ground water. It is classified as runoff water and shallow groundwater which are recharged by rainfall, while classifieds as fossil groundwater which is not recharged by rainfall in a short term shown in Table B.1-25.

Table B.1-25 Classification for Conventional Water

Classification	Definition
Runoff Water	Recharged by rainfall (Renewable water)
Shallow Groundwater	Recharged by rainfall (Renewable water)
Fossil Groundwater	Not recharged by rainfall

1.3.2 Previous Study for Runoff Water and Groundwater

To aid in grasping the hydrological characteristics and plan for water resources development facilities as well as cost survey, Ministry of Water and Agriculture started the hydrological study in five Wadis: Al Lith, Tabalah, Yiba, Habawnah and Liyyah, in 1984.

The principal objectives of the study for five Wadis are:

1) To obtain a quantities understanding of the water balance of the representative basins
2) To assess the water resources
3) To establish new and/or improve existing hydrological data banks.

Table B.1-26 Description on 5 Wadis Study

Items	Study Description
1. Study Area	Al Lith (A= 3,079 Km^2), Tabalah (A=1,900 km^2), Yiba(A= 2,830 km^2), Habawnah (A= 4,930km^2), Liyya(A=456 km^2)
2. Study Period	1984 -1989
3. Output of the Study	1) Basin descriptions, 2) Climate, 3) Rainfall, 4) Evapotranspiration, 5) Soil moisture 6) Surface water, 7) Groundwater, 8) Water Quality Sediment, 9) Land Classification 10) Hydrological simulation by HSPF, 11) Water Resources assessment and development
4. Execution Agency	Water resources development department, MOAW

注: Basin Report for each Wadi, Saudi Arabian Dames & Moore

According to the reports, catchment area, annual rainfall and available water in MCM are shown in Table B.1-27.

Table B.1-27 Available Water Resources Volume in 5 Wadis

Items	Wadi Lith	Wadi Yiba	Wadi Liyyah	Wadi Tabalah	Wadi Habawnah
Catchment Area (km^2)	3,079	2,830	456	1,900	4,930
Annual Rainfall (MCM/Year)	583.2	982.0	134.8	346.7	665.0
Available Water(MCM/Year)	16.1	19.7	12.5	22.2	30.7

Notes) 1.Annual rainfall is mean values of the 50 year based on the simulation
2. Available water is estimated by “hydrological simulation program FORTRAN” (HSPF)

Of these Wadis, proposals for the construction of dam are made in Wadi Lith, Wadi Yiba and Wadi Tabalah. In parallel to the study for 5 Wadis, the Ministry of Agriculture (MOA) started the study on water resources such as dams including well field.

Table B.1-28 Planned Dams and Dimension (Planned 1983-1987)

No.	Dams	Region	Catchment Area (km^2)	Reservoir Volume ($10^*3\ m^3$)	Purpose of Dam
1	Rabigh Dam	Makkah	3,456	220,350	Control
2	Al Muruwani Dam	Makkah	2,762	183,600	Control
3	Al-Lith Dam	Makkah	1,838	88,570	Control
4	Ranyah Dam	Al Baha	4,375	219,750	Control & Recharge
5	Aqiq Dam	Al Baha	304	22,500	Drinking
6	Tabalah Dam	Asir	863	54,600	Control
7	K.Fahd Dam	Asir	7,600	325,000	Recharge
8	Hali Dam	Makkah	4,843	249,560	Control
9	Wadi Baysh Dam	Jazan	4,600	193,644	Drinking
10	Qissi Dam	Jazan	272	12,000	Control & Irrigation
11	Sabya Dam	Jazan	376	-	Control & Irrigation
12	Damad Dam	Jazan	903	55,500	Potable

Sources) 1 Final Report for each dam (1983-1987)、2. Water Project in the Kingdom of Saudi Arabia

Among these dams, the two dams currently in operation are Aqiq Dam and King Fahd Dam. All other dams are under construction as of 2009.

To cover the required demand 20,000 m^3/day for potable water in the area including the Cities Abha, Khamis Mushayt and Ahad-Rifayda in Asir Region, the water resources development study was carried out by MOAW in 1997. Wadi Itwad and two tributaries flowing near Ad Darb Town in the south coastal area were selected for the sites of development of water resources. Description of Water resources development project is shown in Table B.1-29.

Table B.1-29 Description in Wadi Itwad

Facilities	Dimension	Supply volume	Cost
Underground Dam	30m (depth) and 300 m (width)	12.85 MCM/Year	Total Cost: 220 MSR Unit Water Cost: SR 0.93/m^3
Maraba Dam	Concrete Faced Rockfill Dam, H=37m, Dam Volume=664,000 m^3, Reservoir=10,000,000 m^3		
Itwad Dam	Concrete Faced Rockfill Dam, H=36m, Dam Volume=920,000 m^3, Reservoir=10,200,000 m^3		
Wells	10 Wells from No.1 to No.10		

Souece: Wadi Itwad Development for Water Supply reconnaissance report (July, 1997)

To develop water resources of Wajid and overlying aquifers located in the northern area of Najran, MOWE contracted with Deutsche Gesellschaft fur Technische Zusammenarbeit (GTZ) in April, 2006. The project titled "Detailed Water Resources Studies of Wajid and Overlying Aquifers", abbreviated " Wajid Project", will be executed for 3 years until April, 2009. The study is divided in two phases. Phase I includes a reconnaissance stage and a preliminary study. Phase II is the continuation of Phase I in detailed form.

The Wajid Aquifer belongs to the southern part of the hydro-geological area called Arabian Platform, and is divided into Lower Wajid Aquifer mainly located in the lower part, and Upper Wajid Aquifer (mainly sandstone) located in the upper part.

Besides between the aquifers of a part and the lower part, the Middle Jurassic-Lower Cretaceous Aquitard exists.

The overview of the Wajid Project is shown in Table B.1-30

Table B.1-30 Overview of the Study of Wajid Project

Items	Overview
1. Study Area	Entire surface water catchment of the recharge area of the Wajid aquifer The outcrop of the Wajid sandstone on the Arabian Peninsula and currently known subsurface extension of the Wajid aquifer.
2. Survey Area	Located between the outcrop of the Wajid aquifer in the west longitude 49°east in the east, and between the Yemen border in the south and latitude 22° north in the north.
3. Main objectives	1) To evaluate the surface water and groundwater potential of the aquifers 2) To get a quantitative understanding of surface water processes for all major basins 3) To establish new hydrological network 4) To assess recharge to shallow and deep aquifers from direct rainfall.

Items	Overview
	5) To determine optimal and safe yield study of the aquifers 6) To determine restrictions on the usage of the available water resources 7) To create a computed database. etc.
4. Study period	April, 2006 – April, 2009 (36 months)
5. Project cost	Project consulting cost : SR 47,779,176 Drilling and testing of wells : SR 28,900,000

Source: Detailed water resources studies of Wajid and overlying aquifers, Phase I Completion Report (GTZ)

Based on the Final Main Report, study results are summarized as follows.

Table B.1-31 Study Results of Wajid Study (GTZ)

Items	Study Results（Main Report）
1. Results	1) Filed investigations (Water point inventory, Monitoring network, Pumping tests) 2) Drilling program, geology and hydrogeology 3) Ground water abstractions 4) Groundwater quality 5) Groundwater model 6) Groundwater resources 7) Case study: wadi Ad Dawasir
2. Recommendations for water management	1) Sustainable water use on the Arabian shield 2) Smart groundwater mining on the Arabian Platform

Source: Detailed water resources studies of Wajid and overlying aquifers, Main Report (June, 2009)

The water budget of the main Wadis in Wajid Study based on the simulation is shown in Table B.1-32. In conclusion, since outflows are larger than inflows, it shows reduction of 171MCM/Year.

Table B.1-32 Water Budget in Major Wadis(2006)

Wadi	Inflows (MCM/Year)		Outflows(MCM/Year)			Balance
	G.W Recharge	Reservoir extraction	Domestic & Industry	Agriculture	Groundwater Outflow	In - Out
Turaba	171	0	4.97	134.3	0	31.73
Ranya	103	0	2.47	81.4	0	19.13
Bisha	211	100	14.38	444.3	0	-147.68
Tathlith	165	4	5.16	23.5	4	136.34
Yadamah	20	0	1.68	0.4	0	17.92
Habawnah	37	0	2.62	90.8	0	-56.12
Najran	39	0	18.54	162.4	30	-171.94
Total	746	104	50	937	34	-171

Source: Detailed water resources studies of Wajid and overlying aquifers, Main Report (June,2009)

Groundwater budget of the Lower Mega Aquifer System for the predevelopment state and present state have brought the following results. At the present state and due to over abstraction for agricultural use, budget of inflows and outflows are in negative, and leads to a drawdown in piezometric height, summing up to more than 150m in 30 years.

Table B.1-33 Groundwater Budget (Predevelopment State and Present State)

(MCM/Year)

Budget Component	Predevelopment State	Present State
Groundwater recharge from precipitation	32	50
Irrigation return flow	0	246
Wadi flow	117	41
Total Inflow	149	319
Evaporation	35	65
Outflow to upper Mega Aquifer System	38	38
Domestic groundwater abstraction	0	65
Agriculture groundwater abstraction	95 (including domestic)	2,051
Total Outflow	168	2,151
Change in Storage	-19	-1,832

Source: Detailed water resources studies of Wajid and overlying aquifers, Main Report (June, 2009)

Recommendations for water management by GTZ are summarized as follows.

Sustainable Water Use in the Arabian Shield

As shown in Table B.1-32, outflows exceed inflows by 171 MCM/year. In the future, a more sustainable use of water resources is possible. Measures to achieve sustainability include:

1) Enhancement of groundwater recharge by new dams, improved management of existing dams and landscaping of groundwater infiltration areas.
2) Reduction of agricultural groundwater abstraction by enhancement of irrigation efficiencies, limitation of cultivated area and use of reclaimed wastewater.

Smart Groundwater Mining on the Arabian Platform

Groundwater of the Arabian platform represents a non-renewable natural resource. Groundwater use is characterized by locally high abstraction rates for agricultural purposes. It is the objective e of groundwater management to conduct the groundwater mining as smart as possible. These recommendations include:

1) Diversion of abstraction locations, to avoid long aquifer recovery times and groundwater quality deterioration.
2) Reduction of total rate, to use the groundwater resources as long as possible.
3) A shift usage characteristics from agricultural use to domestic use, to enhance the economic value of the abstracted groundwater.

1.3.3 Dams and Wells

(1) Dams

In the Kingdom of Saudi Arabia, as measure of surface water development, dam constructions have been introduced. 126 dams had been already constructed and 86 dams are under construction in the study area as shown in Table B.1-34. The Number of dams in the Asir Region shows the largest number.

Table B.1-34 Dams in Study Area

Region	Existing					Under Construction					Total
	Potable	Recharge	Control	Irrigation	Total	Potable	Recharge	Control	Irrigation	Total	
Makkah	2	23	3	0	28	0	8	4	0	12	40
Al Baha	1	21	3	1	26	4	5	0	0	9	35
Asir	13	35	15	0	63	10	24	5	0	39	102
Jazan	1	0	1	1	3	12	0	1	0	13	16
Najran	0	3	3	0	6	1	11	1	0	13	19
	17	82	25	2	126	27	48	11	0	86	212

Source: Project Execution Department, MOWE

Although there are dams, which have multiple-purposes in KSA, only a single purpose is shown in the data of MOWE, and classified into this specific purpose.

Since development supply volume of water is not shown, it is taken as arrangement of the planned reservoir storage of the dam. Total Reservoir Volume of Dams including the existing dams in the 5 Regions is 1,920 Mm^3. Of which 1,260 Mm^3 (66%) are occupied by under construction dams.

Table B.1-35 Reservoir Volume in Dams (MCM)

Region	Existing					Under Construction					Total
	Potable	Recharge	Control	Irrigation	Total	Potable	Recharge	Control	Irrigation	Total	
Makkah	42.8	54.1	12.8	0.0	109.6	0.0	189.0	559.4	0.0	748.4	858.0
Al Baha	22.5	7.9	0.1	0.5	31.1	76.4	21.7	0.0	0.0	98.1	129.2
Asir	19.2	352.2	2.5	0.0	373.8	45.5	8.1	81.1	0.0	134.7	508.5
Jazan	0.3	0.0	0.2	51.0	51.4	79.9	0.0	193.6	0.0	273.6	325.0
Najran	0.0	1.3	86.9	0.0	88.2	0.0	7.8	0.6	0.0	8.4	96.6
	84.8	415.4	102.4	51.5	654.1	201.8	226.6	834.7	0.0	1263.2	1917.3

Source: Project Execution Department, MOWE

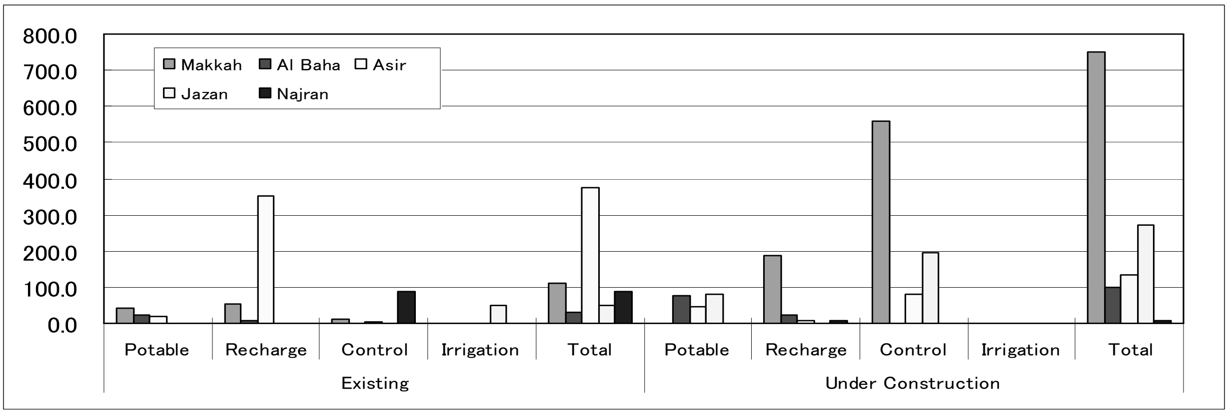


Figure B.1-20 Reservoir Volume for each Region

(2) Wells

Many wells have been drilled in the Kingdom of Saudi Arabia for the purposes of provision of water, monitoring of water level and water quality and agricultural use. According to a book on water resources development facilities in the KSA, 824 wells are listed during the period from 1989 to 2005 by Regions as shown in Table B.1-36.

Table B.1-36 Number of Wells in the Study Area

Region	Pipe Wells	Dug Wells	Total
Makkah	55	118	173
Al Baha	0	105	105
Asir	8	231	239
Jazan	91	127	218
Najran	76	13	89
Total	230	594	824

Source: Water Project in the Kingdom of Saudi Arabia

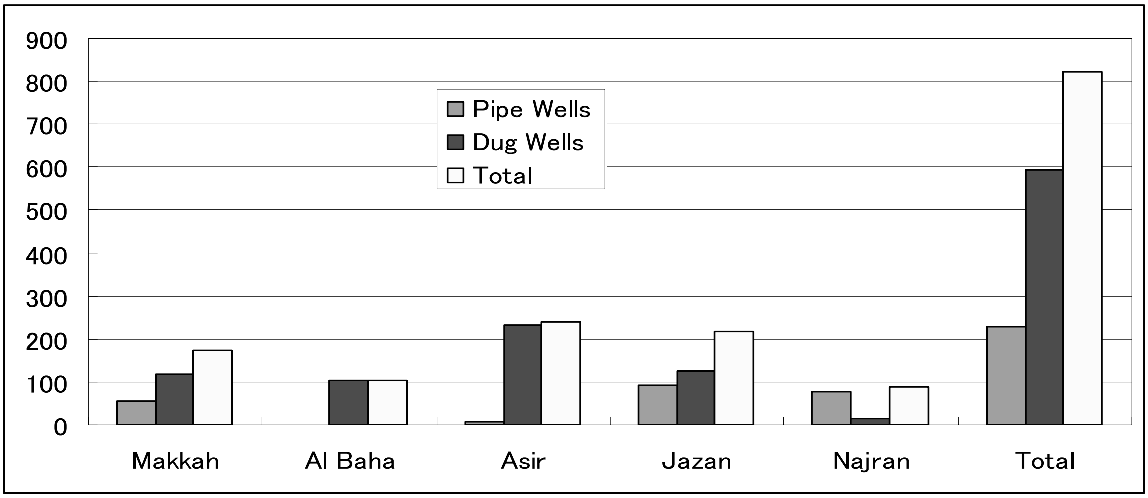


Table B.1-21 Number of Wells in the Study Area(1982-2006)

1.3.4 Issues on Development of Conventional Water Resources

Issue on development of conventional water resources is arranged as follows.

- The renewable resources (surface runoff) have the tendency of large changes for every year, and can be utilized as effective water resources by storing of dams. In addition, for storing in dams, it is important to take into consideration the influence of an amount of evaporation.
- The water is mainly stored in Quaternary Wadis sediments. Over abstraction is remarkable in these areas. The water levels of groundwater will need to be managed in the Quaternary areas

along the Red Sea.

- The mountain areas in the west of the Study area, only wadi circumference area has the potential of groundwater development.
- According to areal distribution of rainfall, areas suitable for development of the water resources development will be limited. That is, Jazan Region has high potential of water development, followed by the circumference areas such as southern areas of Makkah Region and Asir Region.
- The northern area of Makkah Region, Al Baha Region, northern area of Asir Region near Bisha, and the Najran Region have little rain, and need large catchment areas for the development water resources by construction of dam.
- Dams in the under construction stages such as Rabigh Dam, Maruwani Dam were planned in the 1980s and started construction in accordance with the year 2000 schedule. Wadi Itwad project was started in 1997 and was completed in 2009.
- Dam sites should be designated by taking into consideration the geographical features, the viewpoint of geology, and the viewpoints of hydrology on discharge a water etc. The Study Team proposed five dam sites selected based on the topographic maps such as the Wadi Gholan and Wadi Khulab. Through meetings with MOWE, however, there were no suitable as dam site identified and therefore judged as appropriate dam sites at present.
- As for the dam operation, it remains only in operation of each dam, and cooperative operation among dams is not made. In major dams located in the Study Area, it is necessary to examine the possibility of cooperative operation.
- Regarding fossil aquifer, it is important to check the amount of Resources at first. Furthermore, in consideration of being limited resources, maintenance and preservation plan for fossil aquifer should be draw up and should be done for bare essentials of use.

1.4 Current State and Supply Plan on Desalinated Seawater and Waste Water Reuse

1.4.1 General

Non-conventional water resources in the KSA are classified as desalinated seawater and reclaimed wastewater. The former carries out desalination processing by making seawater into fresh water. The latter aims at reuse of reclaimed wastewater, and is used as the source for agriculture, water in the city, and industrial water. It is classified as shown in Table B. 1-37.

Table B.1-37 Classification for Non-conventional Water

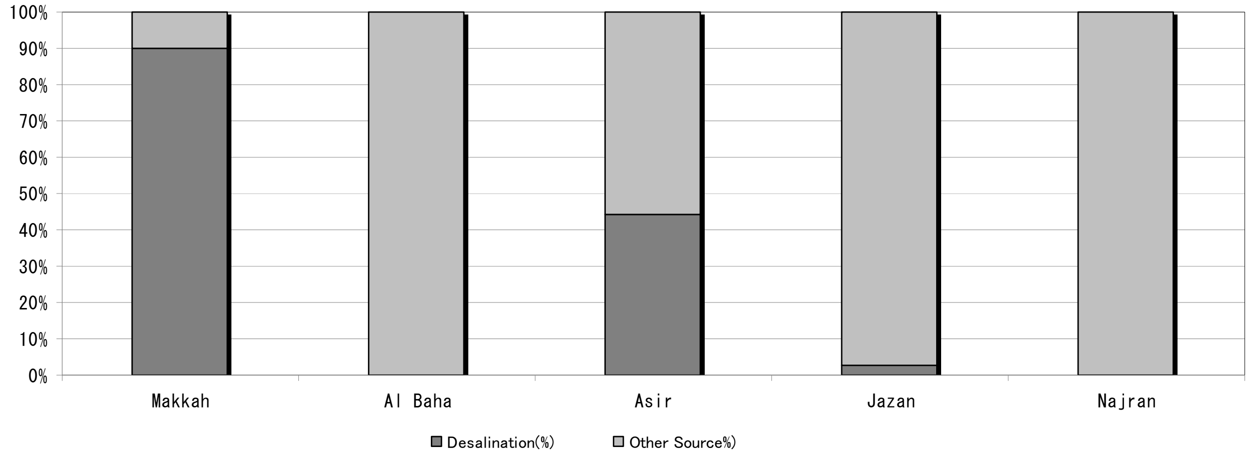
Classification	Definition
Desalinated Seawater	Water which treated by deseminarated processing
Reclaimed Wastewater	Water which is processed through the sewer by the predetermined water quality standard

In many urban areas in the KSA, domestic water supply depends on the desalinated seawater. According to the National Water Strategy 2007, about 50 % of water sources used for the water supply facilities, comes from desalination plants, around 40% from groundwater, and the remaining 10% from surface and reuse water.

1.4.2 Desalinated Seawater

(1) Historical Supply of Desalinated Seawater

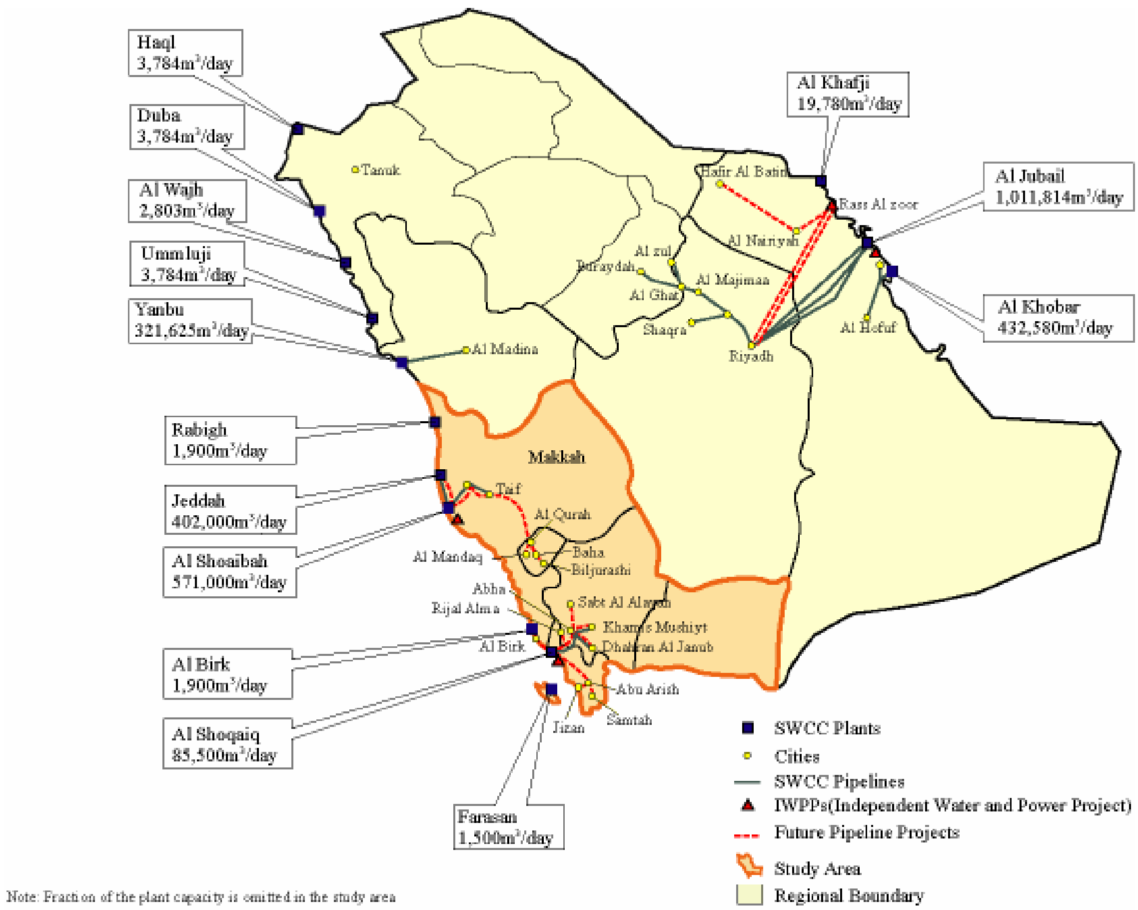
The Makkah region gets about 90% of its water via desalination plants, which is the highest percentage in the five regions studied. (See Figure B.1-22) The Saline Water Conversion Corporation (SWCC), which is supervised by the MOWE, is engaged in desalination work. There are 11 plants on the West Coast and 3 plants on the East Coast, for a total of 14 desalination plants, as shown in Figure B.1-38. In 2005, the combined total capacity of these 14 plants was approximately 2.8 million m^3 per day. The combined total capacity of the plants located in the five regions studied is 1.1 million m^3 per day, which is a little less than 40% of the combined total capacity of all the plants in the country (see Table B.1-38).



Source: Regional General Directorate, MOWE

Note: Most of others are the water that stored in recharge dam, penetrated into ground and pumped up from wells.

Figure B.1-22 Occupation Ratio of Desalinated Water and Other Sources for Potable Water



Source: Regulated by JICA Study Team based on SWCC Annual Report 2006

Figure B.1-23 Location of SWCC Desalination Plants

Table B.1-38 Supply Amount of Desalinated Water in 2005

Plant	Annual Supply (Million m^3)	Daily Supply (m^3)
Jeddah	132.8	402,000*
Yanbu	115.6	321,625
Al Shuaibah	224.7	571,000*
Al Shuqaiq	36.4	85,500*
Other Plants	9.0	19,590
West Coast Total	518.5	1,399,715
Al Jubail	359.1	1,011,814
Al Khobar	140.4	432,580
Al Khafji	6.7	19,780
East Coast Total	506.2	1,464,174
Total	1,025.0	2,863,889
Supply Amount of Desalinated Water in 5 Regions	388.3	1,063,800
	388÷1,025*100= 38%	

Source: SWCC Annual Report 2006

Note: A discrepancy is found in the calculations in the source document.

(2) Supply Plan of Desalinated Seawater

Table B.1-39 shows current distributed amount of water by region and amount of water to be expanded by SWCC. Asir Region and Jazan Region are supplied by desalinated seawater as of 2006

Table B.1-39 Supply Water by Desalination (2006)

Region	Supply Volume（MCM）	Daily Supply (m^3/day)
Makkah	356.5	976,800
Al Baha	0	0
Asir	30. 1	82,500
Jazan	1.6	4,500
Najran	0	0
Total	388.2	1,063,800

Souece: SWCC Annual Report (2006)

1.4.3 Current Status of Reclaimed Waste Water

As shown in Table B.1-40, about 40% of total amount of the reclaimed waste water in the five regions is used for industries, irrigation and landscaping. Reclaimed water is used not only for irrigation and landscaping but also for construction use mainly in the Asir Region where the rate of reclaimed water use is highest of the five regions.

Table B.1-40 Current Status of Reclaimed Waste Water Use

Region	Numbers of Sewerage Treatment Plant	Design Capacity (1000 m^3/day)	[a]: Actual Treated Water (1000m^3/day)	[b]: Reclaimed Water (1000m^3/day)	Ratio of Reclaimed Water [b]/[a]	Use of Reclaimed Water	Remarks
Makkah	21	1,716	384	139	36.2%	Industry / Irrigation	
Al Baha	1	-	-	-	0.0%		Under Construction
Asir	4	81	71	50	70.4%	Irrigation/ landscaping	
Jazan	1	20	10	0	0.0%		
Najran	1	-	-	-	0.0%		Under Study
Total	**28**	**1,817**	**465**	**189**	**40.6%**		

Source: Investigation and Engineering Design for Treated Wastewater Reuse in KSA

1.4.4 Issues on Development of Non-conventional Water Resources

Issue on development of non-conventional water resources is arranged as follows.

- Although a stable supply is possible for desalinated seawater, the fall in cost will be nonexistent if a large-scale plants are not built.

- Reclaimed wastewater may serve as an important future water resource. However, this future water supply resource needs restricting and network system should be developed.
- Supply of reclaimed waste water is a set with network system, and needs to give a priority to advance of network system.

The supply of reclaimed wastewater should work in unison with the development of sewer networks, and the latter needs to take priority to advance development.

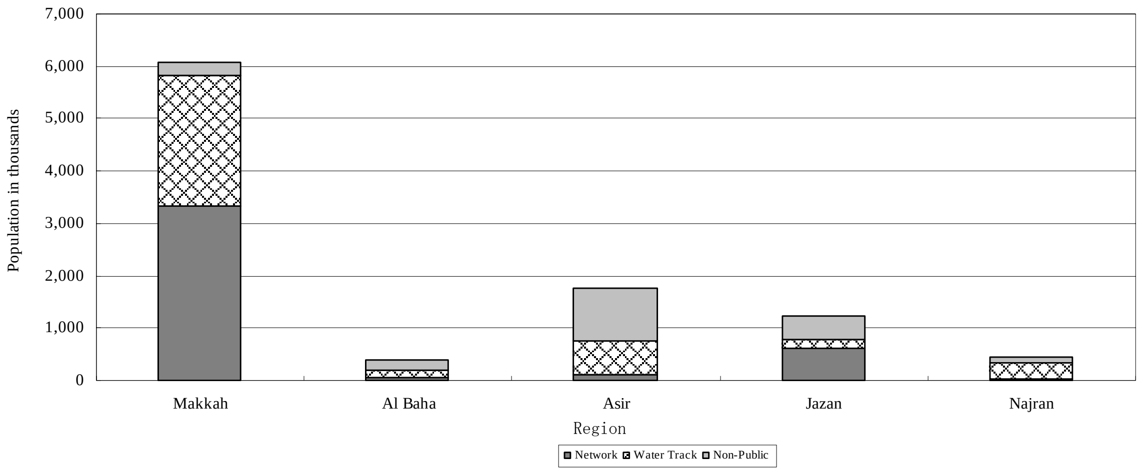
1.5 Current State and Supply on Water Use

1.5.1 Domestic, Institutional and Commercial Water

(1) Service Population

Facilities of water use are categorized into public and private water supply facilities. Types of water users are composed of users of network system which receive water pipelines directly and that of water trucks for public water supply. The remained users rely on individual water sources.

Figure B.1-24 shows service population of five regions by type of water use in 2004. Water supply facilities with pipelines are one of the most common types, supplying approximately 4 million people, and representing about 42% of the total population in the five regions studied (see Table B.1-41).



Source: MOWE Regional General Directorates

Figure B.1-24 Population by Type of Water Provision and the Five Regions in 2007

Table B.1-41 Population by Type of Water Provision and the Five Regions in 2007

Unit: 1000

Region	Public Water Supply				Non-Public Water Supply		Total
	Network		Water Truck				
Makkah	3,335	55%	2,486	41%	243	4%	6,063
Al Baha	43	11%	141	36%	208	53%	392
Asir	106	6%	652	37%	1,004	57%	1,762
Jazan	610	49%	187	15%	448	36%	1,245
Najran	22	5%	326	74%	93	21%	441
Total	4,116	42%	3,792	38%	1,996	20%	9,903

Source: MOWE Regional General Directorates

(2) Water Use

In many areas of the KSA, since there are no water meters in most of private households, data of revenue water has systematically not developed.

On the other hand, Annual Report 2007 of MOWE shows supply amount (MCM: million m^3/year) of water of KSA. The supply amount of water includes unaccounted for water such as leakage.

Table B.1-42 Historical Domestic Water Use (Except Industrial Water) in 2007

Region	Population (2007)	Service Coverage Ratio of Public Water Supply (%)	Service Population (2007)	Distributed Water (MCM)	Per-capita Distributed Water (LCD)	Leakage Ratio (%)	Per-capita Water Consumption (LCD)
Makkah	6,062,813	96	5,820,300	389	183	25	146
Al Baha	391,880	47	184,184	10	149	25	119
Asir	1,762,011	43	757,665	53	192	15	167
Jazan	1,245,208	64	796,933	16	55	25	44
Najran	440,778	79	348,215	12	93	15	80
Total	**9,902,690**	**80**	**7,907,297**	**479**	**166**		

Source: Annual Report 2007 of MOWE, Regional General Directorate and JICA Study Team

The daily per-capita water of consumption by annual report MOWE is shown in Table B.1-43. Another data on daily per-capita water consumption were investigated by a questionnaire to the participants of the Stakeholder Meeting.

Table B.1-43 Daily Per-Capita Water Consumption by Water Use (LCD)

Region	Annual Report（2007）	Questionnarir（2009）	Conclusion
Makkah	183	-	180
Al Baha	149	110	110
Asir	192	107	110
Jazan	55	133	130
Najran	93	-	90

Source：Annual Report 2007, JICA Study Team

1.5.2 Industrial Water

The supply amount of industrial water including leakage water of the five regions in 2007 is 150MCM (0.4million m^3/day) as shown in Table B.1-44, making up about 20% of overall industrial water (716MCM) of KSA and about 23% of municipal water (629MCM) in five regions.

Table B.1-44 Industrial Water of Five Regions in 2007

Region	Supply amount of Industrial Water (MCM)
Makkah	90
Al Baha	0
Asir	10
Jazan	50
Najran	0
Total	**150**

Source: Annual Report 2007 of MOWE

1.5.3 Agricultural Water

Gross water requirement, calculated above in Table B.1-45 and Figure B.1-25, multiplies the planted area of each year by the unit net water requirement of different crops. Details for these calculations are shown in the Supporting Report.

Table B.1-45 Gross Water Requirements in 5 Regions

Region/Crops	Net Irrigation Water(m3/ha)	2002		2003		2004		2005		2006		2007	
		ha	MCM	ha	MCM	ha	MCM	ha	MCM	ha	MCM	ha	MCM
Makkah		45,311	**834**	41,941	**749**	37,697	**639**	38,237	**669**	39,912	**705**	42,077	**751**
Cereal	6,753	12,588	155	10,467	129	8,128	100	7,608	93	7,708	95	8,386	103
Fodder	18,420	9,732	326	7,883	264	4,885	164	5,262	176	5,698	191	5,761	193
Fruits	16,420	11,396	267	11,343	266	12,005	282	13,201	310	13,930	327	15,447	362
Vegetable	5,175	11,595	86	12,249	91	12,680	94	12,166	90	12,576	93	12,483	92
Al Baha		2,769	**32**	2,927	**34**	3,459	**39**	3,584	**41**	5,023	**61**	4,450	**54**
Cereal	3,637	549	4	443	3	713	5	608	4	604	4	532	4
Fodder	11,160	168	3	139	3	136	3	94	2	147	3	185	4
Fruits	9,223	1,788	24	2,075	27	2,280	30	2,603	34	3,974	52	3,457	46
Vegetable	2,863	264	1	271	1	330	1	278	1	298	1	276	1
Asir		22,508	**304**	22,695	**297**	22,038	**279**	21,023	**269**	20,368	**263**	21,054	**268**
Cereal	4,691	6,477	55	7,318	62	8,159	70	7,550	64	6,780	58	7,744	66
Fodder	13,259	2,796	67	1,930	47	1,581	38	1,680	41	1,644	40	2,001	48
Fruits	11,384	10,159	165	10,644	173	9,633	157	9,220	150	9,334	152	8,579	140
Vegetable	3,736	3,076	16	2,803	15	2,664	14	2,572	14	2,610	14	2,730	15
Jazan		186,350	**2,393**	157,747	**1,987**	148,450	**1,880**	120,268	**1,542**	117,032	**1,513**	113,558	**1,502**
Cereal	6,119	159,461	1,774	136,609	1,520	128,551	1,430	101,302	1,127	97,484	1,085	92,204	1,026
Fodder	15,276	18,095	503	12,956	360	12,204	339	10,552	293	10,852	301	12,247	340
Fruits	14,010	4,151	83	3,843	77	4,322	87	4,786	96	5,049	101	5,525	111
Vegetable	4,951	4,643	33	4,339	31	3,373	24	3,629	26	3,647	26	3,582	25
Najran		13,212	**245**	12,286	**232**	12,185	**236**	13,107	**254**	11,747	**226**	11,430	**217**
Cereal	6,077	984	11	708	8	1,001	11	1,019	11	659	7	908	10
Fodder	15,748	3,237	93	2,520	72	2,479	71	2,879	82	2,435	70	2,287	65
Fruits	14,197	5,962	121	6,682	136	7,007	142	7,272	147	6,658	135	6,311	128
Vegetable	4,725	3,029	20	2,375	16	1,698	11	1,937	13	1,995	13	1,924	13
Total		**270,150**	**3,807**	237,596	**3,299**	223,829	**3,071**	196,219	**2,775**	194,082	**2,767**	**192,569**	**2,791**

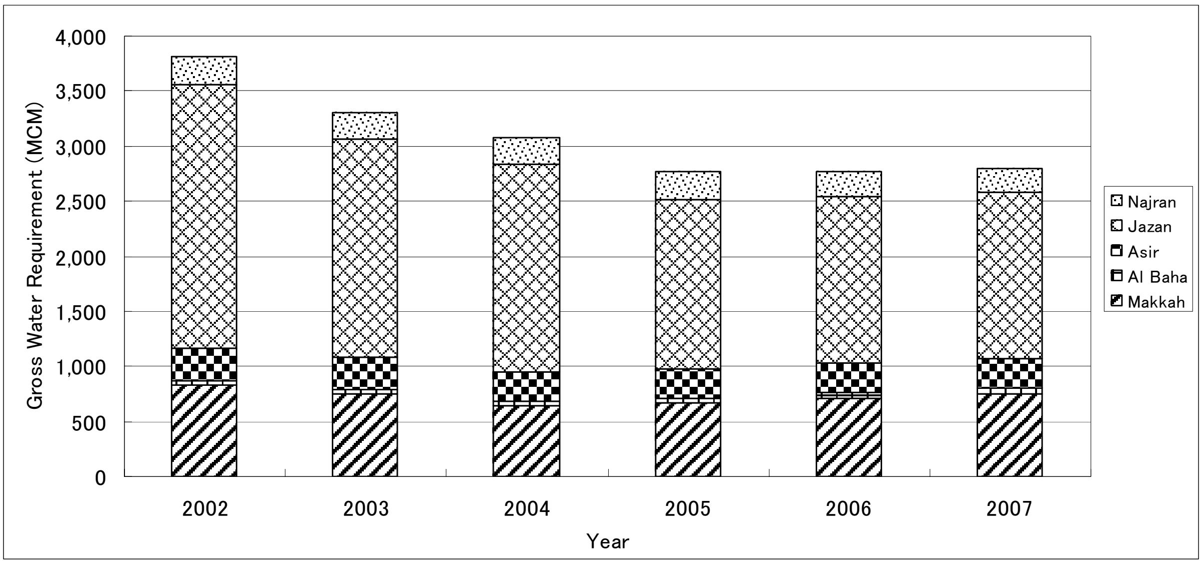


Figure B.1-25 Gross Water Requirements in 5 Regions

CHAPTER 2 NATIONAL PLANS, STRATEGIES AND LAWS ON WATER RESOUECES DEVELOPMENT AND MANAGEMENT

2.1 Five-Year National Development Plans

2.1.1 Introduction

The Five-Year National Development Plans have been prepared by the Ministry of Economy and Planning (MOEP).

First 5-Year National Development Plan (1970/71 – 1974/75) was formulated in 1970 and eighth 5-Year National Development Plans had been issued in 2006. The latest 5-Year National Development Plan was formulated in 2005 that will be effective up to 2009.

The Study Team reviewed those 5-Year National Development Plans to examine historical changes of the water vision, policies, strategies and action plans and to evaluate the achievements of those strategies and plans in the past.

2.1.2 Review Results of Water Related Portions in the 5-Year National Development Plans

The Study Team organized information on the water related portions under the following categories:

(1) Present conditions, (2) Main issues, (3) Saudiization, (4) Economic efficiency, (5) Role of private sector, (6) Water demand forecast, (7) Future water vision, (8) Development strategy, (9) Establishment of Ministry of Water and then consolidation of water and electricity, etc.

(1) Present Conditions

The basic information on available water resources such as conventional and non-conventional sources, water consumption and water supply & demand balance had fully been reported since the Third 5-Year National Development Plans (1980/81 – 1984/85). Water cost and budgetary allocation were reported in detail in the latest Eighth Five-Year National Development Plan (2005/06 – 2009/10).

(2) Main Issues

In Second and Third development plans, wasteful practices of irrigation and severe water shortage by over-pumping were recognized as a main issue.

Up to the 1990s, increase of water consumption of non-renewable groundwater and agricultural consumption of water had become an issue. The formulation of National Water Plan had been necessitated in almost all development plans.

After the1990s, water pricing, reclaimed water, water conservation and water & waste water services have become a main issue. In the latest development plan, monitoring, follow-up and enforcement of regulation, strengthening of water legislation and administrative centralization became a main issue.

(3) Saudiization

The Saudiization was promoted in the Fifth and Sixth development plans. In those plans, the Saudiization in water sector was considered to be achieved.

(4) Economic Efficiency

The economic efficiency was firstly highlighted in the Sixth development plan (1995/96 – 1999/2000).

(5) Role of Private Sector

Since the Third development plan, the private sector role has been emphasized.

The MOWE is in the process of reforming the water sector in KSA. The basic idea of this reform process is to improve the overall performance of the sector in various areas through the transfer of services to a business minded environment and the involvement of the private sector. The reform program in the water sector aims at the following objectives:

a) Provide access to clean and good quality potable water for all residents

b) Provide sanitation connections to all households and safe disposal of wastewater

c) Improve organization performance and customer service, with a view to gradually becoming a commercially oriented organization

d) Provide reasonably priced water and sanitation services with a view to cost recovery

e) Progress towards privatization to facilitate the enhanced performance of the sector

f) Protect the natural environment and conserve natural resources in KSA.

MOWE has completed a Strategic Transformation Plan (STP) over the past two years that provides a framework of and guidance for the further reform and privatization path. In addition, MOWE has carried out a number of groundwork studies and audits on the technical status of the water supply and wastewater collection system that result in concrete recommendations for the improvement of the physical infrastructure.

The STP main results can be summarized as:

a) Initiation of Public Private Partnership (PPP) projects (Management/O&M Contract and BOO) for the water and wastewater operations of the four main cities of Saudi Arabia: Riyadh, Jeddah, Madina and Damman/Khobar. In the long term, MOWE has plans to move to more complex contracts like Concession and/or total privatization, etc.

b) Formation of National Water Company (NWC) that will in the short term facilitate privatization process and oversee the regional operations under the PPP contracts. In the long term, NWC will oversee most water and wastewater operations in the KSA. NWC will include regional business units (RBUs) and a core to manage and provide strategic guidance to RBUs.

c) Gradual transfer of manpower and assets from the existing entity to NWC.

d) Review the proposed institutional setting and recommend methodology to regulate the Jeddah City Management/O&M contract in the short term through contractual clauses and study the need for independent regulators to oversee the BOO and concession contracts in the long run. Presently it is MOWE's intention to regulate Management contracts through clauses built within contracts.

(6) Water Demand Forecasts

The water demand forecasts, including the assumption for reclaimed wastewater, water desalination capacity, total water demand and demand for water & wastewater services were firstly prepared in the Fifth development plan (1990/91 – 1994/95).

(7) Future Water Vision

Water vision in the future was firstly manifested in the latest Eighth development plan below:

a) Satisfying the growing demand for water for residential and industrial purposes

b) Gradually decreasing the demand for water for agricultural purposes

This water vision manifested is expected to be realized through the following measures:

a) Development of non-conventional and renewable water resources

b) Enhancing water conservation and protection of water resources

c) Applying the economic value of water

d) Administrative development

The national vision for water sector is to be prepared every five years by the MOEP, and instituted by

Royal Decree (currently in the Eighth Development Plan).

(8) Development Strategy

The development strategy including objectives and policies has clearly been indicated since the First development plan up to the latest Eighth development plan.

The development strategy in the Seventh and Eighth Five-Year National Development Plan is summarized below:

Table B.2-1 Development Strategy in 7th and 8th 5-Year National Development Plan

Development Plan	Main Development Strategy
Seventh (2000/01 – 2004/05)	**Objectives** 1. Continue with the supply of potable water in sufficient quantities and good quality 2. Consider water as basic factor and an important determination in assessing the economic viability of public and private projects 3. Conserve water resources and rationalize water consumption 4. Increase the role of the private sector in management, operation and maintenance of water facilities **Policies** 1. Review the existing policies of the agriculture and water sectors and regulate water consumption priorities 2. Reconsider the administrative organization of the water sector 3. Support a computerized central database 4. Expand and upgrade the hydrological and hydrogeological monitoring network 5. Develop and support renewable surface and ground water resources 6. Upgrade the detailed hydrogeological studies and issue the national water plan 7. Improve the system of collecting water fees 8. Enhance the role of the private sector in the field of water services 9. Develop non-conventional water resources 10. Develop Saudi manpower in the water sector
Eighth (2005/06 – 2009/10)	**Objectives** 1. Conserve and develop water resources, along with ensuring rationalized use of these resources 2. Provide water and wastewater services for all segments of the population of the Kingdom at a high level of quality and reliability and at the lowest possible cost while taking into consideration the purchasing power of low income citizens 3. Provide water for industrial and agricultural purposes within the limit of what is dictated by sustainability of water resources and socio-economic effectiveness 4. Realize the integrated management of the Kingdom's water resources **Policies** 1. Intensify water rationalization and conservation techniques 2. Develop desalination and reclaimed wastewater as additional non-conventional water resources 3. Apply the economic value of water approach in all uses and realize sustainable balance between water prices and the cost of production 4. Increase the efficient utilization of renewable water, and endeavor to develop such water 5. Protecting natural water resources against pollution 6. Give priority to meeting the demand for water used for drinking and municipal purposes while encourage the utilization of reclaimed wastewater for agricultural , industrial and other purposes 7. Improve the standard of water sector's management 8. Encourage the private sector to invest in wastewater collection and treatment facilities 9. Increase the actual capacity of water desalination and encourage private investment in the desalination sector 10. Enhance the contribution of national manpower in the water sector 11. Finalize the studies and research pertaining to the preparation of the National Water Plan 12. Review the legislation that regulates water uses 13. Establish comprehensive databases of the water sector

(9) Establishment of Ministry of Water and then Consolidation of Water and Electricity

To secure more effective water resources management and national leveled water planning and a higher level of sustainability and continuity of water development and progress of KSA, in 2002 all water agencies and authorities were merged under the Ministry of Water. The specific objectives of the new Ministry as stated in the **Royal Decree No. 125 on 16 July 2001** are to:

a) Supervise the management, monitoring and organization of the water sector and its facilities

b) Carry out all related studies needed to assess the country's water supplies and storage volumes

c) Prepare a comprehensive water plan defining policies for water resources development, protection and conservation

d) Prepare a national program to expand the drinking water and wastewater networks in all urban areas of KSA

e) Suggest the required organizations needed for water resources protection

f) Study and propose new water tariffs for all users of water

g) Determine how to improve the performance of wastewater collection systems

h) Develop mechanisms, frameworks and implementation strategies for private sector involvements, operation and maintenance

In addition to those responsibilities of the Ministry of Water listed above, measures are also needed to:

a) Reduce the irrigation water consumption to increase the long-term productivity and quality of the aquifers

b) Control leakage and minimize water losses from water supply networks

c) Augment groundwater resources from non-conventional resources such as desalination, wastewater reuse

d) Implement artificial aquifer recharge

In September 2003, responsibilities for the electricity sector were added to the mission of the Ministry of Water (MOW) and its name was changed to the MOWE. This decision was made to achieve better coordination between the water and power sectors as most of seawater desalination plants produce both water and electricity. The Ministry has adopted an Integrated Water Resources Management (IWRM) tools to implement its short-term and long-term water strategies, which are presently under development.

(10) Characteristics of the Eighth 5-Year National Development Plan

The Eighth development plan marked a new phase in the development process that has spanned over three decades, and also represented the first landmark in a strategic approach for the national economy, which extends over the next twenty years and encompasses four consecutive five-year plans. As such, this approach reflected a new turn in the methodology adopted for strategic planning in KSA. In previous plans, the long-term general objectives that defined the government's strategic development directions served as the point of departure for setting priorities and the areas of focus of each plan.

The Eighth Development Plan defined more precise targets and translated them into quantitative terms (whenever possible) and clearly spelled out implementation schedules and the responsibilities of the implementation agencies, as well as the issues they would address.

(11) Water Demand and Supply Balance in 5-Year National Development Plans

Since the Second 5-Year National Development Plan (1975 – 80), the present and future water demand and supply balance was estimated as shown in Table B.2-2.

The latest Eighth 5-Year Development Plan expected the low growth rate of water supply by renewable surface and groundwater and the sharp reduction of water supply by non-renewable groundwater and the high growth rate of non-conventional water as summarized below.

Table B.2-2 Water Demand, Consumption and Annual Growth Rate in Latest Development Plan

Water Resources	Water Consumption in 2004 (MCM/year)	Expected Water Demand In 2009 (MCM/year)	Annual Growth Rate (%)
Renewable Surface and Groundwater (Arabian Shield & Continental Shelf)	6,500	6,900	1.0
Non-Renewable Groundwater	12,400	9,270	-5.0
Non-conventional water (Desalinated Water and Reclaimed Wastewater)	1,370	2,090	8.0
Total	20,270	18,260	-2.0

2.2 Long-Term Strategy 2025

The work on the Long-Term Strategy 2025 (LTS 2025) began with the Royal Consent on July 2, 1998 giving the responsibility to the MOEP to organize a National Symposium on the "**Future Vision for the Saudi Economy**" held on October, 2002.

The Symposium reviewed the past performance of the Saudi economy and development strategic options for dealing with current and future challenges facing the Saudi economy.

2.2.1 Long-Term Strategy for Water Sector

Vision 2025 listed the following challenges that are facing the Saudi economy:

a) Employment generation

b) Poverty reduction

c) Improvement in Quality of Life

d) Achievement of sustainable development by diversification of the economy, rationalization of water usage, promotion of balanced regional development and improving management of public finances

e) Improvement in implementation and execution of public policies

Vision 2025 listed the following core set of strategic policies in water sector:

a) Issue a clear statement of water policy

b) Revive benchmarking of water utilities

c) Implement Result-oriented conservation drive

d) Increase PSP (Private Sector Participation) in water and wastewater sector (including dams)

e) Tariff reform

f) Update estimates of total water resources

2.3 National Water Strategy

2.3.1 Background and Present Status

(1) Background

In 2003, the MOWE requested World Bank (WB) to support for the development of an Integrated Water Resources Management Strategy and Short/Long Term Action Plans for KSA. A scope of work, based on a comprehensive assessment of the water resources, focuses on the following:

a) Broad-based water demand management rather than supply management policy

b) A cross-sectoral program for reducing non-renewable groundwater withdrawal and more sustainable aquifer management

c) A comprehensive program for reclaimed wastewater reuse in agriculture irrigation

d) Reorganization of the legal and institutional framework

The overall scope of the MOWE-WB Cooperation Program was agreed upon to include the following three phases:

a) Phase I: Assessment of the current water resources management situation

b) Phase II: Development of strategic water sector management policies through extensive in-country consultations

c) Phase III: Development of an action plan for implementation of the strategy

According to MOWE, the Action Plan, which has not been opened yet, will include the following plans:

a) Updating of groundwater mathematical models of major aquifers

b) Detailed water resources studies of non-sedimentary rock which is known as Arabian Shield and to depend on renewable water resources

c) Study of water potentials in basaltic and sub-basaltic aquifers

d) Preparation of comprehensive water system and development of needed regulation for its execution

e) Preparation of studies and designs for treated wastewater reuse for different purposes, excluding domestic use

f) Updating and development of hydrological and observation well network

2.3.2 Issues in the Water Sector

The WB Study Team identified the most pressing issues that the water sector in KSA is facing, and grouped those issues under the definition of five policy gaps as summarized below:

Table B.2-3 Contents of Issues in the Water Sector of KSA

Items	Contents
(1) Water Scarcity Gap:	a) The current levels of groundwater withdrawals, mostly water for irrigation, exceed beyond its sustainable yield. b) A fundamental reason for the over-draft of the aquifers is the high subsidies which farmers have been receiving for the 25 years. They induced a precipitous increase in the cultivated area and discouraged water savings. The negative externality emerges due to the unrestricted access to groundwater. c) The problems are progressing. On one hand farmers are treating groundwater as a free good, assuming that it is their right to take (and to waste) as much water as they want. On the other hand there is the lack of government control and regulation of the irrigation activity.
(2) Water Conservation Gap:	a) The tariff for urban water supply (levels and structure) provides no incentive to conserve water, yielding per capita consumption levels that are inconsistent with the water scarcity condition. The low pricing of water is also a disincentive for reducing the excessive water losses occurring along the distribution networks. b) There is the imbalance between treated wastewater supply and its reuse. This is attributed to the lack of a central policy and long-term plan considering treated wastewater as an additional source with economic value. The benefit of such a policy is two-fold: as a safeguard against pollution and environmental degradation; as a way of securing additional water supplies for a variety of uses. c) Irrigation is the area with the worst water conservation results. The 45% irrigation efficiency mentioned earlier occurs despite the large investments made in the modernization of the irrigation infrastructure (financed by large government subsidies). This is attributed to giving farmers unrestricted and free access to the resource.
(3) Water Service Gap:	a) Water supply and sanitation (WSS) services present a mixed record. Aside from just a few exceptional cities with good service, the quality of service remains noticeably

Items	Contents
	below internationally acceptable standards. An important portion of the population remains dependent on supply through water tankers, and wastewater collection and treatment are the areas requiring the most improvement. b) Although SWCC provides bulk desalinated water to the regional directorates free of charge, utilities recover on average less than 5 per cent of their O&M cost (water tariffs are among the lowest in the world). Such a low level of cost recovery has prevented the investments necessary to keep up with the networks expansion and service improvements. Furthermore, the lack of cost recovery from users discourages the private sector from getting involved in the financing of the sector.
(4) Water Governance Gap :	a) Past water administrators have dedicated their best efforts to building the major water infrastructure and providing water services, with little attention to base resource management. b) The MOWE should institute radical management changes by adding new functions to its day-to-day water administration, enhance coordination with water actors as well as provide the means and technical instruments for successful management. At that stage political support will be needed to establish the new organizations, build capacity and improve upon current recruitment policies.
(5) Financial Gap :	a) Water related activities impose a heavy burden on the government budget. The cost derives mainly from two fronts: the high level of farm subsidies supporting commercial irrigation activities and the lack of cost recovery in water provision services (urban areas). Agriculture and macroeconomic policies have aggravated the situation by encouraging farmers to select low-valued crops rather than higher valued, tradable crops. Under the current situation one should expect a substantial gap between the productions cost to farmers and the true cost of agriculture to the Saudi economy as a whole. b) Outside the agriculture sector the negative financial impact is equally severe. Irrigation competes with urban areas for water supply making household use even more dependant on desalinated sea water, a more expensive proposition considering the high production and conveyance costs of desalinated water. This occurs despite the fact that most urban areas are close to or lay directly above sufficient groundwater reserves to meet their domestic needs at a much lower cost. c) On the other hand, the lack of cost recovery hinders the WSS sector capacity to extend sewerage services to more areas and build new treatment facilities. Given the high cost of infrastructure and the many projects competing for government funds, it is doubtful that the government alone can meet the goal of increasing sewerage coverage up to 94% in 25 years and simultaneously increase the capacity for wastewater reuse.

2.3.3 Policy Framework for National Water Strategy (NWS)

Three premises such as Sustainability, Efficiency and Equity embody the essence of the KSA water strategy. The three premises were translated into a series of clear mandates that guided the preparation of the water strategy as listed below:

a) Declare water a national good for public use, subject to government regulation

b) Stop the devastation of the base resource and reverse the course of action

c) Shift in paradigm: from water supply management to water demand management

d) Find a balance between water development and resource protection

e) Adopt a virtual water strategy to relieve the pressure on the water resources

f) Promote high value of water so as to increase water productivity

g) Reach universal coverage of water supply and sanitation services

h) Attain cost recovery for water services

i) Provide legal protection to water users

j) Adopt integrated planning as the rationale for water allocation

k) Exercise water management at the lowest appropriate level

l) Improve public awareness and encourage water conservation

2.3.4 Coordination of Water Allocation and Interests

a) The conflict should not come as a surprise since by its own nature water allocation is characterized by competing and at times mutually exclusive demands. It is this particular condition that makes imperative the harmonization of the sectoral strategies and action plans that directly or indirectly impact the water resources.

b) The process needs to create horizontal linkages across all water users to find the best possible solution to the water allocation problem. Conflicting interests can be reconciled by establishing technical and political coordination so that a coordinated approach to development can be implemented. Technical coordination can be achieved by setting up an integrated water resources planning (IWRP) process. This is the instance when all water related agencies gather (at the technical level) to harmonize water demands with water availability, yielding as output unambiguous instructions for bulk water allocation.

c) However, establishing effective coordination is more a political challenge than a technical one. For that reason the KSA should create an executive body to overcome sectoral interests and set the government in motion to ensure the coordination of sectoral policies affecting the water resources and to arbitrate in possible conflicts if necessary. The NWS recommends the formalization of an intra-governmental and interagency coordination body to be named the Kingdom's Water Council (KWC), to focus coordination and integrated planning in the water sector and enforce collaborative decision making.

2.3.5 Recommendation for Implementing Goals

The following are recommendations for implementing the goals in the NWS.

a) Goals shown in the NWS are water use efficiencies, water conservation, equitable and efficient water allocation, monitoring and protection of the sources, increasing the reuse of water, enhancing water productivity and expansion in the population served. A number of reforms to the water institutional structure are necessary such as new enabling legislation, new organization, new management instruments, mechanisms for policy coordination, building and recruiting new capacities, reformulation of staff retribution regimes.

b) The new institutional structure will be founded in a modern legal and regulatory framework, supported by proper instruments, to give the MOWE the power to exercise specific water management functions. The various laws in place within the Kingdom will be revised to assure compatibility with MOWE's new mandate in order to conform to a new National Water Law (NWL) –a law of principles– spelling out the water policies of the Kingdom and setting the framework for more detailed by laws and regulations within each separate area of responsibility and water using sectors.

c) While the "public good" character of the water is undisputed in the Kingdom, government had been absent from the basic functions of resource management. Hence a new organizational structure is in order, aimed at promoting integrated water resources management functions in the Kingdom.

2.4 Laws and Regulations related to Water Resources Development & Management

2.4.1 Current State on Development of Laws & Regulations in Water Sector

TableB.2-3 shows the summary on the current state on the development of the laws and regulations related to water resources development and management in KSA by focusing the categories and issues in water sector.

Table B.2-4 Summary on Current State of Laws and Regulations in Water Sector

No.	Category / Issue	Corresponding Laws or Regulation
1. Water Resources Development and Management		
1.1	Middle-term Development on Water Resources Development and Management	• 8th National Development Plan • 9th National Development Plan (under preparation)
1.2	Overall Water Resources Management	• 8th National Development Plan • Royal Decree No M/34 dated 24/08/1400H (7 July 1980G) • The Council of Ministers' Resolution No. 62044 dated 07/07/1409H
2.Reuse or Reclamation of Treated Wastewater		• Royal Decree No. M/6 dated 13/02/1421H (18 May 2000G)
3. Water Right (Priority Use on Water)		• Royal Decree No M/34 :Priority Use on Water • The Council of Ministers' Resolution No. 62044 :Priority Use on Water
4. Legislation on Water Tariff		• the Council of Ministers' Resolution No. 125 dated 25/04/1422H (17 July 2001G): One of the key tasks of MOWE is to propose water tariffs for all consumers • The Council of Ministers' Resolution No.96 dated 26 Dec. 1994G
5. License for Well Digging		• Royal Decree No M/34 • The Council of Ministers' Resolution No. 62044
6. Monitoring (Water Quantity, quality, etc.)		• Royal Decree No M/34 • The Council of Ministers' Resolution No. 62044 • Royal Decree No. M/6
7. Institutional & Organizational Demarcations / Mandates of Relevant Agencies		
7.1	Set-up of Two Distinct Entities into Water and Agriculture Departments from the former Ministry of Water	• The Council of Ministers' Resolution No. 125
7.2	Delegation of Authority on Water Resources Development & Management to MOWE	• Royal Decree No 27472 dated 09/07/1423H (17 September 2002G)
7.3	Saline Water Conversion Corporation Law	• Royal Decree No M/49 dated 20/08/1394H (7 September 1974G) • Royal Decree No M/10 dated 27/02/1427H (27 March 2006G) (Revision of M/49)
7.4	The Saudi Geological Survey Regulation	• The Council of Ministers' Resolution No. 115 dated 16/07/1420H (26 October 1999G)
8. PPP (Private Public Partnerships)		
8.1	Lists of Projects to be privatized	• The Council of Ministers' Resolution No. 219 dated 16/07/1420H (26 October 1999G)

The policy on water resources development and management is replaced with the new plan of 9th National Development Plan which is scheduled to commence its execution in 2010.

The Royal Decree No M/34 dated 24/08/1400H (corresponding to 7 July 1980G) is a fundamental law for the water resources management in addition to the 8th National Development Plan. The enforcement regulations relating to water resources management are provided in the Council of Ministers' Resolution No. 62044 dated 07/07/1409H. The Treated Wastewater and Re-use of Wastewater Law were issued under Royal Decree No. M/6 dated 13/02/1421H (corresponding to 18 May 2000G).

The laws and regulations which clearly provide water right were not clearly identified, however, the provisions on priority use of water were identified in above Royal Decree No M/34 and the Resolution No. 62044 as the enforcement regulations of the Royal Decree No M/34.

In relation to the provisions on water tariff, MOWE can set up water tariffs for all consumers according to the Council of Ministers' Resolution No. 125 dated 25/04/1422H (corresponding to 17 July 2001G). The regulations on the overall water tariff are in the process of restructuring its system in MOWE. The Council of Ministers' Resolution No.96 dated 26 Dec. 1994G provides the water tariff for municipal water.

Contents of these Royal Decrees and Resolutions are to be summarized in the supporting report.

2.4.2 Laws and Regulations relating to Organizational Demarcations / Mandates of Relevant Agencies of Water Resources Development and Management

The Council of Ministers' Resolution No. 125 is the fundamental regulation which provides the establishment of MOWE, and the water and agricultural departments which had been under the jurisdiction of the former Ministry of Water and Agriculture was divided separately. Afterwards, Royal Order No. 27472 dated 09/07/1423H (corresponding to 17 September 2002G), confirming Resolution No. 125, provides the establishment of MOWE and its mandate of the nationwide water resources development and management.

Royal Decree No M/49 dated 20/08/1394H (corresponding to 7 September 1974G) and Royal Decree No M/10 dated 27/02/1427H (corresponding to 27 March 2006G) of its amendment, provide the establishment of SWCC. The Council of Ministers' Resolution No. 115 dated 16/07/1420H (corresponding to 26 October 1999G) provides the Saudi Geological Survey (SGS) with the mandate of the study of water resources potential.

2.4.3 Laws and Regulations relating to PPP (Private Public Partnerships)

The Council of Ministers' Resolution No. 219 dated 16/07/1420H (26 October 1999G) listed the infrastructure projects such as; Water, sewage, desalination, telecommunications, air transport, railway, etc. including construction, operation and maintenance.

2.5 Institutional, Organizational and Budgetary Aspect

2.5.1 Current State on Institutional and Organization Framework

The current state on institutional and organizational framework relating to water resources development and management in KSA is shown in Figure B.2-1.

- MOWE is currently a core body for water resources development and management in KSA, which has the mandate to formulate a basic policy on water sector, permit well digging for well digging contractors, inspection the facilities and actual implementation on water and sewerage sector.
- MOA formulates an agricultural policy in the agriculture sector which currently consumes over 85 % of water resources in KSA, and MOA also authorizes permits / license for reuse of treated wastewater.
- SWCC, an inter-agency of MOWE, operates saline water conversion plants nationwide KSA and supply its bulk desalinated water to MOWE and municipalities for their water distribution to customers.
- Saudi Geological Survey (SGS) has a mandate to carry out survey works to identify water resources and water storage, determine the qualities and quantities of surface and groundwater, and determine water suitability in consultation with MOWE.
- MOEP formulates a national development plan including water and agricultural sectors based on the data / information supplied by MOWE and MOA.

The demarcation of major agencies relating to water sector is shown in Table B.2-5.

Table B.2-5 Demarcation of Major Agencies relating to Water Sector

Agencies	Water Resources Development & Management					Water Users		
	Infrastructure	Policy / Legislation	Management	Political / Economy	Tariff Collection	Irrigation	Sanitation (Wastewater)	Others (e.g. Industries)
MOWE	✓	✓	✓	✓			✓	
MOA						✓	✓	
MOMRA	✓		✓				✓	
MOEP		✓		✓				✓
MOF				✓	✓			
SWCC	✓							✓

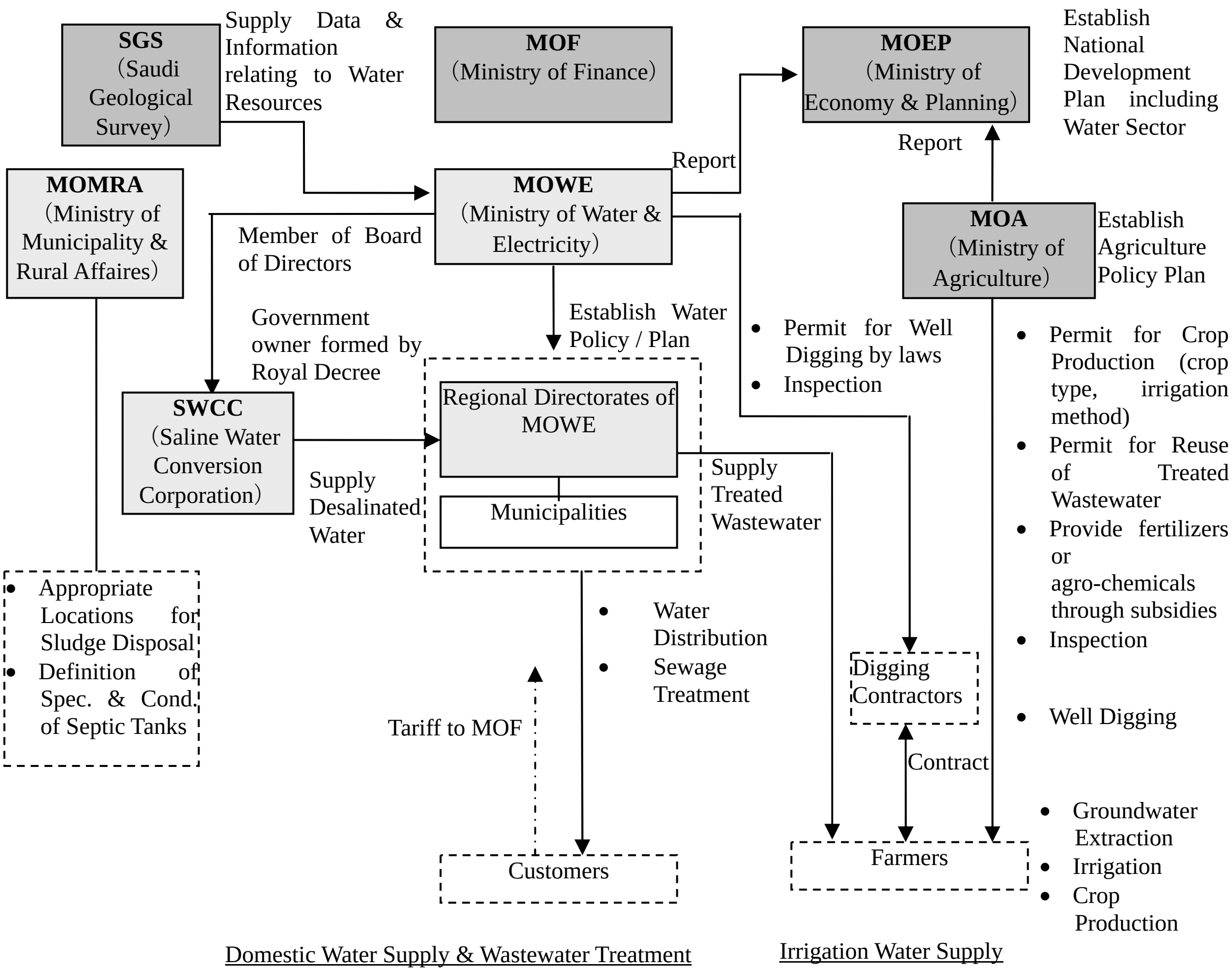


Figure B.2-1 Current State on Institutional and Organizational Structures relating to Water Resources Development and Management

2.5.2 Institutional and Organizational Reform Process in Water Sector

In order to deal with the challenges the KSA faces, the Government of the KSA has launched a reform process in the water sector. The government's overall key objectives for the reform are:

- Providing access to clean and good quality potable water for all residents
- Providing sanitation access to all households and safe disposal of wastewater
- Providing reasonably priced water and sanitation services, which can contribute cost recovery and improved services
- Radically streamline, and improve the water sector performance, operational efficiency, and be in line with international best practices
- Improve customer services
- Protecting the environment and encouraging the conservation of natural water resources.

Reform 1: Centralization in Water & Sewerage Sector, Establishment of MOWE

Before 2001, the jurisdiction for the provision of water and sewerage services in KSA was divided into a number of ministries and subordinate agencies. The Ministry of Agriculture and Water (MOAW) was responsible for the development of natural water resources. The Saline Water Conversion Corporation (SWCC) which was established in 1974 has supplied desalinated water for municipal use. The Ministry of Municipalities and Rural Affairs (MOMRA) was responsible for the provision of both water and wastewater services to domestic customers.

In order to centralize and streamline roles and responsibilities within the water sector, the creation of a Ministry of Water (MOW) was authorized by the Government in July 2001. This Ministry was expected to oversee the country's water sector, and has taken over the water-related roles from the MOWA, and MOMRA. In 2003, the Ministry was expanded to incorporate the electricity sector and established as the MOWE.

Reform 2: Introduction of PPP

In 1999, the Supreme Economic Council was established, aimed at increasing investment and promoting privatization. Several new investment regulations have been introduced, opening up most sectors to foreign investment and reducing taxes on such investment in most sectors to 20%, and to 30% in the natural gas sector.

Public-Private Partnerships (PPP) was expected to deliver on the promise of improved water quality and customer service and visible increases in capital investment and the replacement of aging facilities, taking into account best practices, successful business models and adherence to international efficiency standards and given the projected increases in water demand in KSA. The Kingdom's Supreme Economic Council passed a Resolution (5/23), in June 2002, which established a framework for the involvement of the private sector in investing in water infrastructure.

Furthermore, the incorporation document (No. 27472 dated 9/7/1423H) for the creation of MOWE also specifies MOWE shall have responsibilities directly related to PPP:

Setting the suitable mechanisms, frameworks and arrangements for the private sector investment in water sector

Water Sector is among the 20 different sectors approved for privatization pursuant to Council of Ministers' Resolution No. 219 (6/9/1423H)

The privatization strategy approved by the Supreme Economic Council including all possible contracts in privatization such as management, leasing, financing and financing (e.g. BOT and Concession) contracts

Reform 3 : Establishment of NWC

The Government intends to reform the sector further through introducing a new institutional and regulatory framework and revising the tariff structure. A restructuring of the sector is also expected to include water demand management initiatives, including a reduction in non-revenue water, and the introduction of metering system nationwide KSA.

A major result of this reform process will be the establishment of the National Water Company (NWC) to improve the overall performance of the sector in various aspects through the transformation of the service providers to commercially oriented organizations and the involvement of the private sector. NWC is expected to start as a government-owned statutory company formed by Royal Decree and registered as a joint-stock-company. As the privatization process evolves, the role of the NWC will change to accommodate the requirements of the sector. It will gradually integrate the operations of the other major cities. The short-term institutional structure in water sector is shown in Figure B.2-2.

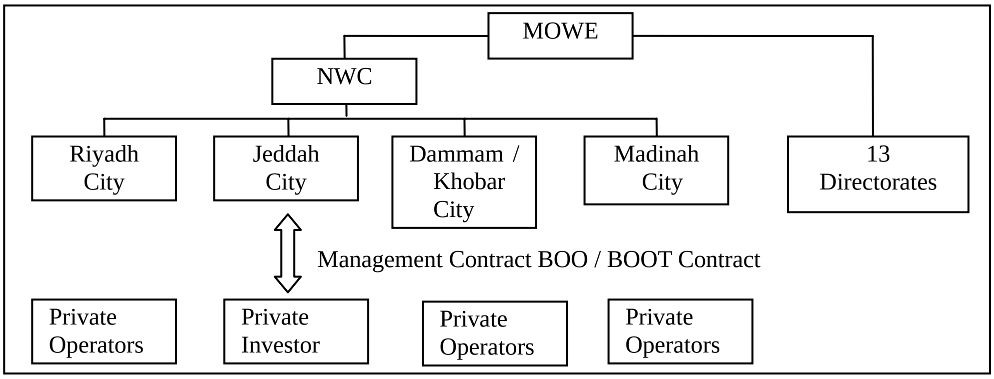


Figure B.2-2 Short-term Institutional Structure in Water Sector (Under Process)

2.5.3 Current State on Organizational Demarcations / Mandates of Relevant Authorities

Ministry of Water and Electricity (Head Quarter)

In accordance with Resolution No.125, the water directorates and departments of the MOA and the water directorates and departments of the MOMRA, came under the jurisdiction of MOWE.

Pursuant to Resolution No. 125, the key tasks of MOWE in relation to the water sector include:

- Supervising, managing, observing and regulating the water sector and its utilities,
- Conducting studies relating to water to identify its sources and the available stored resources,
- Preparation of a national comprehensive plan for water, devising water policies, developing and maintaining water resources and urging the rationed use of water,
- Preparation of an integrated program to spread drinking water and wastewater networks in the cities, regions and centers of KSA,
- Development of water policies and proposing the necessary regulations for maintaining water resources and regulating proper utility of water,
- Preparation of a study of water tariff for all categories of consumers,
- Setting up an effective mechanism to improve the performance of collecting water revenues,
- Setting up the necessary mechanisms, frames and arrangements for the private sector to invest in the finance, implementation, operation and maintenance of the water, and
- Granting necessary permits for digging wells

MOWE headquarter currently has the departments as shown in Figure B.2-3. Each department has 20 to 40 staffs.

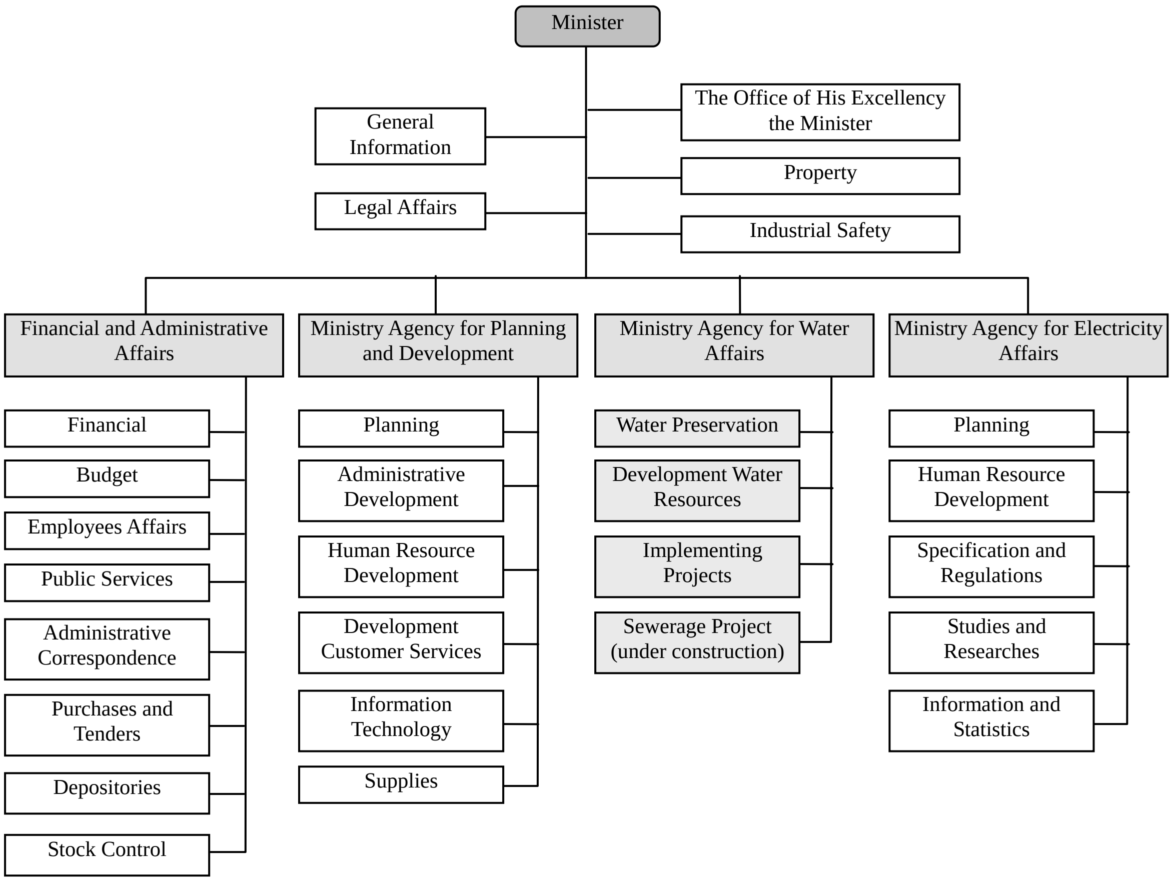


Figure B.2-3 Organization Chart of MOWE

Ministry of Agriculture

MOA is the former organization body which had the mandate for water resources development and management before it came under the jurisdiction of MOWE.

The organization chart of MOA is shown in Figure B.2-4. The departments relating to reuse of treated wastewater and irrigation water which is consuming 85% of the total water consumption in KSA is independent from the following major departments. The regional offices of MOA in 13 regions are under the direct jurisdiction of the minister.

- General Authority for Administrative and Financial Affairs
- Under Secretary Assistant for Lands Affairs
- Under Secretary Assistant for Live Stock
- Under Secretary for Fish Resources
- Under Secretary for Agriculture Research and Development
- Under Secretary for the Agriculture Affairs

Saline Water Conversion Corporation

SWCC is the authority that supplies water in KSA. SWCC is administratively related to MOWE whose minister is currently a chairman of the board of directors of SWCC. The organization chart of SWCC is shown in Figure B.2-5. SWCC has all necessary powers to achieve its main objective, which is to support natural water resources through providing desalination in 13 regions and cities in which water sources are insufficient.

Pursuant to Council of Ministers' Resolution No. 219 (6/9/1423H), the privatization of desalination has been given a top priority among various utilities.

Saudi Geological Survey

SGS was established as an independent entity attached to the Ministry of Petroleum and Mineral Resources following a Council of Ministers Decision in 1999.The tasks and duties of the SGS are similar to those of most geological surveys worldwide, and include mapping, grass-roots mineral exploration, geo-hazard and geo-environmental studies, hydro-geological studies and services to the community. Its organization chart is shown in Figure B.2-6. SGS has about 800 staffs and the head office in Jeddah with the staff number of about 650.

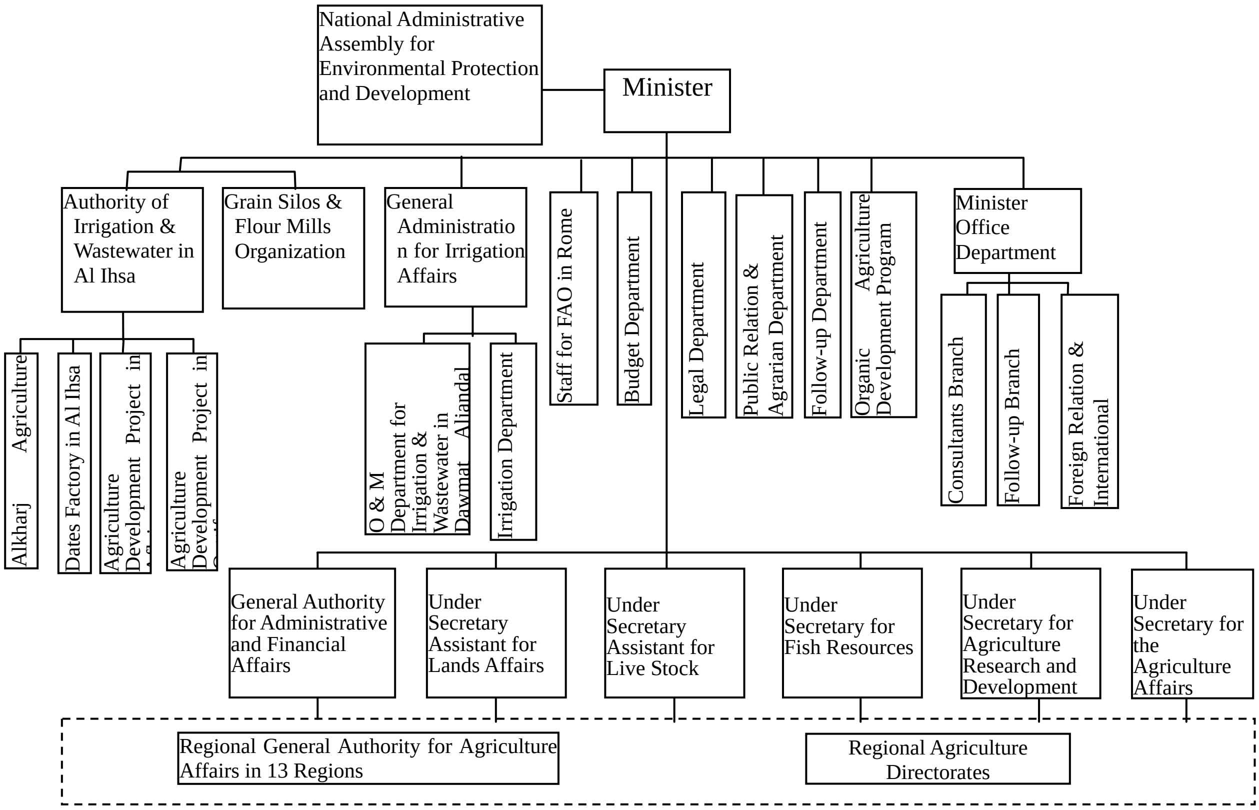


Figure B.2-4 Organization Chart of MOA

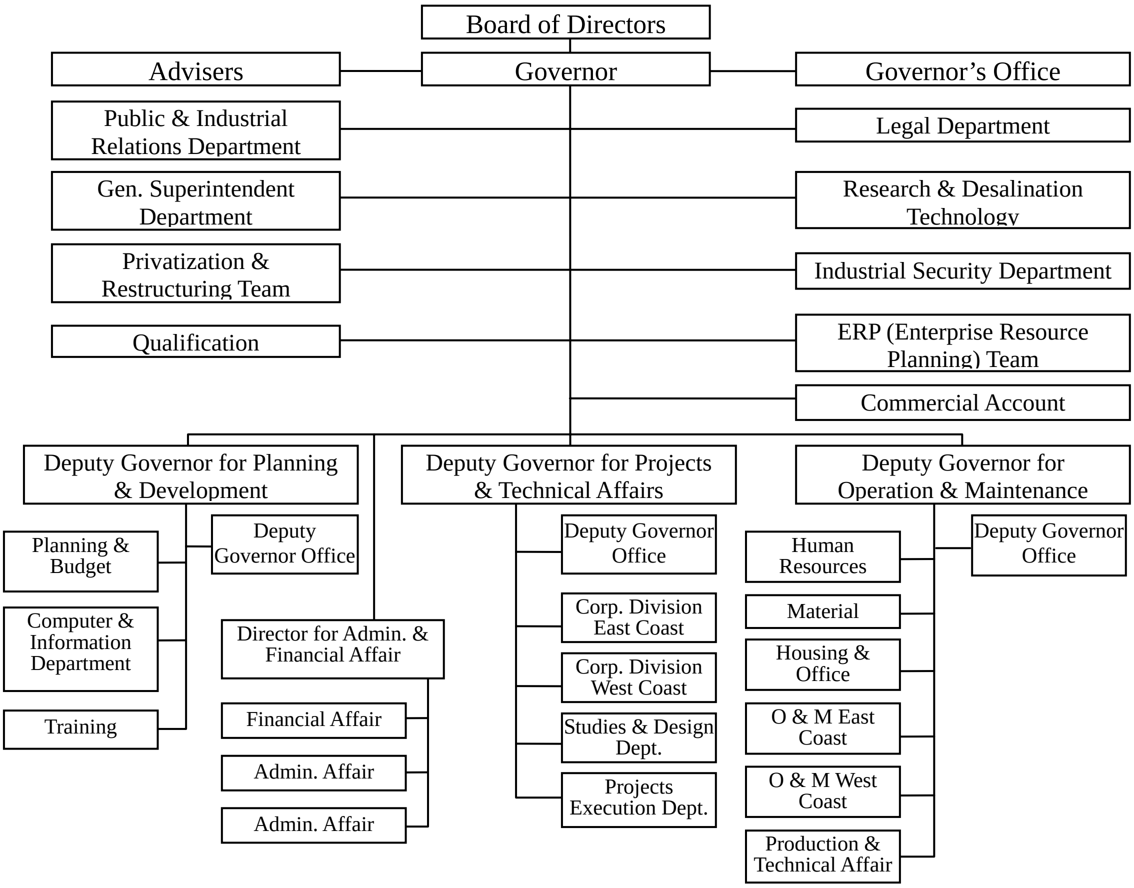


Figure B.2-5 Organization Chart of SWCC

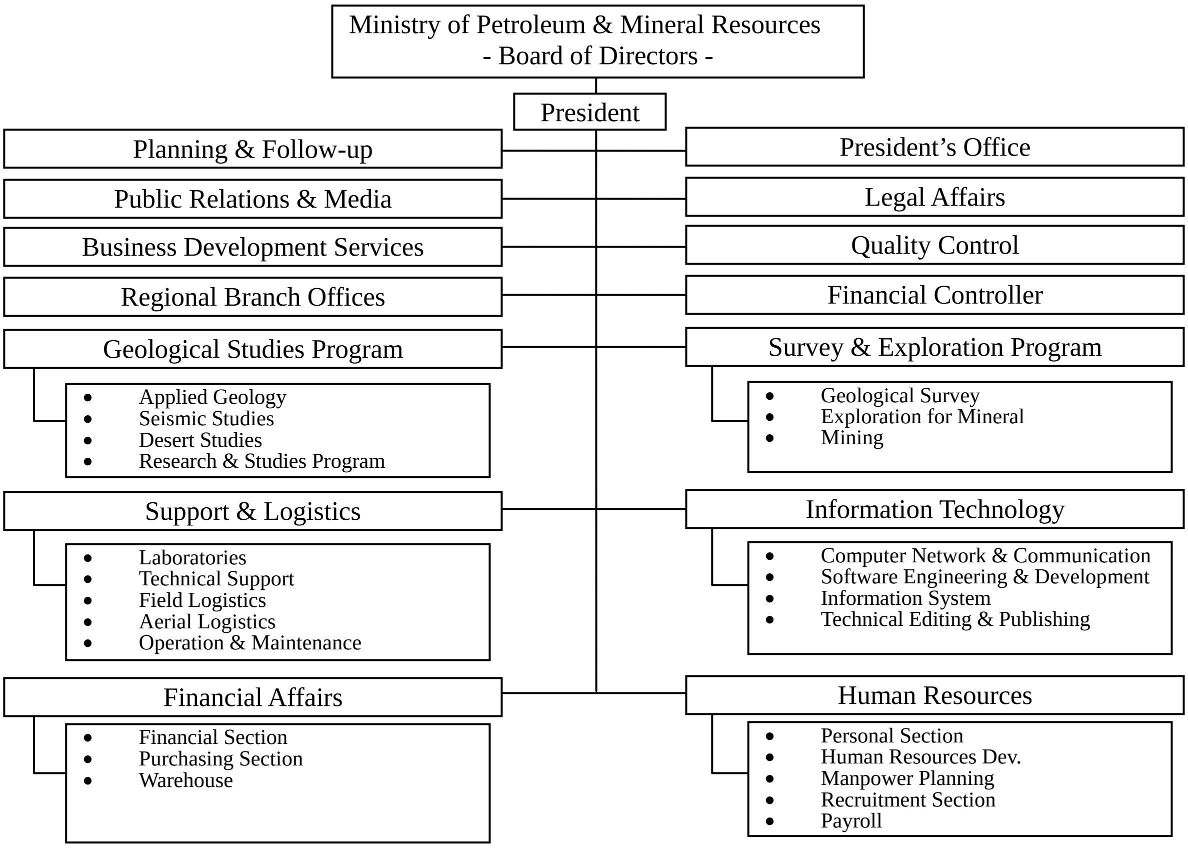


Figure B.2-6 Organization Chart of SGS

2.5.4 Budgetary Aspect relating to Water Resources Development and Management

Pursuant to Royal Decree No.381, the Ministry of Finance (MOF) was established. MOF has had the mandates for the organization, maintenance and collection of the government's finances, as well as for initiating budgeting methods.

(1) National Budget in Last 3 Years and Public Investment to Water Sector

The national budget consisting of revenues and expenditures for the last 3 fiscal years of 2005, 2006 and 2007 is shown in Table B.2-6.

Table B.2-6 National Budget in 2005, 2006 and 2007 (Performance)

Unit in Billion Saudi Riyals

Year	Revenue	Expenditure	Surplus / Deficit	
2005	555	341		214
2006	655	390		265
			Breakdown;	
			Additional Development Projects:	40
			Public Investment Fund:	20
			Government's Reserves Account:	100
			Others (incl. public debt):	105
2007	621.5	443		178.5
			Breakdown;	
			Real Estate Development Bank:	25
			Government's Reserves Account:	100
			Others (incl. public debt):	53.5

Source:
1) Ministry of Finance
2) http://www.saudiembassy.net/2006News/Statements

Table B.2-7 Budget Allocation to Each Sector (Projection)

Unit in Billion Saudi Riyals (Percentage)

No.	Sector	Year		
		2006	2007	2008
1	Education & Human Resource Development	87.3 (26.1)	96.7 (25.4)	105.0 (25.6)
2	Health & Social Affairs	31.0 (9.3)	39.5 (10.4)	44.4 (10.8)
3	Water, Agriculture & Infrastructure	22.5 (6.7)	24.8 (6.5)	28.5 (7.0)
4	Municipal Services	12.4 (3.7)	15.5 (4.1)	17.0 (4.1)
5	Transportation & Telecommunications	11.5 (3.4)	13.6 (3.6)	16.4 (4.0)
6	Others	170.3 (50.8)	189.9 (50.0)	198.7 (48.5)
Total Expenditure		335.0	380.0	410.0

Source:
1) Ministry of Finance
2) http://www.saudiembassy.net/2006News/Statements
3) http://www.soietz.gov.sa/

(2) Annual Budget of MOWE

The annual budget in the past 4 years of 2004 to 2007 is shown in Table B.2-8. The annual increase rate of investment for new projects is 20 % to 50% for the previous year.

Table B.2-8 Annual Budget of MOWE

Unit in 1,000 Saudi Riyals

Category	Regions	2004	2005	2006	2007
Third (Operation & Maintenance)	The Public Office	2,146	2,297	1,702	328
	Riyadh	1,063	1	2,393	3,298
	Makkah	**1,325**	**1,480**	**1,582**	**1,748**
	Ash Sharqiyah	1,325	856	1,191	1,085
	Al-Madinah	574	551	741	682
	Ha'il	0	0	0	296
	Al-Qasim	603	697	1,084	843
	Al-Hudud Ash Shamaliyah	0	0	0	290
	Asir	**199**	**209**	**510**	**599**
	Tabuk	63	82	199	197
	Al-Jawf	0	0	0	180
	Al Baha	**0**	**0**	**0**	**191**
	Jazan	**0**	**0**	**0**	**266**
	Najran	**0**	**0**	**0**	**102**
	Others	0	181	0	0
	Total	7,298	6,353	9,402	10,105
Fourth (New Project)	The Public Office	10,563	11,121	10,362	9,129
	Riyadh	3,683	4,482	9,782	10,319
	Makkah	**3,914**	**4,820**	**8,947**	**13,351**
	Ash Sharqiyah	2,013	2,106	3,263	3,738
	Al-Madinah	1,000	0	1,926	2,275
	Ha'il	0	1,312	0	1,320
	Al-Qasim	1,201	0	2,522	3,266
	Al-Hudud Ash Shamaliyah	0	1,207	0	1,166
	Asir	**902**	**436**	**2,104**	**2,871**
	Tabuk	349	0	1,181	1,627
	Al-Jawf	0	0	0	836
	Al Baha	**0**	**0**	**0**	**979**
	Jazan	**0**	**0**	**0**	**1,507**
	Najran	**0**	**0**	**0**	**965**
	Others	2,955	5,441	8,765	8,086
	Total	26,579	30,927	48,852	61,437

Source: Ministry of Water & Electricity

Notes: The figures of First (Salary) and Second (Bonus) categories were not available.

2.5.5 Problems Surrounding Institutional / Organizational Issues

The water resources development and management in KSA has been consolidated to MOWE since 2003 institutionally and is still in reform process at the present.

The institutional / organizational problems surrounding in water sector are shown as follows;

1) Organizational and jurisdictional problems surrounding irrigation water:

The jurisdiction of irrigation water, which is exceeding 85% of total water consumption, is not clear between MOWE and MOA. MOA has the irrigation department, while the jurisdiction of water resources including groundwater legally belongs to MOWE. There is no cross-sectional organization body or coordination institution of the two ministries for alleviating jurisdictional problems.

It runs short about the regulating function within the basin and among the basins for using renewable water efficiently in accordance with the hydrological runoff fluctuation and demand among the water sectors.

2) Law enforcement and MOWE’s human resource capability:

In view of the laws and regulations concerning water resource management (Royal Decree No M/34 or Council of Ministers' Resolution No. 62044), MOWE shall grant licenses for digging wells, inspecting sights and carrying out oversight of water resource management. However, it is uncertain that MOWE has enough human resource capacity to enforce above legal provisions.

3) Role, demarcation and mandates among the headquarter and regional offices of MOWE:

The role, demarcation and mandates among the headquarter and regional offices of MOWE are not clear. In some instances, the regional offices have more data / information on water resources management necessary for formulating mid-term or strategic long-term plans, while the headquarter has the mandates for preparing such plans.

4) Private extraction of groundwater and the limits of government’s involvement:

The land owner extracts groundwater privately within his land in Middle-East Countries, in which there is a limit for government organs to manage the groundwater compared to surface water.

5) Uncertain origins or no origins for water allocation and data gathering:

It is uncertain whether there is an origin, which controls / manages the data for water allocation and water use amount, or not. Therefore, it will be hard for the government to conduct the planned water management based on scientific data. No monitoring is done for use of irrigation water of renewable water. The provision on water right is not clear.

Free of charge for irrigation water: No estimated tariff is charged for water used for irrigation purposes at present, which is allowing the farmers to extract groundwater unimpeded and without limitations.

6) Educational campaign for water saving measures:

Water saving is currently carried out for municipal water. However, for irrigation water use, it is doubtful that such education including technical knowledge on irrigation methods for saving water is implemented for farmers.

7) Tariff issues:

The water tariff of municipal water is remarkably cheap compared with an international level. There is no water charge for irrigation water utilization. Even concerning municipal water, its water tariff is extremely lower compared to international levels or its water cost (e.g. water tariff to per capita GDP: 0.14 % in KSA in 1999 compared to that of over 0.75% in the world, and tariff to water cost: the average tariff for a family of 6 is 0.1 SR/m^3 because of its consumption of around 41 m^3/month is higher the water cost 4.0 SR/m^3 consisting of production cost 1.5 SR/m^3 plus distribution cost 2.5 SR/m^3). Furthermore, the tariff structure is the same for all domestic, institutional, commercial or industrial use.

CHAPTER 3 WATER DEMAND PREDICTION

3.1 Municipal and Industrial Water

3.1.1 Basic Policy and Frame Work for Water Demand Prediction

(1) Definition of Water Use

Municipal Water

Municipal water includes industrial water but in this study is defined in the following categories 1) and 2).

1) Domestic Water

Domestic water is residential water such as drinking, toilets, laundry, cleaning for daily use. Its consumption increases in unison with population growth and improved living standards. In the KSA, domestic water is defined as the total amount of three categories 1) residential, 2) institutional and 3) commercial water.

2) Institutional and Commercial Water

Institutional and commercial water is defined as water used for civil functions, such as governmental and private offices, hotels, small scale factories (not registered in SOIETZ), commercial facilities, hospitals, landscaping and schools. Institutional and commercial water consumption increases along with urban development and human activities. In the KSA, institutional and commercial water is defined and characterized as domestic water and not listed separately.

3) Industrial Water

Industrial water is used for various purposes of industrial activities, including machinery cooling, product treatment, washing, and as a raw material. Its usage increases along with socio-economic development and it is defined as water used for large scale industries registered in SOIETZ.

Unaccounted for Water (UFW)

UFW is water lost due to water meter operation errors, leakage on pipeline, taps and service reservoirs, and illegal connections. In this study, UFW is defined as leakage water.

(2) Basic Policy for Water Demand Prediction

The followings are basic policy for estimating future water demand.

- Population size: Population size is the basic factor for establishing the per-capita water consumption and supply coverage and is divided into three (3) categories shown in Table B.3-1.
  1) At least 85,000 population (Densely populated urban area: Large scale urban area)
  2) More than 5,000 and less than 85,000 population (Urban area)
  3) Less than 5,000 population (Rural community area)

Approximately 90% of total population lives in densely populated urban areas (>85,000) and urban areas (5,000-85,000) as shown in Table B.3-1.

Table B. 3-1 Population Size and Its Distribution in 2008 (%)

Region	>85,000 Densely Populated Urban Areas	5,000-85,000 Urban Areas	<5,000 Rural Communities	Total
Makkah	83	15	2	100
Al Baha	23	66	11	100
Asir	47	50	3	100
Jazan	38	60	2	100
Najran	59	31	10	100

Source: MOEP

- Water service coverage ratio by population size: Water service coverage ratio that is defined as the supply ratio of water shall be set up by population size.

- Domestic water consumption (including institutional and commercial water): Population multiplied by water consumption rates (daily per-capita water consumption), and by population size shall constitute domestic water consumption.
- Per-capita water consumption: Criteria for the per-capita water consumption disclosed by MOWE on May 2009 shall be applied for estimating water demand.
- Industrial water consumption: Labors in factories registered in SOIETZ multiplied by the daily per-labor water consumption shall represent industrial water consumption.
- Unaccounted for water (Leakage water): The rate of about 20% as a leakage amount of water, which was included in the water consumption rate of ministerial ordinance of MOWE, shall be applied for setting up future leakage. In addition, other scenario that the rehabilitation plans of pipelines is taken into consideration in sensitive analysis as is mentioned in the latter part.
- Seasonal fluctuations of water demand: The purpose of this study is to evaluate the water resource potential, to formulate a development strategy, and to plan for water resources but does not consider the plans and designs of the water supply system. Therefore, daily peak factors shall not be applied for estimating future water demand. However, in order to estimate the project cost, daily maximum water demand shall be taken into account.

3.1.2 Basic Framework for Municipal Water Demand Prediction

(1) Water Supply Service Ratio

In order to establish future water supply service ratio, the population size of administrative areas such as cities, towns and rural communities shall be taken into account hence the necessity to develop a water supply system that depends on human activities. The population sizes are followed by three categories for per-capita water consumption criteria of MOWE's ministerial ordinance that MOWE applies for achieving the goal of 100%.

On the other hand, it is envisaged that current water supply service ratio and rate of development in urban areas are different from that in rural communities except large-scale urban areas. Thus, the service coverage ratio is set by scale of area and target year as follows:

Table B.3-2 Water Service Coverage by Scale of Area and Target Year

Items		Service Coverage (%)
Large Scale Urban Areas	2010	90
	2015	95
	2020	100
	2025	100
	2030	100
	2035	100
Urban Areas	2010	50
	2015	60
	2020	70
	2025	80
	2030	90
	2035	100
rural communities	2010	40
	2015	52
	2020	64
	2025	76
	2030	88
	2035	100

In the sensitivity analysis scenarios, the service coverage ratio of 75% in urban areas and 50% in rural communities for year 2035 were predicted.

(2) Daily Per-capita Water Consumption of Domestic (Including Institutional and Commercial) Water

The criteria for the per-capita water consumption are classified by population size. The criteria for the per-capita water consumption by size of population were established as a mandate of MOWE in 2008. All the projects being executed in MOWE are instructed to apply criteria estimates for future water demand.

The per-capita water consumption is divided into the following three categories:

- For at least 85,000 population (Large scale urban area): 250LCD
- For more than 5,000 and less than 85,000 population (Urban area): 200LCD
- For less than 5,000 population (Rural community area): 150LCD

In sensitive analysis, on the basis of current water consumption rate, the water consumption rate, which is 10% lower than that of MOWE's ordinance, applied as in other scenarios. This water consumption rate is further likely to be the current water consumption rate.

- For at least 85,000 population (Large scale urban area): 225LCD
- For more than 5,000 and less than 85,000 population (Urban area): 180LCD
- For less than 5,000 population (Rural community area): 135LCD

(3) Industrial Water

In terms of future water demand of industrial use, as there are no differences in daily per-labor water consumption by industrial sector, the daily per-labor water consumption which is applied for estimating general industrial water demand as shown in Table B.3-3 shall be applied for estimating future industrial water demand.

On the other hand, In Jazan region, there is the development plan of Jazan Economic City, which is composed of the heavy, light industries and residences will be established for a target year of 2037. Developer of the development plan (the plan developer) is a private company of KSA and Malaysia, and Saudi Arabia General Investment Authority (SAGIA) is responsible governmental organization for the development of the Jazan Economic City. Desalination plant with a capacity of 0.2 million m^3 per day will be established in the Jazan Economic City as well as other industry facilities. This is an independent plan which is not managed by SWCC. Therefore, water demand of the Jazan Economic City shall not be included in the study.

Table B.3-3 Daily Per-labor Water Consumption of Industrial Water

Industrial Sector	Daily Per-labor Water Consumption (m^3/day/labor)
Food and Beverages	1.00
Textiles, readymade clothes and leather	0.43
Wood, wooden products and furniture	0.46
Paper, printing and publication	0.27
Chemical industries and plastic products	2.30
Building materials, glass, ceramic and metal basic industries	2.50
Basic Metallic	0.54
Manufactured metals, machines and equipment	2.10
Other industries (including transportation)	0.05

Source: Technical Book (Water Supply Fifth Edition)

(4) Rate of Waste Water Use

Landscaping water is included in water consumption rate of MOWE's mistrial ordinance. Reclaimed waste water can be utilized for this purpose. Rate of reclaimed wastewater use is required for estimating the amount of reclaimed wastewater for landscaping. From the aspect of water use composition (about 6% of overall water consumption in KSA), the JICA study team proposed that the rate of reclaimed wastewater be 5% and only be applied for large-scale urban areas.

According to the regulation of reclaimed use in the KSA, reclaimed wastewater can be utilized for industrial purposes with exception of beverage and food processing factories.

30% of the total industrial water demand in the five (5) regions is applied for estimating reclaimed wastewater. The basis of 30% was examined based on the following criteria.

- Utilize for coolant and temperature control use
- It is envisaged that about 50% of the served water is utilized for coolant and temperature control for the future because water might be recycled.
- Reclaimed wastewater is not utilized for beverage and food processing factory.
- Based on Japanese Industrial Statistics (2007), rates of coolant and temperature control water which was made up in industrial water are as follows:
  - ✓ Chemical industries and plastic products: 88.5%
  - ✓ Building materials, glass, ceramic and metal basic industries: 78.9%
  - ✓ Manufactured metals, machines and equipment: 68.3%

As a result of these estimations, the rate of reclaimed wastewater, which is to be utilized for industrial water in the five (5) regions, is to be 60% as shown in Table B.3-4.

Table B.3-4 Rate of Utilized Reclaimed Wastewater

Industrial Sector	Labor Ratio by Sector [1]	Daily Per-labor Water Consumption (m^3/day/labor) [2]	% of Total Industrial Water [3]=[1]x[2]/Total [2]	% of Coolant and Temperature Control [4]	% of Reclaimed Wastewater utilized [5]=[3]x[4]
Makkah					
Food and Beverages	20.8%	1.00	15.0%		
Textiles, readymade clothes and leather	6.0%	0.43	1.9%		
Wood, wooden products and furniture	3.1%	0.46	1.0%		
Paper, printing and publication	7.5%	0.27	1.5%		
Chemical industries and plastic products	21.1%	2.30	34.9%	88.5%	30.9%
Building materials, glass, ceramic and metal basic industries	12.2%	2.50	21.9%	78.9%	17.3%
Basic Metallic	15.2%	0.54	5.9%		
Manufactured metals, machines and equipment	11.8%	2.10	17.8%	68.3%	12.2%
Transportation	0.2%	0.05	0.0%		
Others	2.0%	0.05	0.1%		
Total	**99.9%**	**1.39**	**100.0%**		**60.3%**
Al Baha					
Food and Beverages	26.7%	1.00	18.5%		
Textiles, readymade clothes and leather	10.9%	0.43	3.3%		
Wood, wooden products and furniture	0.0%	0.46	0.0%		
Paper, printing and publication	17.5%	0.27	3.3%		
Chemical industries and plastic products	21.9%	2.30	35.0%	88.5%	31.0%
Building materials, glass, ceramic and metal basic industries	23.0%	2.50	39.9%	78.9%	31.5%
Basic Metallic	0.0%	0.54	0.0%		
Manufactured metals, machines and equipment	0.0%	2.10	0.0%	68.3%	0.0%
Transportation	0.0%	0.05	0.0%		
Others	0.0%	0.05	0.0%		
Total	**100.0%**	**1.44**	**100.0%**		**62.5%**
Asir					
Food and Beverages	17.1%	1.00	9.7%		
Textiles, readymade clothes and leather	1.1%	0.43	0.3%		
Wood, wooden products and furniture	0.7%	0.46	0.2%		
Paper, printing and publication	9.4%	0.27	1.4%		
Chemical industries and plastic products	18.8%	2.30	24.6%	88.5%	21.8%
Building materials, glass, ceramic	42.3%	2.50	60.1%	78.9%	47.4%

Industrial Sector	Labor Ratio by Sector [1]	Daily Per-labor Water Consumption (m^3/day/labor) [2]	% of Total Industrial Water [3]=[1]x[2]/Total [2]	% of Coolant and Temperature Control [4]	% of Reclaimed Wastewater utilized [5]=[3]x[4]
and metal basic industries					
Basic Metallic	9.6%	0.54	2.9%		
Manufactured metals, machines and equipment	0.6%	2.10	0.7%	68.3%	0.5%
Transportation	0.0%	0.05	0.0%		
Others	0.4%	0.05	0.0%		
Total	**100.0%**	**1.76**	**100.0%**		**69.7%**
Jazan					
Food and Beverages	22.6%	1.00	11.3%		
Textiles, readymade clothes and leather	1.6%	0.43	0.3%		
Wood, wooden products and furniture	0.0%	0.46	0.0%		
Paper, printing and publication	0.6%	0.27	0.1%		
Chemical industries and plastic products	6.3%	2.30	7.2%	88.5%	6.4%
Building materials, glass, ceramic and metal basic industries	64.4%	2.50	80.4%	78.9%	63.4%
Basic Metallic	2.3%	0.54	0.6%		
Manufactured metals, machines and equipment	0.0%	2.10	0.0%	68.3%	0.0%
Transportation	2.3%	0.05	0.1%		
Others	0.0%	0.05	0.0%		
Total	**100.1%**	**2.00**	**100.0%**		**69.8%**
Najran					
Food and Beverages	26.9%	1.00	15.0%		
Textiles, readymade clothes and leather	0.0%	0.43	0.0%		
Wood, wooden products and furniture	0.0%	0.46	0.0%		
Paper, printing and publication	0.0%	0.27	0.0%		
Chemical industries and plastic products	24.1%	2.30	30.9%	88.5%	27.3%
Building materials, glass, ceramic and metal basic industries	35.9%	2.50	50.1%	78.9%	39.5%
Basic Metallic	13.1%	0.54	3.9%		
Manufactured metals, machines and equipment	0.0%	2.10	0.0%	68.3%	0.0%
Transportation	0.0%	0.05	0.0%		
Others	0.0%	0.05	0.0%		
Total	**100.0%**	**1.79**	**100.0%**		**66.9%**

Source: JICA Study Team

However, considering the progress of facility development for utilizing reclaimed wastewater and recycled water improvement, the rate of reclaimed wastewater is less than 60%. Accordingly, it is proposed that the rate of reclaimed wastewater is 30% (a half of 60%) on the safe side.

(5) Leakage Ratio

In order to set up leakage ratio, Leakage ratio of about 20% which is included in MOWE' basic scenario (Ministerial Ordinance) is applied for estimating municipal water demand in this study, because current status of the existing pipe network and data of leakage ratio on pipe rehabilitation were not clarified.

Furthermore, considering the construction year of the existing pipeline system and leakage reduction through improvement of the system in each region, it is proposed that 15%, which is the lowest ratio in the KSA, is also applied as other scenarios in the sensitivity analysis.

(6) Condition of Water Demand Prediction

Condition of water demand prediction applied to development of water supply facility is summarized as follows:

Table B.3-5 Basic Condition of Water Demand Prediction

Items		Basic Condition
Per-capita water Consumption (L/capita/day)		
• Large Scale Urban		250
• Urban		200
• Rural Community		150
Leakage Ratio		20%
Rate of Wastewater Use		
• Municipal Water (Landscaping)		5%
• Industrial Water		30%
Water Service Coverage		
Large Scale Urban	2010	90%
	2015	95%
	2020	100%
	2025	100%
	2030	100%
	2035	100%
Urban	2010	50%
	2015	60%
	2020	70%
	2025	80%
	2030	90%
	2035	100%
Rural Community	2010	40%
	2015	52%
	2020	64%
	2025	76%
	2030	88%
	2035	100%

In addition, water demand is estimated in multiple options taking into consideration that water demand fluctuation through water demand management and practical rate of water supply facility development as shown in the table above in the sensitive analysis.

3.1.3 Daily Peak Factor for Planning Capacity of Facilities

In order to design water supply facilities such as conveyance, transmission lines, rising pumps, service reservoirs, storage tanks, maximum water demand throughout the year shall be taken into consideration. Daily maximum water demand is generally estimated based on the historical data of daily peak factors. In the KSA, water consumption for tourist and pilgrim is one of the causes of increased water demand in a certain period of year. As shown in Table B.3-6, peak season for tourist and pilgrim is from June to October, and water demand increases as shown.

In this study, it is proposed that the daily maximum factor is set to be 1.29 on the influx of tourism. Accordingly, in order to set up the capacity of each water supply facility, 29% of total water demands which was estimated above shall be taken into account.

Table B.3-6 Circumstance of Tourist Inflow

Category	Inbound		Domestic		Total		Average
Jan.	2,292,469	2.04	3,167,322	1.28	5,459,791	1.52	1.29
Feb.	728,113	0.65	1,267,614	0.51	1,995,727	0.55	
Mar.	626,282	0.56	1,405,901	0.57	2,032,183	0.57	
Apr.	879,584	0.78	1,595,079	0.65	2,474,663	0.69	
May.	874,979	0.78	1,909,630	0.77	2,784,609	0.77	
Jun.	973,236	0.87	2,763,733	1.12	3,736,969	1.04	
Jul.	1,419,932	1.26	3,638,019	1.47	5,057,951	1.41	
Aug.	1,490,114	1.33	3,358,919	1.36	4,849,033	1.35	
Sep.	1,449,729	1.29	2,753,320	1.11	4,203,049	1.17	
Oct.	1,099,907	0.98	3,365,834	1.36	4,465,741	1.24	
Nov.	695,946	0.62	2,138,219	0.86	2,834,165	0.79	
Dec.	948,285	0.84	2,308,794	0.93	3,257,079	0.91	
Average	1,123,215		2,472,699		3,595,913		

Source：Statistics Summary Province (Makkah, Asir, Al Baha, Jazan and Najran) for 2007, Tourism Information and Research Center

3.1.4 Predicted Municipal Water Demand (Domestic, Institutional, Commercial Water)

(1) Future Population

Future population of the five regions shall be estimated based on the following conditions.

- Case 1: Based on the past trends of population
- Case 2: Based on future population growth rate as mentioned in the Eighth Development Plan
- Case 3: Based on future population that was officially forecasted by MOEP in 2009.

In terms of Case 1, there are population data in 1974, 1992 and 2004 but since the population data of 1974 is too old to estimate the future population, the future population is estimated by arithmetical formula based on the trends between 1992 and 2004.

In terms of Case 2, the following percentages are the annual, average, population growth rates that were mentioned in the Eighth Development Plan. Annual average growth rate from 2010 to 2015 is 1.5-1.7% and that from 2015 to 2035 is 1.1-1.3%. Those annual growth rates were followed by a National Policy (Saudization) for reducing foreign laborers in the KSA.

- Until 2010: 1.7%
- 2010 to 2015: 1.5%
- 2015 to 2020: 1.3%
- 2020 to 2025: 1.1%
- 2025 to 2035: 1.1%

Future population growth rates shown in the Eight Development Plan are the growth rates of the overall KSA due to Saudization. In order to establish future population growth rates of each region, the rate of the annual average population growth rate (2.6%) in the KSA for 1992 -2004 and population growth rate of each region shall be estimated in converting the future population growth rates of the KSA, as shown in Table B.3-7.

Table B.3-7 Future Population Growth Rate of Case 2 (%)

Year	KSA	Makkah	Al Baha	Asir	Jazan	Najran
Growth rates of each region/that of overall KSA (1992-2004) →		88%	42%	77%	108%	115%
1992-2004	**2.6**	2.3	1.1	2.0	2.8	3.0
2004-2010	**1.7**	1.5	0.7	1.3	1.9	2.0
2010-2015	**1.5**	1.3	0.6	1.2	1.6	1.7
2015-2020	**1.3**	1.1	0.5	1.0	1.4	1.5
2020-2025	**1.1**	1.0	0.4	0.8	1.2	1.3
2025-2035	**1.1**	1.0	0.4	0.8	1.2	1.3

Source: JICA Study Team

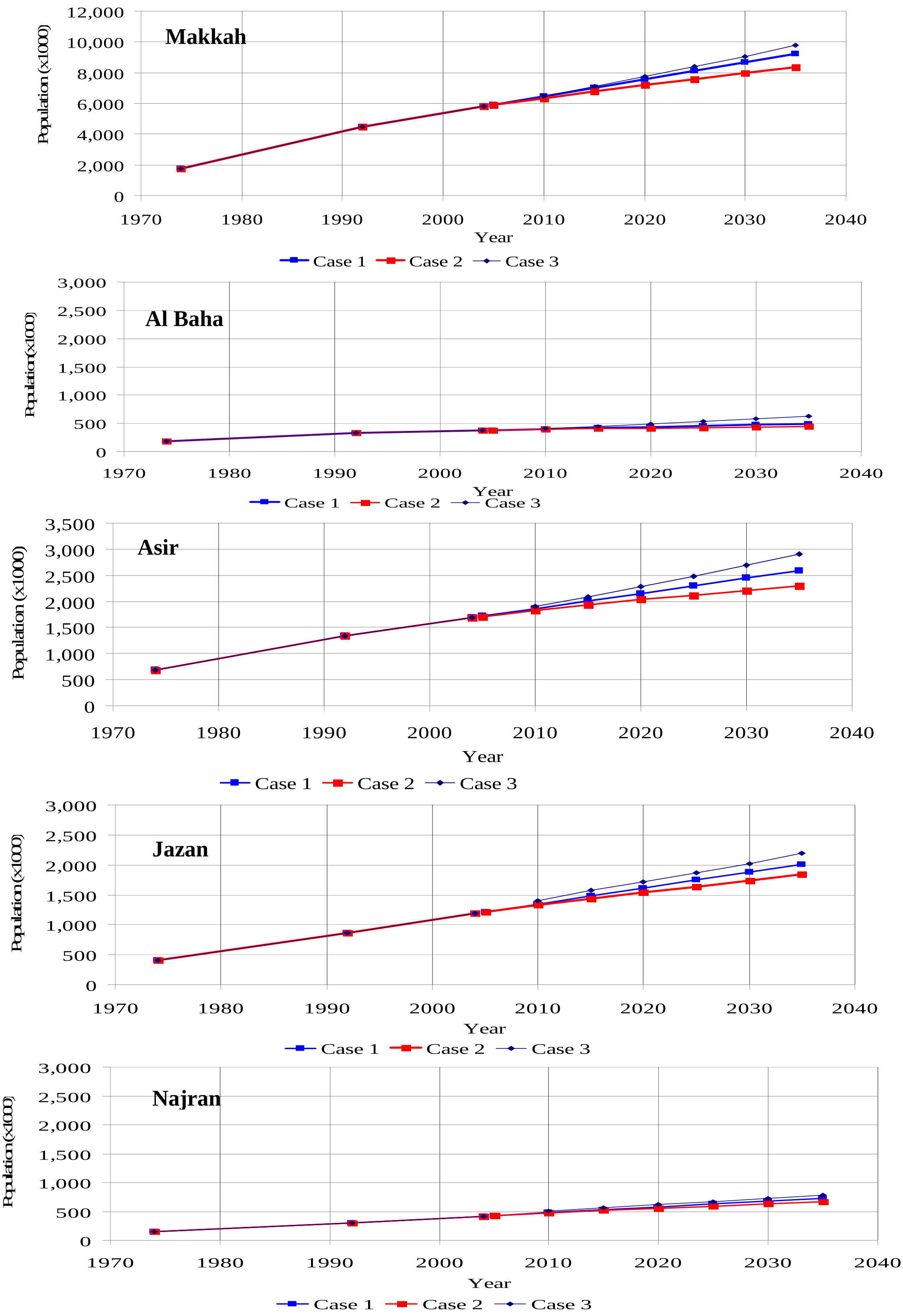
In terms of Case 3, future population of administrative areas with the lowest level such as cities, towns and communities under sub-divisions (Governorates) was forecasted in Saudi and Non-Saudi people. Table B.3-8 summaries the average, population growth rate by region for the future. It was estimated on basis of population growth rate set up by areas such as cities, towns and communities by MOEP.

Table B.3-8 Population Growth Rate by Ministry of Economy and Planning (%)

Year	Makkah	Al Baha	Asir	Jazan	Najran
1992-2004	2.3	1.1	2.0	2.8	3.0
2004-2010	1.9	2.0	2.0	2.8	2.9
2010-2015	1.9	2.0	2.0	2.0	2.0
2015-2020	1.6	1.7	1.7	1.7	1.7
2020-2025	1.6	1.6	1.6	1.6	1.6
2025-2035	1.6	1.6	1.6	1.6	1.6

Source: MOEP

Figure B.3-1 shows the results of population prediction in three cases.



Note: Case 1: Arithmetical, Case 2: Annual growth rates based on the Eighth Development Plan
Where,
Arithmetical: y=ax + b (y : Value of the fiscal year concerned , x : Value for the numbers of years elapsing from the design reference fiscal year , a, b : Constant)
Annual growth rate: y=y0 x (1+r)x (y : Value of the year concerned , y0 : Value of the reference year , x : Value corresponding to the numbers of years elapsing from the design reference year , r : Annual growth rate)

Figure B.3-1 Predicted Population for Five Regions

In Case 3, estimating domestic water consumption is applied based on the future population that is predicted by MOEP hence projects coordinating and planning are executed under MOWE. Table B.3-9 shows the future population sum by region based on the future population by areas such as city, town and community.

Table B.3-9 Future Population Prediction by Region (1000 persons)

Year	Makkah	Al Baha	Asir	Jazan	Najran	Five Regions
1974	1,754	186	681	403	148	3,172
1992	4,468	332	1,340	866	301	7,307
2004	5,798	378	1,688	1,186	419	9,469
2010	6,468	411	1,895	1,404	502	10,680
2015	7,115	449	2,090	1,572	564	11,790
2020	7,755	492	2,288	1,720	617	12,872
2025	8,379	533	2,480	1,864	669	13,925
2030	9,054	578	2,688	2,021	725	15,066
2035	9,785	627	2,914	2,190	786	16,302

Source: JICA Study Team

(2) Municipal Water Demand (Domestic, Commerce and Institution)

Tables B.3-10- B.3-14 summarizes municipal water demand excepting industry.

Table B.3-10 Estimated Municipal Water Demand (Makkah Region)

m^3/day

Governorate	2010	2015	2020	2025	2030	2035
Option-1						
Makkah Al Mukarramah	330,803	384,420	441,202	477,290	516,616	558,953
Jeddah	713,267	828,382	959,383	1,035,424	1,117,549	1,206,252
Al Taif	197,006	232,457	270,877	298,619	329,128	362,946
Al Qunfidah	26,769	35,485	45,369	56,267	68,930	83,086
Al Lith	11,474	16,009	20,506	25,467	31,365	37,831
Rabigh	7,433	9,877	12,867	15,940	19,435	23,402
Al Jjumum	7,992	10,659	13,903	17,265	21,341	25,722
Khulays	5,003	6,943	9,147	11,367	13,896	16,771
Al Kamil	1,765	2,388	3,098	3,884	4,780	5,800
Al Khurmah	4,275	5,674	7,257	9,002	10,990	13,249
Ranyah	4,680	6,242	8,015	9,972	12,203	14,740
Turbah	4,298	5,995	7,699	9,580	11,973	14,442
Total	**1,314,764**	**1,544,530**	**1,799,322**	**1,970,076**	**2,158,206**	**2,363,194**

Source: JICA Study Team

Table B.3-11 Estimated Municipal Water Demand (Al Baha Region)

m^3/day

Governorate	2010	2015	2020	2025	2030	2035
Option-1						
Al Baha	21,727	25,182	29,122	31,769	34,657	37,808
Biljurashi	6,480	8,530	10,917	13,548	16,544	20,211
Al Mandaq	4,809	6,341	8,125	10,094	12,594	15,179
Al Mukhwah	6,412	8,963	11,485	14,268	17,694	21,335
Al Aqiq	2,819	3,748	4,832	6,030	7,887	9,505
Qilwah	5,514	7,770	9,954	12,364	15,112	18,491
Al Qari	3,054	4,026	5,159	6,409	7,833	9,453
Total	**50,815**	**64,560**	**79,595**	**94,482**	**112,322**	**131,983**

Source: JICA Study Team

Table B.3-12 Estimated Municipal Water Demand (Asir Region)

m³/day

Governorate	2010	2015	2020	2025	2030	2035
Option-1						
Abha	70,014	83,788	99,095	111,403	124,838	139,753
Khamis Mushayt	102,562	120,638	140,211	154,038	169,206	185,846
Bishah	33,786	41,285	49,344	56,324	64,136	72,871
An Namas	5,365	7,099	9,058	11,216	13,672	16,460
Muhayl Asir	34,499	41,465	49,106	55,327	62,253	70,218
Sarat Abidah	6,323	8,436	11,306	14,014	17,100	20,608
Tathlith	4,883	6,782	8,729	11,378	13,898	16,765
Rijal Almah	6,610	8,761	11,196	13,880	16,941	20,421
Ahad Rifaydah	11,028	14,628	18,705	23,199	34,568	38,984
Zahran Al Janub	6,139	8,148	10,423	12,932	15,791	19,041
Balqarn	7,342	9,745	12,466	15,465	18,882	22,765
Al Majardah	9,916	13,162	16,840	20,896	25,517	30,773
Total	**298,465**	**363,936**	**436,479**	**500,073**	**576,803**	**654,504**

Source: JICA Study Team

Table B.3-13 Estimated Municipal Water Demand (Jazan Region)

m³/day

Governorate	2010	2015	2020	2025	2030	2035
Option-1						
Jazan	44,848	55,908	67,344	77,721	89,377	106,910
Sabya	44,505	53,671	62,859	69,838	77,551	86,074
Abu Arish	32,958	38,974	44,895	48,666	52,754	57,187
Samtah	28,105	34,029	40,000	44,659	49,820	55,538
Al Harth	5,656	7,603	9,704	12,019	14,654	17,646
Damad	7,406	9,950	12,687	15,700	19,128	23,016
Ar Rayth	1,502	2,034	2,614	3,255	3,986	4,819
Baysh	6,903	9,279	11,843	14,668	17,885	21,538
Farasan	1,652	2,221	2,837	3,515	4,288	5,166
Ad Dair	5,658	7,637	9,787	12,160	14,866	18,197
Ahad Al Musarihah	8,276	22,021	25,371	27,505	29,819	32,329
Al Idabi	6,512	9,047	11,831	14,670	17,908	21,591
Al Aridah	7,330	9,875	12,635	15,677	19,146	23,090
Ad Darb	6,092	8,199	10,475	12,983	15,838	19,082
Total	**207,404**	**270,448**	**324,882**	**373,036**	**427,018**	**492,181**

Source: JICA Study Team

Table B.3-14 Estimated Municipal Water Demand (Najran Region)

m³/day

Governorate	2010	2015	2020	2025	2030	2035
Option-1						
Najran	68,062	80,823	93,392	101,941	111,029	120,928
Sharurah	8,576	21,766	25,263	27,661	30,285	33,155
Hubunah	2,640	3,607	4,650	5,803	7,117	9,128
Badr Al Janub	690	1,233	1,618	2,046	2,778	3,368
Yadamah	1,621	2,200	2,821	3,507	4,289	5,178
Thar	1,206	1,693	2,220	2,805	3,475	4,238
Khubash	2,024	3,001	3,846	4,779	5,841	7,051
Al Kharkhir	272	610	779	965	1,176	1,416
Total	**85,091**	**114,933**	**134,590**	**149,506**	**165,990**	**184,461**

Source: JICA Study Team

3.1.5 Predicted Industrial Water Demand

(1) Predicted Number of Industries

According to the economic Report 2007 (SAGIA), industries in each region increase yearly since all regions focus on industrial development. Thus these numbers of industries increase based on arithmetic way. The forecasting results concerning the number of industries are shown in Table B.3-15.

Table B.3-15 Number Prediction of Industries

Region	Historical Data			Future Plan					
	1999	2004	2006	2010	2015	2020	2025	2030	2035
Makkah	861	965	1,012	1,096	1,203	1,310	1,417	1,524	1,632
Al Baha	12	14	15	17	19	21	23	25	27
Asir	72	84	89	99	111	123	135	147	159
Jazan	35	38	38	40	43	45	47	49	52
Najran	19	19	22	22	23	24	25	26	27
Total	**999**	**1,120**	**1,176**	**1,273**	**1,398**	**1,523**	**1,647**	**1,772**	**1,897**

Source: JICA Study Team

(2) Number Prediction of Industrial Labors

Multiplying the predicted numbers of industries shown in Table B.3-15 by the numbers of labors per industry (2006) indicate the predicted numbers of labors as is shown in Table B.3-16. In addition, the future number of labors by sectors are estimated based on the ratio of composition against the number of labors by sectors (see Table B.3-17~ Table B.3-21).

Table B.3-16 Predicted Numbers of Labors

Region	2010	2015	2020	2025	2030	2035
Makkah	105,212	115,495	125,778	136,062	146,345	156,628
Al Baha	532	600	667	735	803	871
Asir	5,918	6,645	7,372	8,098	8,825	9,552
Jazan	1,489	1,574	1,659	1,745	1,830	1,915
Najran	670	706	742	777	813	849
Total	**113,821**	**125,020**	**136,218**	**147,417**	**158,616**	**169,815**

Source: JICA Study Team

Table B.3-17 Predicted Numbers of Labors by Sector in Makkah Region

Sector	Labor Ratio by Sector	2006	2010	2015	2020	2025	2030	2035
Food and Beverages	20.8%	22,022	21,884	24,023	26,162	28,301	30,440	32,579
Textiles, readymade clothes and leather	6.0%	6,387	6,313	6,930	7,547	8,164	8,781	9,398
Wood, wooden products and furniture	3.1%	3,312	3,262	3,580	3,899	4,218	4,537	4,855
Paper, printing and publication	7.5%	7,917	7,891	8,662	9,433	10,205	10,976	11,747
Chemical and plastic products	21.1%	22,297	22,200	24,369	26,539	28,709	30,879	33,049
Building materials, glass, ceramic and metal basic	12.2%	12,942	12,836	14,090	15,345	16,600	17,854	19,109
Basic Metallic	15.2%	16,051	15,992	17,555	19,118	20,681	22,244	23,807
Manufactured metals, machines and equipment	11.8%	12,461	12,415	13,628	14,842	16,055	17,269	18,482
Transportation & Warehouse	0.2%	217	210	231	252	272	293	313
Other industries	2.0%	2,107	2,104	2,310	2,516	2,721	2,927	3,133
Total	**100.0%**	**105,713**	**105,107**	**115,378**	**125,653**	**135,926**	**146,200**	**156,472**

Source: JICA Study Team

Table B.3-18 Predicted Numbers of Labors by Sector in Al Baha Region

Sector	Labor Ratio by Sector	2006	2010	2015	2020	2025	2030	2035
Food and Beverages	26.7%	117	142	160	178	196	214	233
Textiles, readymade clothes and leather	10.9%	48	58	65	73	80	88	95
Wood, wooden products and furniture	0.0%	0	0	0	0	0	0	0
Paper, printing and publication	17.5%	77	93	105	117	129	141	152
Chemical and plastic products	21.9%	96	117	131	146	161	176	191
Building materials, glass, ceramic and metal basic	23.0%	101	122	138	153	169	185	200
Basic Metallic	0.0%	0	0	0	0	0	0	0
Manufactured metals, machines and equipment	0.0%	0	0	0	0	0	0	0
Transportation & Warehouse	0.0%	0	0	0	0	0	0	0
Other industries	0.0%	0	0	0	0	0	0	0
Total	**100.0%**	**439**	**532**	**599**	**667**	**735**	**804**	**871**

Source: JICA Study Team

Table B.3-19 Predicted Numbers of Labors by Sector in Asir Region

Sector	Labor Ratio by Sector	2006	2010	2015	2020	2025	2030	2035
Food and Beverages	17.1%	801	1,012	1,136	1,261	1,385	1,509	1,633
Textiles, readymade clothes and leather	1.1%	50	65	73	81	89	97	105
Wood, wooden products and furniture	0.7%	33	41	47	52	57	62	67
Paper, printing and publication	9.4%	439	556	625	693	761	830	898
Chemical and plastic products	18.8%	883	1,113	1,249	1,386	1,522	1,659	1,796
Building materials, glass, ceramic and metal basic	42.3%	1,982	2,503	2,811	3,118	3,425	3,733	4,040
Basic Metallic	9.6%	451	568	638	708	777	847	917
Manufactured metals, machines and equipment	0.6%	28	36	40	44	49	53	57
Transportation & Warehouse	0.0%	0	0	0	0	0	0	0
Other industries	0.4%	18	24	27	29	32	35	38
Total	**100.0%**	**4,685**	**5,918**	**6,646**	**7,372**	**8,097**	**8,825**	**9,551**

Source: JICA Study Team

Table B.3-20 Predicted Numbers of Labors by Sector in Jazan Region

Sector	Labor Ratio by Sector	2006	2010	2015	2020	2025	2030	2035
Food and Beverages	22.6%	409	337	356	375	394	414	433
Textiles, readymade clothes and leather	1.6%	29	24	25	27	28	29	31
Wood, wooden products and furniture	0.0%	0	0	0	0	0	0	0
Paper, printing and publication	0.6%	11	9	9	10	10	11	11
Chemical and plastic products	6.3%	114	94	99	105	110	115	121
Building materials, glass, ceramic and metal basic	64.4%	1,165	959	1,014	1,068	1,124	1,179	1,233
Basic Metallic	2.3%	41	34	36	38	40	42	44
Manufactured metals, machines and equipment	0.0%	0	0	0	0	0	0	0
Transportation & Warehouse	2.3%	41	34	36	38	40	42	44
Other industries	0.0%	0	0	0	0	0	0	0
Total	**100.0%**	**1,810**	**1,491**	**1,575**	**1,661**	**1,746**	**1,832**	**1,917**

Source: JICA Study Team

Table B.3-21 Predicted Numbers of Labors by Sector in Najran Region

Sector	Labor Ratio by Sector	2006	2010	2015	2020	2025	2030	2035
Food and Beverages	26.9%	173	180	190	200	209	219	228
Textiles, readymade clothes and leather	0.0%	0	0	0	0	0	0	0
Wood, wooden products and furniture	0.0%	0	0	0	0	0	0	0
Paper, printing and publication	0.0%	0	0	0	0	0	0	0
Chemical and plastic products	24.1%	155	161	170	179	187	196	205
Building materials, glass, ceramic and metal basic	35.9%	231	241	253	266	279	292	305
Basic Metallic	13.1%	84	88	92	97	102	107	111
Manufactured metals, machines and equipment	0.0%	0	0	0	0	0	0	0
Transportation & Warehouse	0.0%	0	0	0	0	0	0	0
Other industries	0.0%	0	0	0	0	0	0	0
Total	**100.0%**	**643**	**670**	**705**	**742**	**777**	**814**	**849**

Source: JICA Study Team

(3) Industrial Water Demand

Multiplying per-labor water consumption shown in Table B.3-3 by numbers of labors mentioned above indicates industrial water demand in Table B.3-22

Table B.3-22 Industrial Water Demand (1000m^3/day)

Region	2006	2010	2015	2020	2025	2030	2035
Makkah	147	147	160	175	189	203	218
Al Baha	1	1	1	1	1	1	1
Asir	8	10	12	13	14	16	17
Jazan	4	3	3	3	3	4	4
Najran	1	1	1	1	1	1	2
Total	**161**	**162**	**177**	**193**	**209**	**225**	**241**

Source: JICA Study Team

3.1.6 Future Water Demand on Municipal and Industrial Water

Table B.3-23 to B.3-27 shows the overall municipal water demand for domestic, institutional and commercial, and industrial use as public water supply, and the reclaimed wastewater utilized for landscaping, etc. The amounts of water which is provided with renewable water and desalinated water are estimated due to a deduction of some water amounts which can be covered by reclaimed wastewater from the overall water demand.

Table B.3-23 Total Water Demand (Makkah Region)

1000m^3/day

Makkah Region	2010	2015	2020	2025	2030	2035
Option-1						
Municipal Water Demand [1]	1,315	1,545	1,799	1,970	2,158	2,363
Industrial Water Demand [2]	147	160	175	189	203	218
Overall Water Demand	**1,462**	**1,705**	**1,974**	**2,159**	**2,361**	**2,581**
Water covered by reclaimed wastewater [3]	184	210	242	261	282	304
Total [1]+[2]-[3]	**1,277**	**1,494**	**1,733**	**1,898**	**2,080**	**2,278**

Source: JICA Study Team

Table B.3-24 Total Water Demand (Al Baha Region)

1000m^3/day

Al Baha Region	2010	2015	2020	2025	2030	2035
Option-1						
Municipal Water Demand [1]	51	65	80	94	112	132
Industrial Water Demand [2]	1	1	1	1	1	1
Overall Water Demand	**52**	**66**	**81**	**95**	**113**	**133**
Water covered by reclaimed wastewater [3]	1	2	2	2	2	2
Total [1]+[2]-[3]	**53**	**68**	**83**	**97**	**115**	**135**

Source: JICA Study Team

Table B.3-25 Total Water Demand (Asir Region)

1000m^3/day

Asir Region	2010	2015	2020	2025	2030	2035
Option-1						
Municipal Water Demand [1]	298	364	436	500	577	655
Industrial Water Demand [2]	10	12	13	14	16	17
Overall Water Demand	**308**	**376**	**449**	**514**	**593**	**672**
Water covered by reclaimed wastewater [3]	13	15	17	19	22	23
Total [1]+[2]-[3]	**295**	**361**	**432**	**495**	**571**	**648**

Source: JICA Study Team

Table B.3-26 Total Water Demand (Jazan Region)

1000m^3/day

Jazan Region	2010	2015	2020	2025	2030	2035
Option-1						
Municipal Water Demand [1]	207	241	290	333	382	442
Industrial Water Demand [2]	3	3	3	3	4	4
Overall Water Demand	**210**	**244**	**293**	**336**	**386**	**446**
Water covered by reclaimed wastewater [3]	7	6	7	7	8	9
Total [1]+[2]-[3]	**203**	**238**	**286**	**329**	**379**	**436**

Source: JICA Study Team

Table B.3-27 Total Water Demand (Najran Region)

1000m³/day

Najran Region	2010	2015	2020	2025	2030	2035
Option-1						
Municipal Water Demand [1]	85	115	135	150	166	184
Industrial Water Demand [2]	1	1	1	1	1	1
Overall Water Demand	**86**	**116**	**136**	**151**	**167**	**185**
Water covered by reclaimed wastewater [3]	1	1	1	1	1	1
Total [1]+[2]-[3]	**85**	**115**	**135**	**150**	**166**	**184**

Source: JICA Study Team

Predicted water demand as 'Option -1' based on basic condition by governorate is shown in Figure B.3-2 to B.3-6. The Industrial water is allocated in the particular governorate where industrial development is expected by MOWE regional office and where existing factories are located.

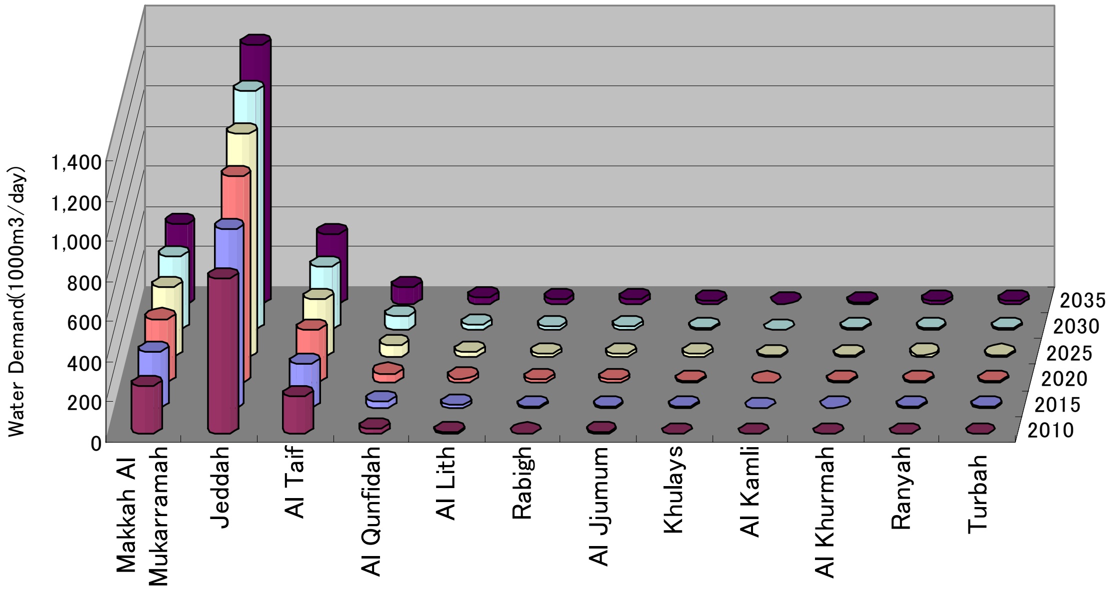


Figure B.3-2 Municipal Water Demand by Governorate in Makkah Region (Option-1)

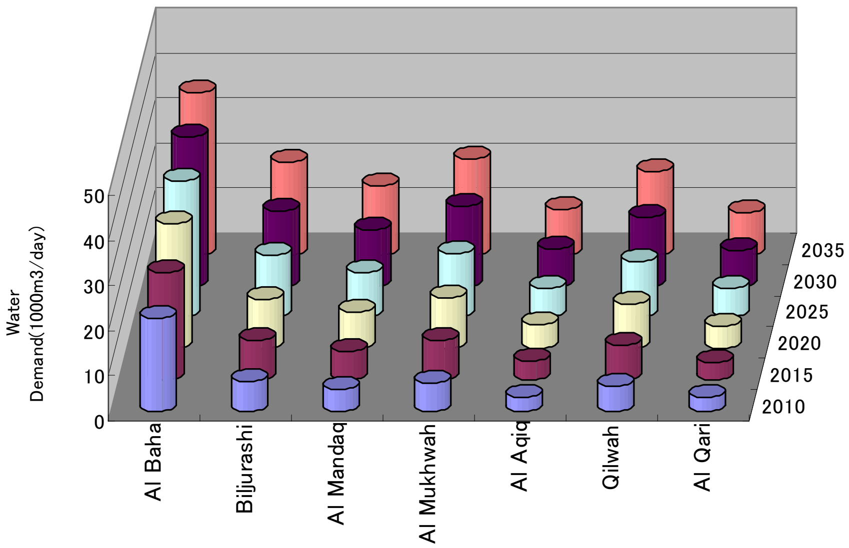


Figure B.3-3 Municipal Water Demand by Governorate in Al Baha Region (Option-1)

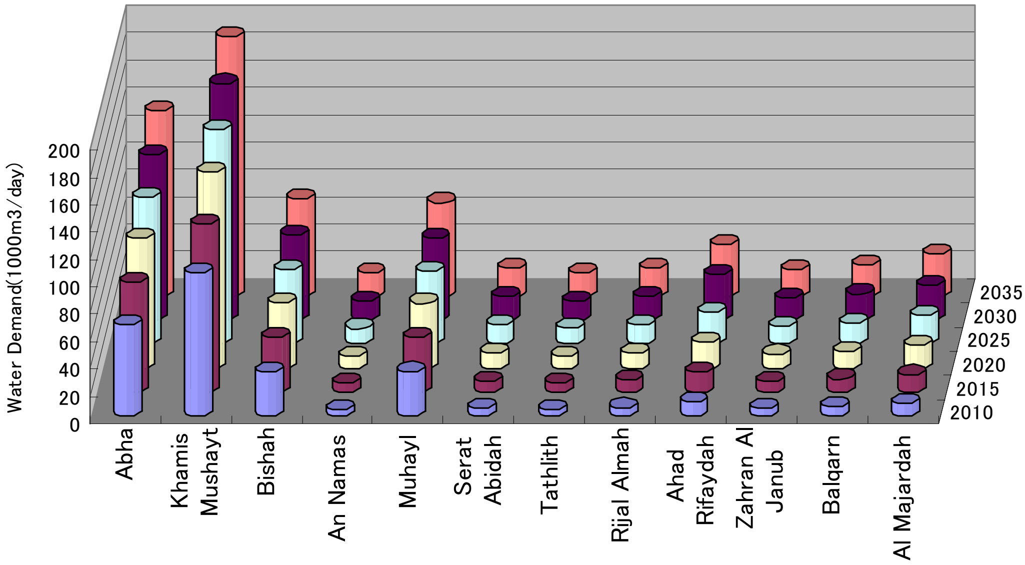


Figure B.3-4 Municipal Water Demand by Governorate in Asir Region (Option-1)

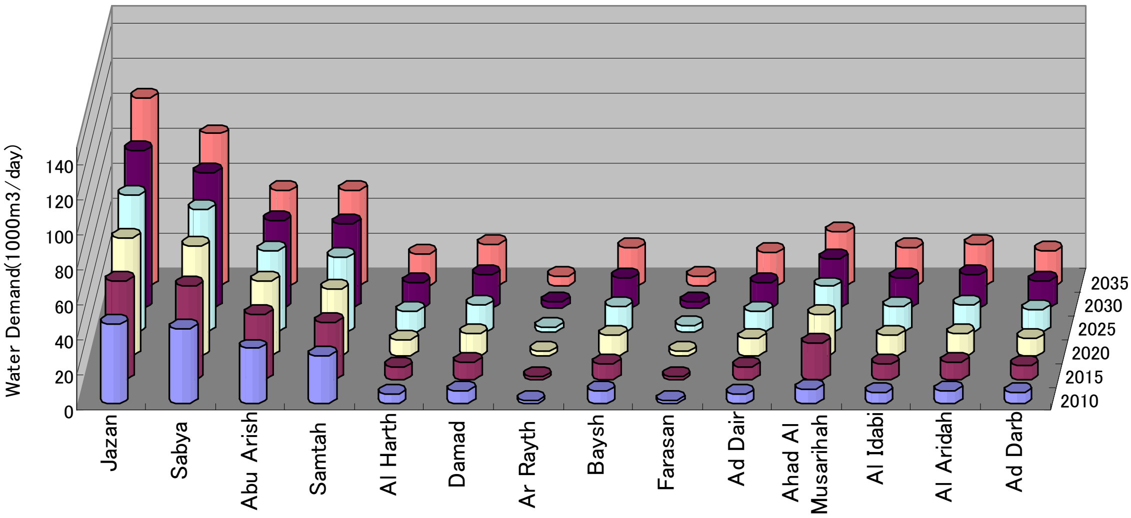


Figure B.3-5 Municipal Water Demand by Governorate in Jazan Region (Option-1)

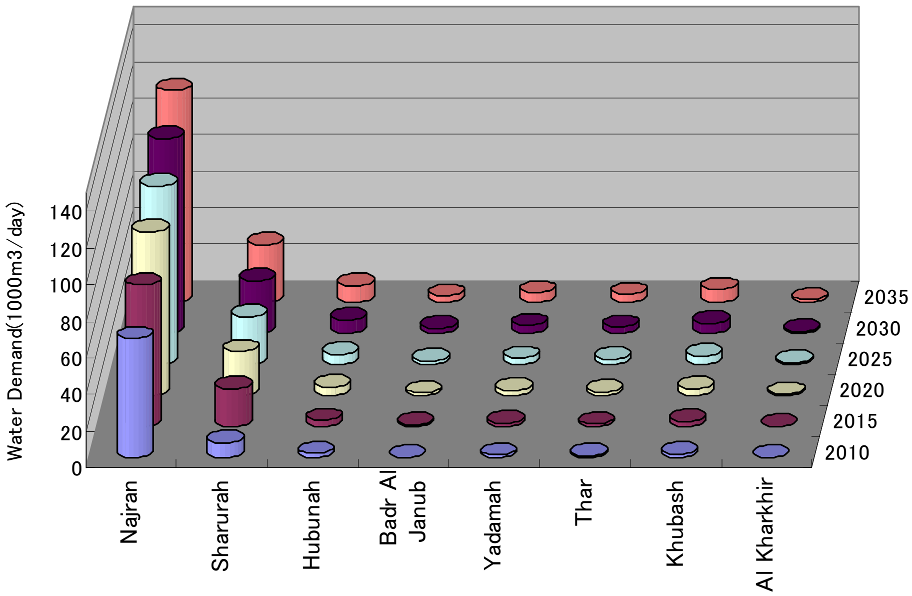


Figure B.3-6 Municipal Water Demand by Governorate in Najran Region (Option-1)

3.1.7 Sensitivity Analysis of Water Demand

(1) Options

In this study, water demand is estimated in four (4) options as well as basic condition (Option -1) as shown in Table B.3-5, taking into consideration that water demand fluctuation through water demand management and practical water service ratio.

Option-1: When the service coverage ratio is 100% for the year of 2035, water demand projection shall be applied for water supply facility plan in this study.

Option-2: Since urban development does not proceed as it is planned in urban areas and rural communities with the exception of large scale urban area, this option is set taking into account that water supply facilities will be developed based on practical situation

Option-3: This option is set for verifying the change in case water consumption rate is practically 15% lower than the proposed water consumption rate.

Option-4: This option is set in case leakage reduces from 20% to 15% due to pipe rehabilitation.

Option-5: This option is set in case water consumption rate is 15% lower than proposed one in addition in case leakage set at 15%.

All the conditions above are summarized as shown in Table B.3-28. 'Option-0' which is targeted for planning future capacity of facilities by KSA is added in the table. In this study, Option-0 is excluded in the sensitive analysis considering a difficulty of urgent development in rural communities from aspect of the current water service ratio and a policy of KSA in promotion of reclaimed water.

Table B.3-28 Criteria on Options for Sensitive Analysis

Items		Option-0 (MOWE)	Option-1	Option-2	Option-3	Option-4	Option-5
Water consumption rate (LCD)							
• Large scale urban		250	250	250	225	237	212
• Urban		200	200	200	180	190	170
• Rural community		150	150	150	135	142	127
Leakage Ratio (%)		20%	20%	20%	20%	15%	15%
Rate of reclaimed wastewater to be utilized (%)							
• Municipal water		0%	5%	5%	5%	5%	5%
• Industrial water		0%	30%	30%	30%	30%	30%
Water supply service ratio (%)							
Large scale urban	2006	100%	85%	85%	85%	85%	85%
	2010		90%	90%	90%	90%	90%
	2015		95%	95%	95%	95%	95%
	2020		100%	100%	100%	100%	100%
	2025		100%				
	2030		100%				
	2035		100%				
Urban	2006	100%	45%	45%	45%	45%	45%
	2010		50%	50%	50%	50%	50%
	2015		60%	55%	60%	60%	60%
	2020		70%	60%	70%	70%	70%
	2025		80%	65%	80%	80%	80%
	2030		90%	70%	90%	90%	90%
	2035		100%	75%	100%	100%	100%
Rural community	2006	100%	35%	35%	35%	35%	35%
	2010		40%	40%	40%	40%	40%
	2015		52%	42%	52%	52%	52%
	2020		64%	44%	64%	64%	64%
	2025		76%	46%	76%	76%	76%
	2030		88%	48%	88%	88%	88%
	2035		100%	50%	100%	100%	100%

Note: Criteria that was highlighted in white-gray is applied for water supply facility plan in this study
Source: JICA Study Team

Table B.3-29 to B.3-33 summaries future water demand based on options above.

Table B.3-29 Total Water Demand (Makkah Region)

1000m^3/day

Makkah Region	2006	2010	2015	2020	2025	2030	2035
Option-1							
Municipal Water Demand [1]	1,109	1,315	1,545	1,799	1,970	2,158	2,363
Industrial Water Demand [2]	147	146	160	175	189	203	218
Overall Water Demand	**1,242**	**1,461**	**1,705**	**1,974**	**2,159**	**2,361**	**2,581**
Water covered by reclaimed wastewater [3]	163	184	210	242	261	282	304
Total [1]+[2]-[3]	**1,079**	**1,277**	**1,494**	**1,733**	**1,898**	**2,080**	**2,278**
Option-2							
Municipal Water Demand [1]	1109	1,315	1,532	1,774	1,929	2,099	2,283
Industrial Water Demand [2]	147	146	160	175	189	203	218
Overall Water Demand	1,242	**1,461**	**1,692**	**1,949**	**2,118**	**2,302**	**2,501**
Water covered by reclaimed wastewater [3]	163	184	210	242	261	282	304
Total [1]+[2]-[3]	**1,079**	**1,277**	**1,482**	**1,707**	**1,856**	**2,020**	**2,197**
Option-3							
Municipal Water Demand [1]	1,077	1,183	1,390	1,619	1,773	1,942	2,127
Industrial Water Demand [2]	147	146	160	175	189	203	218
Overall Water Demand	1,201	**1,329**	**1,550**	**1,794**	**1,962**	**2,145**	**2,345**
Water covered by reclaimed wastewater [3]	144	170	194	223	241	259	280
Total [1]+[2]-[3]	**1,057**	**1,160**	**1,356**	**1,572**	**1,721**	**1,886**	**2,065**
Option-4							
Municipal Water Demand [1]	1,137	1,249	1,467	1,709	1,872	2,050	2,245
Industrial Water Demand [2]	147	146	160	175	189	203	218
Overall Water Demand	1,261	**1,395**	**1,627**	**1,884**	**2,061**	**2,253**	**2,463**
Water covered by reclaimed wastewater [3]	150	177	202	232	251	271	292
Total [1]+[2]-[3]	**1,111**	**1,218**	**1,425**	**1,652**	**1,810**	**1,983**	**2,171**
Option-5							
Municipal Water Demand [1]	1,018	1,118	1,313	1,529	1,675	1,834	2,009
Industrial Water Demand [2]	147	146	160	175	189	203	218
Overall Water Demand	1,142	**1,264**	**1,473**	**1,704**	**1,864**	**2,037**	**2,227**
Water covered by reclaimed wastewater [3]	138	163	186	213	230	248	268
Total [1]+[2]-[3]	**1,004**	**1,101**	**1,287**	**1,491**	**1,633**	**1,789**	**1,959**

Source: JICA Study Team

Table B.3-30 Total Water Demand (Al Baha Region)

1000m^3/day

Al Baha Region	2006	2010	2015	2020	2025	2030	2035
Option-1							
Municipal Water Demand [1]	39	51	65	80	94	112	132
Industrial Water Demand [2]	1	1	1	1	1	1	1
Overall Water Demand	**40**	**52**	**66**	**81**	**95**	**113**	**133**
Water covered by reclaimed wastewater [3]	1	1	2	2	2	2	2
Total [1]+[2]-[3]	**39**	**51**	**64**	**79**	**93**	**111**	**131**
Option-2							
Municipal Water Demand [1]	39	51	61	72	82	94	107
Industrial Water Demand [2]	1	1	1	1	1	1	1
Overall Water Demand	**40**	**52**	**62**	**73**	**83**	**95**	**108**
Water covered by reclaimed wastewater [3]	1	1	2	2	2	2	2
Total [1]+[2]-[3]	**39**	**51**	**60**	**71**	**81**	**93**	**106**
Option-3							
Municipal Water Demand [1]	35	46	58	72	85	101	119
Industrial Water Demand [2]	1	1	1	1	1	1	1
Overall Water Demand	**36**	**47**	**59**	**73**	**86**	**102**	**120**
Water covered by reclaimed	1	1	1	2	2	2	2

Al Baha Region	2006	2010	2015	2020	2025	2030	2035
wastewater [3]							
Total [1]+[2]-[3]	**35**	**46**	**58**	**71**	**84**	**100**	**118**
Option-4							
Municipal Water Demand [1]	37	48	61	76	90	107	125
Industrial Water Demand [2]	1	1	1	1	1	1	1
Overall Water Demand	**38**	**49**	**62**	**77**	**91**	**108**	**126**
Water covered by reclaimed wastewater [3]	1	1	1	2	2	2	2
Total [1]+[2]-[3]	**37**	**48**	**61**	**75**	**89**	**106**	**124**
Option-5							
Municipal Water Demand [1]	32	43	55	68	80	95	112
Industrial Water Demand [2]	1	1	1	1	1	1	1
Overall Water Demand	**33**	**44**	**56**	**69**	**81**	**96**	**113**
Water covered by reclaimed wastewater [3]	1	1	1	1	2	2	2
Total [1]+[2]-[3]	**32**	**43**	**55**	**68**	**79**	**94**	**111**

Source: JICA Study Team

Table B.3-31 Total Water Demand (Asir Region)

1000m^3/day

Asir Region	2006	2010	2015	2020	2025	2030	2035
Option-1							
Municipal Water Demand [1]	239	298	364	436	500	577	655
Industrial Water Demand [2]	8	10	12	13	14	16	17
Overall Water Demand	**247**	**308**	**376**	**449**	**514**	**593**	**672**
Water covered by reclaimed wastewater [3]	11	13	15	17	19	22	23
Total [1]+[2]-[3]	**236**	**295**	**361**	**432**	**495**	**571**	**648**
Option-2							
Municipal Water Demand [1]	239	298	353	412	460	523	581
Industrial Water Demand [2]	8	10	12	13	14	16	17
Overall Water Demand	**247**	**308**	**365**	**425**	**474**	**539**	**598**
Water covered by reclaimed wastewater [3]	11	13	15	17	19	22	23
Total [1]+[2]-[3]	**236**	**295**	**349**	**407**	**455**	**517**	**575**
Option-3							
Municipal Water Demand [1]	217	269	328	393	450	519	589
Industrial Water Demand [2]	8	10	12	13	14	16	17
Overall Water Demand	**225**	**279**	**340**	**406**	**464**	**535**	**606**
Water covered by reclaimed wastewater [3]	10	12	14	16	17	20	22
Total [1]+[2]-[3]	**215**	**267**	**325**	**390**	**447**	**515**	**585**
Option-4							
Municipal Water Demand [1]	229	284	346	415	475	548	622
Industrial Water Demand [2]	8	10	12	13	14	16	17
Overall Water Demand	**237**	**294**	**358**	**428**	**489**	**564**	**639**
Water covered by reclaimed wastewater [3]	11	13	15	17	18	21	22
Total [1]+[2]-[3]	**226**	**281**	**343**	**411**	**471**	**543**	**616**
Option-5							
Municipal Water Demand [1]	206	254	309	371	425	490	556
Industrial Water Demand [2]	8	10	12	13	14	16	17
Overall Water Demand	**214**	**264**	**321**	**384**	**439**	**506**	**573**
Water covered by reclaimed wastewater [3]	9	12	14	15	17	19	21
Total [1]+[2]-[3]	**205**	**252**	**308**	**369**	**423**	**487**	**553**

Source: JICA Study Team

Table B.3-32 Total Water Demand (Jazan Region)

1000m³/day

Jazan Region	2006	2010	2015	2020	2025	2030	2035
Option-1							
Municipal Water Demand [1]	184	207	241	290	333	382	442
Industrial Water Demand [2]	3	3	3	3	3	4	4
Overall Water Demand	**187**	**210**	**244**	**293**	**336**	**386**	**446**
Water covered by reclaimed wastewater [3]	6	7	6	7	7	8	9
Total [1]+[2]-[3]	**181**	**203**	**238**	**286**	**329**	**379**	**436**
Option-2							
Municipal Water Demand [1]	184	207	233	272	304	340	389
Industrial Water Demand [2]	3	3	3	3	3	4	4
Overall Water Demand	**187**	**210**	**236**	**275**	**307**	**344**	**393**
Water covered by reclaimed wastewater [3]	6	7	8	9	10	11	13
Total [1]+[2]-[3]	**181**	**203**	**227**	**266**	**297**	**333**	**380**
Option-3							
Municipal Water Demand [1]	167	187	217	261	300	344	397
Industrial Water Demand [2]	3	3	3	3	3	4	4
Overall Water Demand	**170**	**190**	**220**	**264**	**303**	**348**	**401**
Water covered by reclaimed wastewater [3]	6	7	8	9	10	11	13
Total [1]+[2]-[3]	**164**	**183**	**212**	**255**	**293**	**337**	**389**
Option-4							
Municipal Water Demand [1]	175	197	229	275	317	363	420
Industrial Water Demand [2]	3	3	3	3	3	4	4
Overall Water Demand	**178**	**200**	**232**	**278**	**320**	**367**	**424**
Water covered by reclaimed wastewater [3]	6	7	8	9	9	10	12
Total [1]+[2]-[3]	**172**	**193**	**224**	**270**	**310**	**357**	**411**
Option-5							
Municipal Water Demand [1]	156	176	205	246	283	325	375
Industrial Water Demand [2]	3	3	3	3	3	4	4
Overall Water Demand	**159**	**179**	**208**	**249**	**286**	**329**	**379**
Water covered by reclaimed wastewater [3]	6	7	8	9	9	10	12
Total [1]+[2]-[3]	**153**	**173**	**200**	**241**	**277**	**319**	**367**

Source: JICA Study Team

Table B.3-33 Total Water Demand (Najran Region)

1000m³/day

Najran Region	2006	2010	2015	2020	2025	2030	2035
Option-1							
Municipal Water Demand [1]	54	85	115	135	150	166	184
Industrial Water Demand [2]	1	1	1	1	1	1	1
Overall Water Demand	**55**	**86**	**116**	**136**	**151**	**167**	**185**
Water covered by reclaimed wastewater [3]	1	1	1	1	1	1	1
Total [1]+[2]-[3]	**54**	**85**	**115**	**135**	**150**	**166**	**184**
Option-2							
Municipal Water Demand [1]	54	85	113	131	144	158	173
Industrial Water Demand [2]	1	1	1	1	1	1	1
Overall Water Demand	**55**	**86**	**114**	**132**	**145**	**159**	**174**
Water covered by reclaimed wastewater [3]	1	4	5	6	6	7	8
Total [1]+[2]-[3]	**54**	**82**	**109**	**126**	**138**	**152**	**167**
Option-3							
Municipal Water Demand [1]	51	77	103	121	135	149	166
Industrial Water Demand [2]	1	1	1	1	1	1	1
Overall Water Demand	**52**	**78**	**104**	**122**	**136**	**150**	**167**
Water covered by reclaimed wastewater [3]	1	3	5	5	6	6	7
Total [1]+[2]-[3]	**51**	**74**	**100**	**117**	**130**	**144**	**160**

Najran Region	2006	2010	2015	2020	2025	2030	2035
Option-4							
Municipal Water Demand [1]	52	81	109	128	142	158	175
Industrial Water Demand [2]	1	1	1	1	1	1	1
Overall Water Demand	**53**	**82**	**110**	**129**	**143**	**159**	**176**
Water covered by reclaimed wastewater [3]	1	3	5	6	6	7	7
Total [1]+[2]-[3]	**52**	**78**	**105**	**123**	**137**	**152**	**169**
Option-5							
Municipal Water Demand [1]	45	72	98	114	127	141	157
Industrial Water Demand [2]	1	1	1	1	1	1	1
Overall Water Demand	**46**	**73**	**99**	**115**	**128**	**142**	**158**
Water covered by reclaimed wastewater [3]	1	3	5	5	6	6	6
Total [1]+[2]-[3]	**45**	**70**	**94**	**110**	**123**	**136**	**151**

Source: JICA Study Team

The predicted water demand in five (5) options is shown in Figure B.3-7- Figure B.3-11.

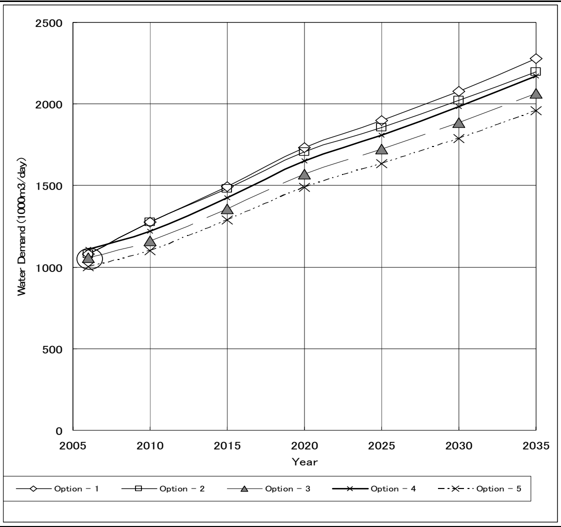


Figure B.3-7 Trends of Water Demand (Makkah)

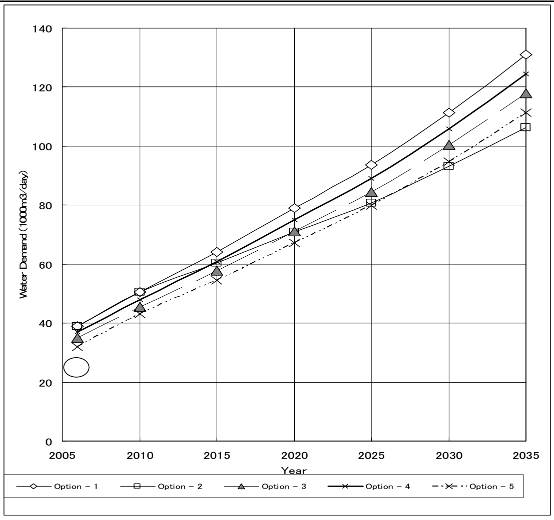


Figure B.3-8 Trends of Water Demand (Al Baha)

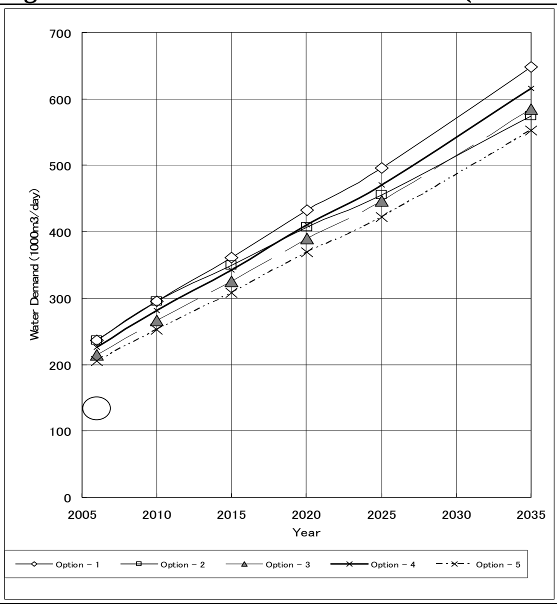


Figure B.3-9 Trends of Water Demand (Asir)

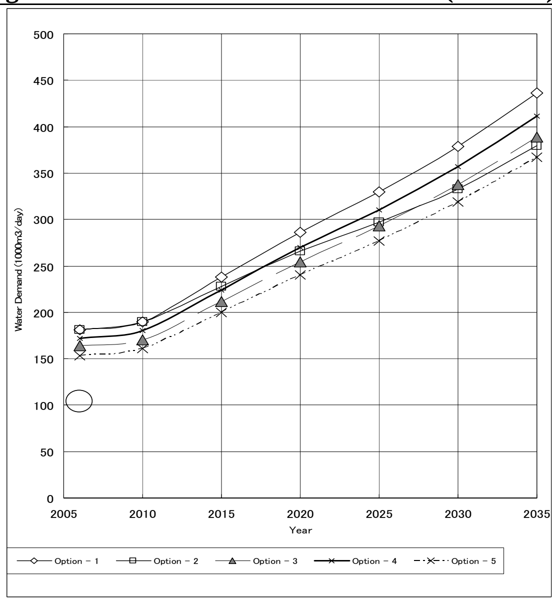


Figure B.3-10 Trends of Water Demand (Jazan)

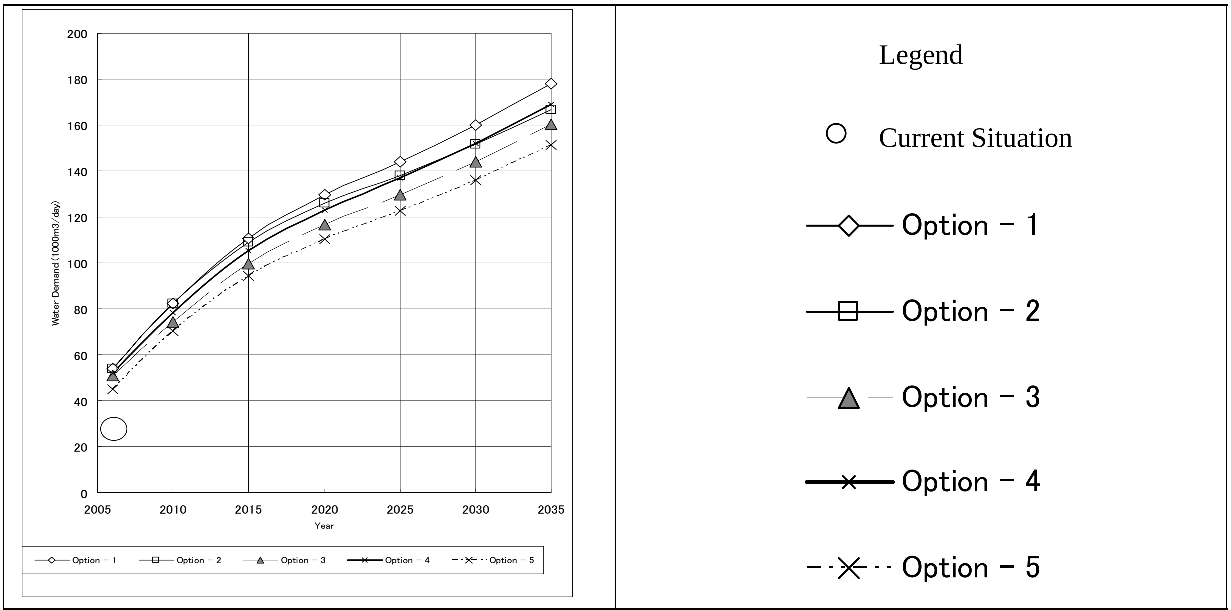


Figure B.3-11 Trends of Water Demand (Najran)

(2) Consideration in Sensitive Analysis

As results of the sensitive analysis, water demand of the year of 2020 and 2035 is summarized by region in Table B.3-34.

Table B.3-34 Water Demand by Option and Region (2020 and 2035) (1000m^3/day, Ratio:%)

Option	Makkah		Al Baha		Asir		Jazan		Najran	
	2020	2035	2020	2035	2020	2035	2020	2035	2020	2035
1	1,733	2,278	79	131	432	648	286	436	130	178
Standard Index (%)	(100)	(100)	(100)	(100)	(100)	(100)	(100)	(100)	(100)	(100)
2	1,707	2,197	71	106	407	575	266	380	126	167
Ratio 2/1 (%)	(98.5)	(96.4)	(89.9)	(80.9)	(94.2)	(88.7)	(93.0)	(87.2)	(93.3)	(90.8)
3	1,572	2,065	71	118	390	585	255	389	117	160
Ratio 3/1 (%)	(90.7)	(90.6)	(90.0)	(90.0)	(90.3)	(90.3)	(89.2)	(89.2)	(90.0)	(89.9)
4	1,652	2,171	75	124	411	616	270	411	123	169
Ratio 4/1 (%)	(95.3)	(95.3)	(94.9)	(94.7)	(95.1)	(95.1)	(94.4)	(94.3)	(94.6)	(94.9)
5	1,491	1,959	67	111	369	553	241	367	110	151
Ratio 5/1 (%)	(86.0)	(86.0)	(84.8)	(84.7)	(85.4)	(85.3)	(84.3)	(84.2)	(84.6)	(84.8)

Source: JICA Study Team

1) Comparisons between Option-2 and Option-1 (Differences of Service Coverage Ratio)

- Large scale urban area and urban areas make up most of Makkah region, which results in small differences in water service coverage ratio.
- There are large differences in the water-service coverage ratio in the Al Baha region. Water demand is 15% and 21% lower than that of Option-1 in 2020 and 2035 respectively.
- Water demand in Asir, Jazan and Najran region shows similar trends. Water demand is 6-7% and 10-20% lower than that of Option-1 in 2020 and 2035 respectively.

2) Comparisons between Option-3 and Option-1 (Differences of Water Consumption Rate)

- Water demand of all the regions decreases to about10% comparison with that Option-1.

3) Comparisons between Option-4 and Option-1 (Differences of Leakage Ratio)

- Leakage of all the regions decreases to about10% in comparison with that Option-1.

4) Comparisons between Option-5 and Option-1 (Differences of Decreased Water Consumption Rate & Leakage Ratio)

- There are almost no differences in all the regions.

Differences between water service coverage ratio of Option-2 and Option-1 is large, as urban size is small. Thus, there are small differences of water demand in the Makkah region where large urbanization is made up out of the five (5) regions, while there are large differences in the Al Baha region where small towns and communities are made up.

The largest decrease rate through the analysis above is Option-5, which results in 15% lower than that of Option-1. This results in decreased water consumption and improvement in the leakage ratio due to awareness improvement in water conservation, where pipeline rehabilitation respectively leads to a decrease in water demand.

For references, the water demand (as 'Option-6') for which current water consumption (see Table B.1-35) by region was applied is as follows:

Since the option 1 has set up the large water consumption rate compared with the present condition, the difference of water demand has made it to the option 6 which is the water consumption rate near the present condition. In actual supply facility plan, it is necessary to check water consumption rate and water service coverage.

Table B.3-35 Water Demand of Option-1 and Option-6 by Region (2020 and 2035)

(1000m^3/day, Ratio:%)

Option	Makkah		Al Baha		Asir		Jazan		Najran	
	2020	2035	2020	2035	2020	2035	2020	2035	2020	2035
1	1,733	2,278	83	135	432	648	286	436	130	178
Standard Index (%)	(100)	(100)	(100)	(100)	(100)	(100)	(100)	(100)	(100)	(100)
6	1,676	2,111	41	52	232	302	193	251	56	71
Ratio6/1(%)	(96.7)	(92.7)	(49.4)	(38.5)	(53.7)	(46.6)	(67.5)	(57.6)	(43.0)	(39.9)

Source: JICA Study Team

There is a significant decrease in water demand in all four (4) regions with the exception of the Makkah region.

In order to save water, it is imperative that the water consumption rate be minimized and leakage be reduced. As a concrete measures, while aiming at reduction of water consumption rate by performing water-saving, by exchanging an old pipeline intentionally, the leakage-ratio will be reduced.

3.2 Agricultural Water

3.2.1 Basic Policy and Frame Work for Water Demand Prediction

(1) Agricultural Policy

The Government has implemented various encouragement policies in the agricultural sector to promote agricultural growth. Especially an important policy is having distributed uncultivated land to farmers and gratuitous involvement in this area continues today. Moreover, the government has provided farmer with loans and subsidies over a long period through the Agricultural Bank, which was established in 1962. The Government paid 50% of the purchase expenses for agricultural equipment and machinery including pumps for irrigation until 2005. In addition, it paid 45% of the purchasing expenses for imported and domestic fertilizer products; even though, seeds etc are distributed at a very low price. Furthermore, the Agriculture Office and the Agricultural Experiment Stations established in each region provided agricultural techniques and services to the farmer.

The old subsidy policy was revised in order to prevent superfluous pumping of groundwater in 2005. As for 50% of the subsidies delivered until 2005 to the purchase of all the agricultural instrument /

machines, and farmstead construction, well drilling, a pump, a house, the lodgings for laborers, and a track (except for the track with a cold-packed warehouse) were removed from the object, and the subsidy was cut to 25%. Although the chief reason for reexamination was preventing superfluous pumping of groundwater and preserving water resources, the purchase of a water-saving irrigation system, an agricultural machine, etc. was reduced by 25% of what serves as a subsidy object as usual.
For example, as for a subsidy, in a well drilling and a pump purchase, in the case of 100% payment (subsidy 0%) for a well drilling and a pump purchase, and in a well drilling and a water-saving irrigation system, in the case of 75% payment (subsidy 25%) for a water-saving irrigation system and 100% payment (Subsidy 0%) for a well drilling. However, there is no interest burden in every case.

(2) Future Frame for Demand Prediction

The future development project for agriculture is negated for developing water resources and increasing farmland area. It is about preventing exhaustion of water resources and how to reduce farmland area. For this reason, in Decision No.335 (Rules and Procedure for the Rationalization of Water Consumption and regulates its use in Agriculture Purpose in all cities and villages within Kingdom of Saudi Arabia), the following policies are examined.

- To discontinue a subsidy for a well construction and a pump purchase,
- To stop a land distribution policy,
- To eliminate import tariffs on agricultural-products,
- To promote import of fodder crops,
- To stop the encouragement price of wheat and barley through the GSMO (Grain Silos and Flour Mills Organization)

Therefore, the future planning of agricultural projects, is another way of saying, how many planted areas were produced after the above-mentioned policy was implemented?

(3) Prediction conditions for future Agricultural Demand

Although MOA envisions a future plan for agriculture in the year 2020 based on agricultural-statistics data taken in 2007, the deviations from the actual planted areas can clearly be seen in southwest areas. Therefore, in order to raise accuracy in demand forecasting, the following three cases are examined in consideration of the future agriculture plan of MOA and both sides of agricultural-statistics data.

Case-1: Case which rectified the future agriculture plan by 2020 upon which MOA decided in 2000 to 2004 by the agricultural-statistics data in 2007.
Case-2: Case presumed in recent years using the agricultural-statistics data of 6 years (2002-2007).
Case-3: Case which the planted area in 2007 where change of the planted area settled down will continue.

3.2.2 Future Frame for Demand Prediction

In the target year (2035), water demand predicts the decreased in farmland areas and implementation condition the governmental agricultural measure classified by region. In consideration of the above-mentioned policy, the demanded amount of water for agricultural use in each region is provisionally calculated based on the following case.

(1) Case-1 (Modified MOA Plan)

MOA was entrusted to King Abdulla Institute for Research from 2002 to 2004, and decided upon the agricultural development plan by 2005 to 2020. This is the newest agricultural development plan of MOA in which reflects the policy based on 1999. As shown in Figure B.3-12., judging from the viewpoint of water-resources preservation, MOA has a plan to decrease the planted area of whole the KSA from 1,100,000 ha in 2007 to 680,000 ha in 2020. However, the South West region blessed with water resources although the planted area is decreased in the whole KSA, MOA plans to increase the planted area of the South West region from 241,000 ha in 1999 to 284,000 ha in 2020.

Summary of MOA plan

- Although cereals and fodder crop are scheduled to be decreased in the whole country as well as fodder crops all five regions, in the South West region, cereals are scheduled to be increased in the Asir and Jazan regions.
- In spite of scheduled decreases in fruit trees throughout the whole country, the modified MOA plan is scheduled to increase fruit tree growth in the four regions except for Jazan in the South West region.
- Vegetable is scheduled to be increased in the whole country; it is also scheduled to make it increase about five regions in the South West region.

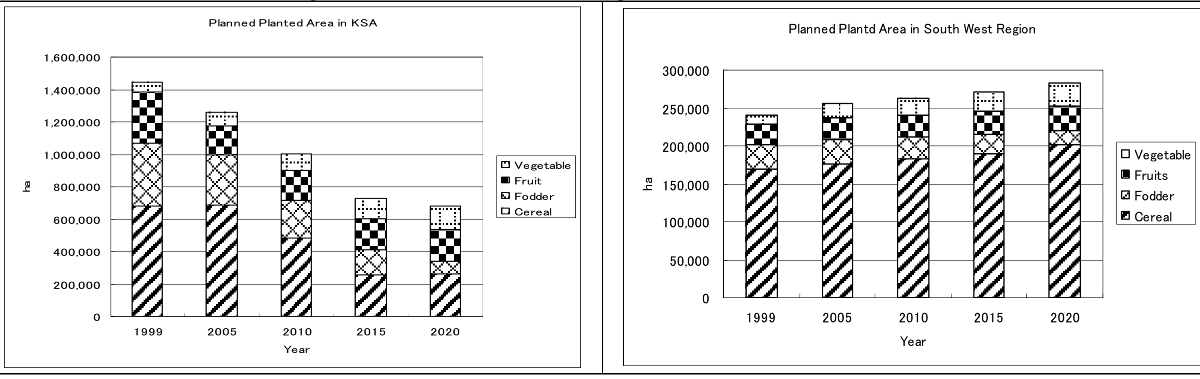


Figure B.3-12 Future Agriculture Plan by MOA (KSA and South West Region)

Because of concerns for further lack of water resources and the need to reexamine subsidies, changes in the agriculture plan (issue of Decision 335 etc.) have arisen after the plan was decided. As compared with the agricultural –statistics data in 2007, there is more planted area of MOA about 66,000 ha in the South West region. Therefore, the plan of MOA needs to be corrected. Here, the extended crops plan was left as is and adjusted by the differences from 2007 to 2035 (Case-1) concerning extension of the planted areas for crops.

(2) Case-2 (2002-2007 Trend)

Aiming at self-sufficiency in agricultural produce, various agricultural policies were implemented including the cutting of farmland distribution gratuity by MOA's 1948 establishment policy through the agricultural bank. Furthermore, as a result of taking preferential treatment measures, such as acquisition of wheat and barley at an encouragement price through the GSMO (Grain Silos and Flour Mills Organization), 100% of the self-sufficiency rate of wheat was attained in 1995, the output amounted to 4,200,000t in 1992, and Saudi Arabia became an exporting country of wheat.

As a result, exhaustion of water resources became an issue, the subsidy policy has improved repeatedly until now, and the agricultural output control policy has been implemented by Decree.

This has appeared in agricultural-statistics data as shown in Figure B.3-13. Throughout the KSA including the South West region, reveals decreasing numbers.

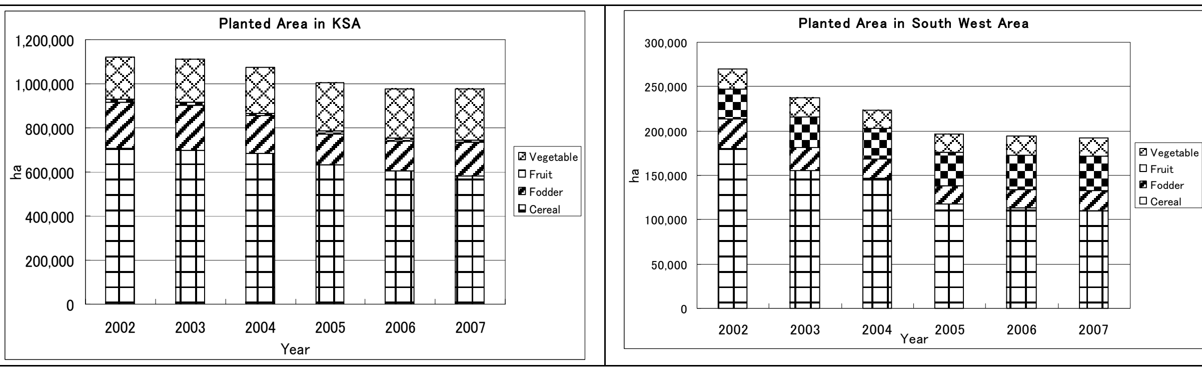


Figure B.3-13 Tendency of the planted area in 2002 to 2007 by Agricultural-statistics Data

However, since the agricultural-statistical data shows that it is in the tendency of a lowering stop in recent years, this reduction sets up Case-2 as a case where 2035 which are a target planning year are presumed using this tendency.

(3) Case-3 (2007 Year Level)

As the case 2 described, according to the agricultural-statistics data, a constant downward converging tendency line of the planted areas in 2007 can be visualized. Although reexamination of agricultural policy also serves as a backdrop, it can be observed approaching the planted area where agricultural activity was actually restricted by exhaustion of water resources as a major factor, as irrigation areas decreased and balanced the amount of water resources. Therefore, Case-3 is set up as a case it was presupposed that the planted area in 2007 continues also into 2035 as a targeted planning year.

3.2.3 Water Demand in the Target Year (2035)

(1) Future Planted Area in South West Region

The result of having calculated the planted area according to the whole South West region and the 5 regions are shown in the following three cases (Figure B.3-14, Table B.3-36). In addition, agricultural water greatly demanded changes in combination with crops. In Case-1 MOA plan was used, in Case-2 the regression curve according to the crops of 6 years (2002-2007) was used, and the value of the agricultural statistics in 2007 was used in Case-3.

Table B.3-36 (1) Breakdown of Future Planted Area and Water Demanded (2010-2035)

Region/Crops	2010						2015					
	Case-1		Case-2		Case-3		Case-1		Case-2		Case-3	
	ha	MCM	ha	MCM	ha	MCM	ha	MCM	ha	MCM	ha	MCM
Makkah	42,657	**756.2**	39,167	**682.7**	42,077	**750.5**	**44,964**	**757.7**	39,173	**681.7**	42,077	**750.5**
Cereal	7,350	90.2	6,631	81.4	8,386	103.0	7,641	93.8	5,869	72.1	8,386	103.0
Fodder	5,895	197.4	4,386	146.9	5,761	192.9	5,024	168.3	3,784	126.7	5,761	192.9
Fruits	15,631	366.6	15,329	359.6	15,447	362.3	15,989	375.1	16,478	386.5	15,447	362.3
Vegetable	13,782	101.9	12,821	94.8	12,483	92.3	16,309	120.6	13,042	96.4	12,483	92.3
Al Baha	4,468	**54.0**	5,150	**62.1**	4,450	**53.9**	4,577	**55.2**	6,003	**73.1**	4,450	**53.9**
Cereal	499	3.3	611	4.0	532	3.5	499	3.3	629	4.2	532	3.5
Fodder	122	2.5	135	2.7	185	3.8	95	1.9	133	2.7	185	3.8
Fruits	3,572	47.1	4,104	54.1	3,457	45.5	3,708	48.9	4,936	65.0	3,457	45.5
Vegetable	275	1.1	300	1.2	276	1.1	275	1.1	306	1.3	276	1.1
Asir	21,757	**275.2**	21,558	**262.1**	21,054	**268.4**	24,407	**299.3**	21,426	**255.6**	21,054	**268.4**
Cereal	8,177	69.7	7,861	67.1	7,744	66.1	10,302	87.9	8,091	69.0	7,744	66.1
Fodder	2,001	48.2	1,476	35.6	2,001	48.2	2,001	48.2	1,334	32.1	2,001	48.2
Fruits	8,730	142.0	8,625	140.3	8,579	139.5	9,024	146.8	8,272	134.5	8,579	139.5
Vegetable	2,849	15.2	3,596	19.2	2,730	14.6	3,080	16.4	3,730	19.9	2,730	14.6
Jazan	116,581	**1,503.0**	100,457	**1,312.4**	113,558	**1,501.9**	119,842	**1,499.7**	88,820	**1,170.8**	113,558	**1,501.9**
Cereal	96,784	1,076.8	82,173	914.2	92,204	1,025.8	101,880	1,133.5	71,336	793.6	92,204	1,025.8
Fodder	10,392	288.6	9,540	265.0	12,247	340.2	8,124	225.6	8,530	236.9	12,247	340.2
Fruits	5,489	109.9	5,516	110.4	5,525	110.6	5,489	109.9	5,944	119.0	5,525	110.6
Vegetable	3,916	27.7	3,228	22.8	3,582	25.3	4,349	30.8	3,009	21.3	3,582	25.3
Najran	11,692	**216.8**	11,652	**225.8**	11,430	**216.5**	12,122	**211.9**	11,476	**223.5**	11,430	**216.5**
Cereal	908	10.0	817	9.0	908	10.0	908	10.0	798	8.8	908	10.0
Fodder	2,127	60.9	2,232	63.9	2,287	65.5	1,409	40.4	2,092	59.9	2,287	65.5
Fruits	6,464	131.1	7,004	142.1	6,311	128.0	7,042	142.8	7,158	145.2	6,311	128.0
Vegetable	2,193	14.8	1,599	10.8	1,924	13.0	2,762	18.6	1,428	9.6	1,924	13.0
Total	**197,154**	**2,805.1**	**177,984**	**2,545.0**	**192,569**	**2,791.3**	**205,912**	**2,823.8**	**166,898**	**2,404.8**	**192,569**	**2,791.3**

Table B.3-36 (2) Breakdown of Future Planted Area and Water Demanded (2010-2035)

Region/Crops	2020						2025					
	Case-1		Case-2		Case-3		Case-1		Case-2		Case-3	
	ha	MCM	ha	MCM	ha	MCM	ha	MCM	ha	MCM	ha	MCM
Makkah	**48,179**	**739.6**	39,330	**684.5**	42,077	**750.5**	**53,316**	**785.8**	39,530	**688.5**	42,077	**750.5**
Cereal	8,152	100.1	5,394	66.2	8,386	103.0	8,663	106.4	5,057	62.1	8,386	103.0
Fodder	3,103	103.9	3,417	114.4	5,761	192.9	3,103	103.9	3,160	105.8	5,761	192.9
Fruits	16,348	383.5	17,321	406.3	15,447	362.3	16,707	391.9	17,996	422.1	15,447	362.3
Vegetable	20,576	152.1	13,197	97.6	12,483	92.3	24,843	183.7	13,317	98.5	12,483	92.3
Al Baha	**4,704**	**56.7**	6,690	**82.1**	4,450	**53.9**	**4,856**	**58.7**	7,277	**89.7**	4,450	**53.9**
Cereal	499	3.3	642	4.2	532	3.5	499	3.3	652	4.3	532	3.5
Fodder	69	1.4	131	2.7	185	3.8	69	1.4	130	2.6	185	3.8
Fruits	3,861	50.9	5,607	73.9	3,457	45.5	4,013	52.9	6,182	81.5	3,457	45.5
Vegetable	275	1.1	310	1.3	276	1.1	275	1.1	313	1.3	276	1.1
Asir	**25,880**	**313.4**	21,359	**251.5**	21,054	**268.4**	**27,354**	**327.5**	21,320	**248.5**	21,054	**268.4**
Cereal	11,251	96.0	8,254	70.4	7,744	66.1	12,200	104.1	8,381	71.5	7,744	66.1
Fodder	2,001	48.2	1,243	30.0	2,001	48.2	2,001	48.2	1,178	28.4	2,001	48.2
Fruits	9,318	151.5	8,036	130.7	8,579	139.5	9,611	156.3	7,860	127.8	8,579	139.5
Vegetable	3,311	17.7	3,826	20.4	2,730	14.6	3,542	18.9	3,900	20.8	2,730	14.6
Jazan	**126,920**	**1,503.9**	81,715	**1,084.6**	113,558	**1,501.9**	**135,863**	**1,559.9**	76,748	**1,024.5**	113,558	**1,501.9**
Cereal	112,518	1,251.8	64,693	719.7	92,204	1,025.8	123,155	1,370.2	60,031	667.9	92,204	1,025.8
Fodder	3,827	106.3	7,895	219.3	12,247	340.2	1,394	38.7	7,442	206.7	12,247	340.2
Fruits	5,489	109.9	6,260	125.3	5,525	110.6	5,489	109.9	6,512	130.3	5,525	110.6
Vegetable	5,086	36.0	2,867	20.3	3,582	25.3	5,823	41.2	2,763	19.5	3,582	25.3
Najran	**12,523**	**204.6**	11,372	**222.2**	11,430	**216.5**	**13,876**	**224.6**	11,303	**221.4**	11,430	**216.5**
Cereal	908	10.0	785	8.7	908	10.0	908	10.0	775	8.6	908	10.0
Fodder	458	13.1	2,001	57.3	2,287	65.5	458	13.1	1,933	55.4	2,287	65.5
Fruits	7,845	159.1	7,266	147.4	6,311	128.0	8,649	175.4	7,350	149.1	6,311	128.0
Vegetable	3,312	22.4	1,321	8.9	1,924	13.0	3,861	26.1	1,244	8.4	1,924	13.0
Total	**218,206**	**2,818.3**	**160,465**	**2,324.9**	**192,569**	**2,791.3**	**235,264**	**2,956.6**	**156,177**	**2,272.6**	**192,569**	**2,791.3**

Table B.3-36 (3) Breakdown of Future Planted Area and Water Demanded (2010-2035)

Region/Crops	2030						2035					
	Case-1		Case-2		Case-3		Case-1		Case-2		Case-3	
	ha	MCM	ha	MCM	ha	MCM	ha	MCM	ha	MCM	ha	MCM
Makkah	**58,453**	**832**	39,742	**693**	42,077	**751**	63,589	**878**	39,954	**697**	42,077	**751**
Cereal	9,174	113	4,800	59	8,386	103	9,686	119	4,593	56	8,386	103
Fodder	3,103	104	2,967	99	5,761	193	3,103	104	2,813	94	5,761	193
Fruits	17,065	400	18,561	435	15,447	362	17,424	409	19,050	447	15,447	362
Vegetable	29,110	215	13,415	99	12,483	92	33,377	247	13,498	100	12,483	92
Al Baha	**5,009**	**61**	7,795	**96**	4,450	**54**	5,161	**63**	8,264	**103**	4,450	**54**
Cereal	499	3	660	4	532	4	499	3	667	4	532	4
Fodder	69	1	129	3	185	4	69	1	128	3	185	4
Fruits	4,166	55	6,691	88	3,457	46	4,319	57	7,151	94	3,457	46
Vegetable	275	1	316	1	276	1	275	1	318	1	276	1
Asir	**28,828**	**342**	21,295	**246**	21,054	**268**	30,302	**356**	21,281	**244**	21,054	**268**
Cereal	13,149	112	8,485	72	7,744	66	14,098	120	8,574	73	7,744	66
Fodder	2,001	48	1,128	27	2,001	48	2,001	48	1,088	26	2,001	48
Fruits	9,905	161	7,720	126	8,579	140	10,199	166	7,605	124	8,579	140
Vegetable	3,772	20	3,962	21	2,730	15	4,003	21	4,014	21	2,730	15
Jazan	**147,238**	**1,684**	73,002	**979**	113,558	**1,502**	158,613	**1,807**	70,033	**943**	113,558	**1,502**
Cereal	133,793	1,489	56,503	629	92,204	1,026	144,431	1,607	53,698	597	92,204	1,026
Fodder	1,394	39	7,094	197	12,247	340	1,394	39	6,814	189	12,247	340
Fruits	5,489	110	6,724	135	5,525	111	5,489	110	6,908	138	5,525	111
Vegetable	6,561	46	2,681	19	3,582	25	7,298	52	2,614	18	3,582	25
Najran	**15,228**	**245**	11,252	**221**	11,430	**217**	16,581	**265**	11,213	**220**	11,430	**217**
Cereal	908	10	767	8	908	10	908	10	761	8	908	10
Fodder	458	13	1,881	54	2,287	65	458	13	1,837	53	2,287	65
Fruits	9,452	192	7,419	150	6,311	128	10,255	208	7,477	152	6,311	128
Vegetable	4,410	30	1,185	8	1,924	13	4,959	33	1,138	8	1,924	13
Total	**254,755**	**3,163**	**153,087**	**2,236**	**192,569**	**2,791**	**274,246**	**3,368**	**150,745**	**2,208**	**192,569**	**2,791**

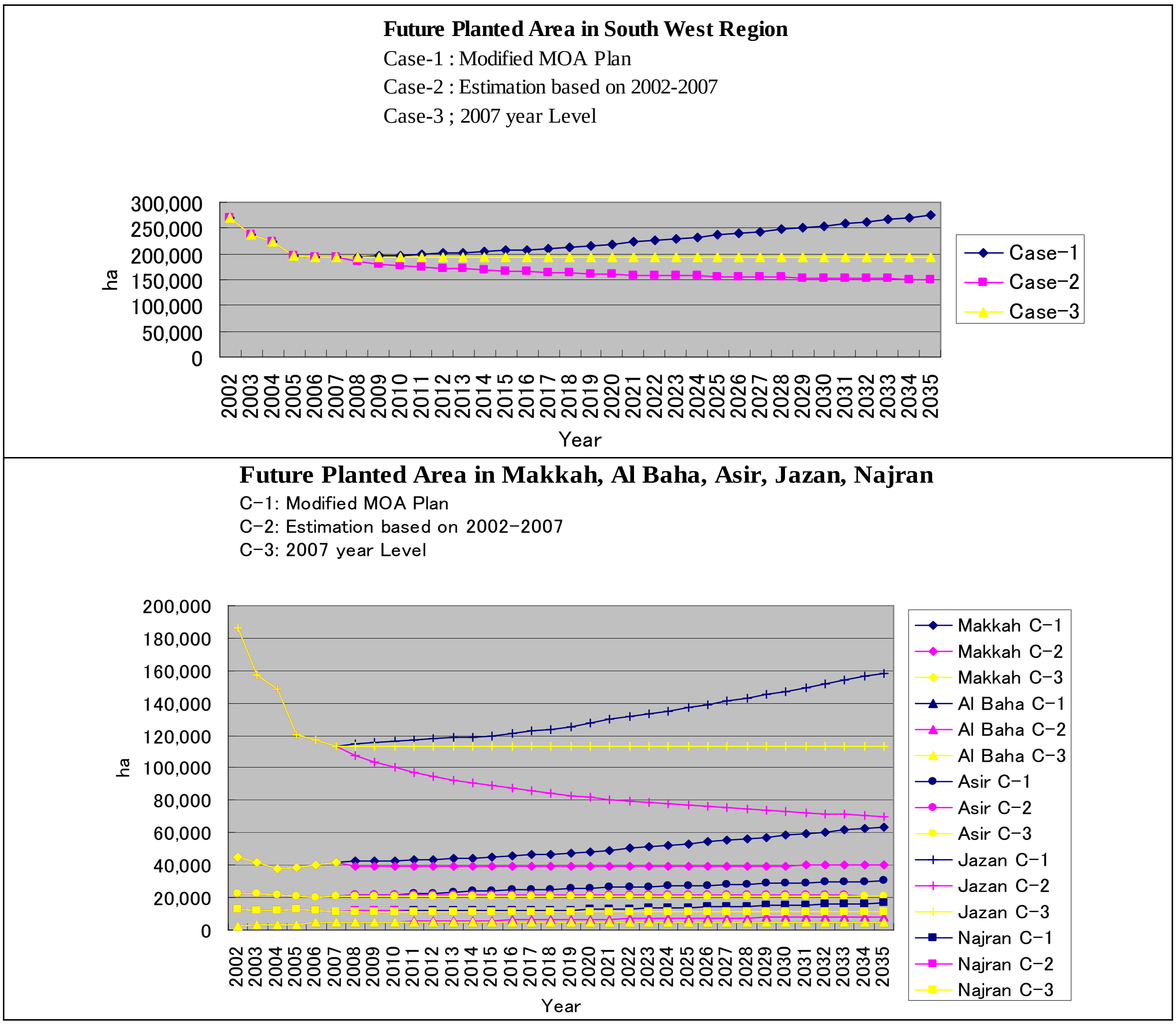


Figure B.3-14 Future Planted Area of 5 Regions in 3 Cases

(2) Net Water Requirements of Different Crops in 5 Regions

The net water requirement of different crops is calculated by ETo x Kc, and the net water requirement of different crops in each region is shown in Table B.3-37. The net water requirement in Al Baha region is small for good climate conditions for farming, on the other hand, the net water requirement in Makkah is 2 times as much water as Al Baha region due to sever climate conditions for farming. Moreover, fodder crops need generally about 2.7 times as much water as cereals.

Table B.3-37 Net Water Requirements of Different Crops in 5 Regions

Crops	Makkah	Al Baha	Asir	Jazan	Najran	Average	Note
Cereal	6,753	3,637	4,691	6,119	6,077	5,455	Wheat, Sorghum, Maize
Fodder	18,420	11,160	13,259	15,276	15,748	14,773	Alfalfa, Rhodes Grass, Sorghum
Fruit	16,420	9,223	11,384	14,010	14,197	13,047	Date, Citrus, Grapes, Fig
Vegetable	5,175	2,863	3,736	4,951	4,725	4,290	Tomato, Onion, Cucumber, Watermelon, Okra

(3) Gross Water Requirements

In the South West region, the irrigation system has a common case where water is pumped up from a well and delivered to farmlands through pipes. When the irrigation method is surface irrigation, by the guideline of MOA, the irrigation efficiency is 55%, in sprinkler irrigation, 70%, in drip irrigation, it is indicated as 85%, and the required amount of gross water requirement also presumes using these values. In order to raise accuracy further from now on, the work which survey the planted area according to irrigation system, and presumes gross water requirement based on net water requirement using the above-mentioned irrigation efficiency is required, but at present, all of cereals and a fodder crop presume gross water requirement, assuming 100% surface irrigation, a fruit tree and vegetables to be 50% of surface irrigation and 50% of drip irrigation.

(4) Future Agricultural Water Demand in South West Region

The result of having calculated the agricultural water demand according to the whole South West region and the 5 regions about the three following cases is shown in Figure B.3-15.

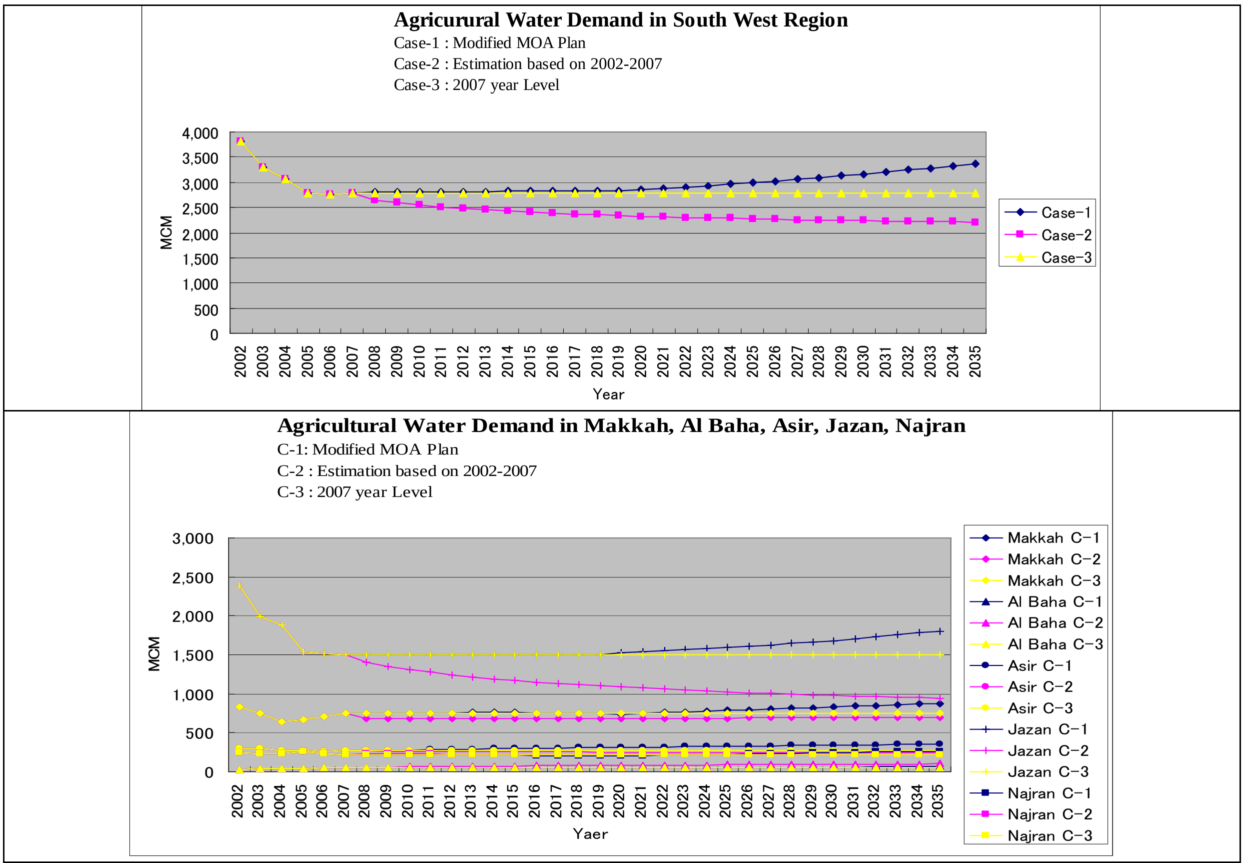


Figure B.3-15 Future Water Demand of 5 Regions in 3 Cases

(5) Water Demand in each Governorate

<u>Data Conversion from Agricultural Branch Office Based to Governorate Units</u>

The agricultural-statistics data of MOA is based on the Agricultural Branch Office, and is not arranged in governorate. In order to follow and to calculate the water demand of Governorate unit, the work which changes the data which has become per agricultural branch office in governorate is required.

The relation of the governorate and agricultural branch office in each region is shown in Table B.3-38. There are 2 cases. Case 1 is two or more agricultural branch offices are in one governorate, and case 2 is one agricultural branch office covers two or more governorates.

When two or more agricultural branch offices are in one governorate, the data of the agricultural branch office, which corresponds, will simply be totaled, but when one agricultural branch office is having two or more jurisdictions, it is necessary to distribute the data of one agricultural branch office to an applicable governorate.

However, since the management area of each agricultural branch office is not clear, and the location on a map is difficult, agricultural water demand of the governorate which refers to the hearing information in Directorate of Agricultural Office and based on the topographical map of 1/500,000 was practically estimated.

It is necessary to obtain the jurisdiction map of each Agricultural Branch Office from now on, to clarify Governorate and the relation of Agricultural Branch Office, and to scrutinize a fractional rate.

Table B.3-38 Relations between Governorate and Agricultural Branch Office

Region	Directorates	Branch	Governorate	Branch→Governorate
Makkah	Makkah	(1)Jiddah	(0)Makkah Almukarramah	(9)Makkah
		(2)Al Qunfudah	(1)Jiddah	(1)Jiddah
		(3)Khelees	(2)Altaif	(1)Al Taif+(3)Bani malek
		(4)Al Lith	(3)Alqunfidhah	(2)Al Qunfudah+(7)Al Arthayat
		(5)Al Kamel	(4)Allith	(4)Al Lith+(8)Athame
		(6)Rabigh	(5)Rabigh	(6)Rabigh
		(7)Al Arthayat	(6)Aljumum	None
		(8)Athame	(7)Khulays	(3)Khelees
		(9)Makkah	(8)Alkamil	(5)Al Kamel
	Taif	(1)Al Taif	(9)Alkhurmah	(5)Alkuma
		(2)Terba	(10)Ranyah	(4)Ranya+(6)Almlah
		(3)Bani malek	(11)Turubah	(2)Terba
		(4)Ranya		
		(5)Alkuma		
		(6)Almlah		
Al Baha	Baha	(1)Al Baha	(0)Albaha	(1)Al Baha
		(2)Baljurashi	(1)Biljurashi	(2)Baljurashi+(6)Benybabayem
		(3)Al Mandaq	(2)Almandaq	(3)Al Mandaq
		(4)Al Aqiq	(3)Almukwah	(7)Al Mekhwat
		(5)Qilwah	(4)Alaqiq	(4)Al Aqiq
		(6)Benybabayem	(5)Qilwah	(5)Qilwah
		(7)Al Mekhwat	(6)Alqari	(8)Baydah
		(8)Baydah		
Asir	Abha	(1)Abha	(0)Abha	(1)Abha+(5)+(12)+(17)
		(2)Al Namas	(1)Khamis Mushayt	(3)Kamis Mushayt+(13)
		(3)Kamis Mushayt	(2)Bishah	(1)Bisha
		(4)Rijal Almah	(3)Annamas	(2)Al Namas+(14)
		(5)Bl Alsamem Al Ahamar	(4)Muhayil	(7)Mahael
		(6)Gana Al Baher	(5)Sarat Abidah	(8)Serat Abeedah
		(7)Mahael	(6)Tathlith	(4)Tatlith
		(8)Serat Abeedah	(7)Rijal Alma	(4)Rijal Almah+(6)
		(9)Dahran Al Janub	(8)Ahad Rifaydah	(11)Tarieb+(15)+(16)
		(10)Al Majardha	(9)Zahran Aljanub	(9)Dahran Al Janub
		(11)Tarieb	(10)Balqarn	(2)Balqarn+(3)Al Basham
		(12)Al Mawin	(11)Almajardah	(10)Al Majardha
		(13)Beny nashble		
		(14)Beny Amare		
		(15)Al Mathah		
		(16)Al Anaine		
		(17)Fanuma		
	Bisha	(1)Bisha		
		(2)Balqarn		
		(3)Al Basham		
		(4)Tatlith		
Jazan	Jazan	(1)Jizan	(0)Jazan	(1)Jizan(5/6)
		(2)Sabya	(1)Sabya	(2)Sabya(6/7)
		(3)Baysh	(2)Abu Arish	(7)Abu Arish
		(4)Al Shaaguge	(3)Samtah	(6)Ahad Al masarba(10/21)
		(5)Ayaban	(4)Alharth	(6)Ahad Al masarba(3/21)
		(6)Ahad Al masarba	(5)Damad	(2)Sabya (1/7)
		(7)Abu Arish	(6)Arrayth	(3)Baysh (10/11)
		(8)Al Ardah	(7)Baysh	(3)Baysh (1/11)
			(8)Farasan	(1)Jizan(1/6)
			(9)Addair	(5)Ayaban(1/3)
			(10)Ahad Almusarihah	(6)Ahad Al masarba(8/21)
			(11)Alidabi	(5)Ayaban(2/3)
			(12)Alaridah	(8)Al Ardah
			(13)Addarb	(4)Al Shaaguge
Najran	Najran	(1)Najran	(0)Najran	(1)Najran*1.0
		(2)Habunah	(1)Sharurah	None
		(3)Yadmah	(2)Hubuna	(2)Habunah*0.5
		(4)Thar	(3)Badr Aljanub	(2)Habunah*0.5
			(4)Yadamah	(3)Yadmah
			(5)Thar	(4)Thar
			(6)Khubash	None
			(7)Alkharkhir	None

Water Demand of Governorate Units

The water demand of the governor rate units in each plan year is shown in Table B.3-39 (Case-1), Table B.3-40 (Case-2), and Table B.3-41 (Case-3) for every case, respectively.

In addition, water demand of the major governorate in a Target year (2035) is as in Table B.3-42.

In addition, water demand of the major governorate in a Target year (2035) is as in Figure B.3-16 to Figure B.3-20.

Table B.3-39 Governorate basis Water Demand (Case-1)

Unit: (MCM)

Case-1	2010	2015	2020	2025	2030	2035
Makkah(12)	**756**	**758**	**740**	**786**	**832**	**878**
(0)Makkah Almukarramah	81.4	81.5	79.6	84.6	89.5	94.5
(1)Jiddah	54.9	55.0	53.7	57.1	60.4	63.8
(2)Altaif	157.3	157.6	153.9	163.5	173.1	182.7
(3)Alqunfidhah	175.9	176.3	172.1	182.8	193.6	204.3
(4)Allith	31.2	31.2	30.5	32.4	34.3	36.2
(5)Rabigh	14.8	14.9	14.5	15.4	16.3	17.2
(6)Aljumum	0.0	0.0	0.0	0.0	0.0	0.0
(7)Khulays	86.4	86.6	84.5	89.8	95.1	100.3
(8)Alkamil	41.4	41.5	40.5	43.1	45.6	48.1
(9)Alkhurmah	28.2	28.3	27.6	29.3	31.1	32.8
(10)Ranyah	52.0	52.1	50.9	54.1	57.2	60.4
(11)Turubah	32.6	32.6	31.9	33.8	35.8	37.8
Al Baha(7)	**54**	**55**	**57**	**59**	**61**	**63**
(0)Albaha	6.8	7.0	7.2	7.4	7.7	7.9
(1)Biljurashi	5.9	6.1	6.2	6.5	6.7	6.9
(2)Almandaq	7.1	7.3	7.5	7.8	8.0	8.3
(3)Almukwah	2.5	2.6	2.7	2.8	2.9	2.9
(4)Alaqiq	12.4	12.6	13.0	13.4	13.9	14.4
(5)Qilwah	0.3	0.3	0.3	0.3	0.3	0.3
(6)Alqari	18.9	19.4	19.9	20.6	21.3	22.0
Asir(12)	**275**	**299**	**313**	**328**	**342**	**356**
(0)Abha	46.9	51.1	53.5	55.9	58.3	60.7
(1)Khamis Mushayt	25.4	27.7	29.0	30.3	31.6	32.9
(2)Bishah	85.7	93.2	97.6	102.0	106.3	110.7
(3)Annamas	12.6	13.7	14.4	15.0	15.7	16.3
(4)Muhayil	17.9	19.4	20.3	21.3	22.2	23.1
(5)Sarat Abidah	6.8	7.4	7.8	8.1	8.5	8.8
(6)Tathlith	8.6	9.4	9.8	10.3	10.7	11.2
(7)Rijal Alma	5.7	6.2	6.5	6.8	7.1	7.4
(8)Ahad Rifaydah	18.8	20.5	21.4	22.4	23.4	24.3
(9)Zahran Aljanub	6.9	7.5	7.9	8.2	8.6	8.9
(10)Balqarn	30.1	32.7	34.3	35.8	37.4	38.9
(11)Almajardah	9.7	10.5	11.0	11.5	12.0	12.5
Jazan(14)	**1,503**	**1,500**	**1,533**	**1,593**	**1,683**	**1,806**
(0)Jazan	47.5	47.4	48.4	50.3	53.2	57.1
(1)Sabya	301.6	300.9	307.5	319.6	337.6	362.4
(2)Abu Arish	124.3	124.1	126.8	131.8	139.2	149.4
(3)Samtah	372.9	372.1	380.3	395.2	417.5	448.2
(4)Alharth	111.9	111.6	114.1	118.6	125.3	134.4
(5)Damad	50.3	50.2	51.3	53.3	56.3	60.4
(6)Arrayth	77.3	77.1	78.8	81.9	86.5	92.9
(7)Baysh	7.7	7.7	7.9	8.2	8.7	9.3
(8)Farasan	9.5	9.5	9.7	10.1	10.6	11.4
(9)Addair	5.4	5.4	5.5	5.7	6.0	6.5
(10)Ahad Almusarihah	298.3	297.7	304.2	316.2	334.0	358.5
(11)Alidabi	10.7	10.7	11.0	11.4	12.0	12.9
(12)Alaridah	56.8	56.7	57.9	60.2	63.6	68.2
(13)Addarb	28.8	28.7	29.4	30.5	32.2	34.6
Najran(8)	**217**	**212**	**205**	**225**	**245**	**265**
(0)Najran	154.2	150.7	145.5	159.8	174.0	188.2
(1)Sharurah	0.0	0.0	0.0	0.0	0.0	0.0
(2)Hubuna	24.8	24.3	23.4	25.7	28.0	30.3

Case-1	2010	2015	2020	2025	2030	2035
(3)Badr Aljanub	24.8	24.3	23.4	25.7	28.0	30.3
(4)Yadamah	7.7	7.6	7.3	8.0	8.7	9.5
(5)Thar	5.2	5.1	4.9	5.4	5.9	6.3
(6)Khubash	0.0	0.0	0.0	0.0	0.0	0.0
(7)Alkharkhir	0.0	0.0	0.0	0.0	0.0	0.0

Table B.3-40 Governorate basis Water Demand (Case-2)

Unit: (MCM)

Case-2	2010	2015	2020	2025	2030	2035
Makkah(12)	**682.7**	**681.7**	**684.5**	**688.5**	**692.8**	**697.3**
(0)Makkah Almukarramah	73.5	73.4	73.7	74.1	74.6	75.0
(1)Jiddah	49.6	49.5	49.7	50.0	50.3	50.6
(2)Altaif	142.0	141.8	142.4	143.2	144.1	145.0
(3)Alqunfidhah	158.8	158.6	159.3	160.2	161.2	162.2
(4)Allith	28.1	28.1	28.2	28.4	28.6	28.7
(5)Rabigh	13.4	13.4	13.4	13.5	13.6	13.7
(6)Aljumum	0.0	0.0	0.0	0.0	0.0	0.0
(7)Khulays	78.0	77.9	78.2	78.7	79.2	79.7
(8)Alkamil	37.4	37.3	37.5	37.7	38.0	38.2
(9)Alkhurmah	25.5	25.5	25.6	25.7	25.9	26.0
(10)Ranyah	47.0	46.9	47.1	47.4	47.7	48.0
(11)Turubah	29.4	29.4	29.5	29.7	29.8	30.0
Al Baha(7)	**62.1**	**73.1**	**82.1**	**89.7**	**96.4**	**102.5**
(0)Albaha	7.8	9.2	10.4	11.3	12.2	13.0
(1)Biljurashi	6.8	8.1	9.0	9.9	10.6	11.3
(2)Almandaq	8.2	9.7	10.9	11.9	12.8	13.6
(3)Almukwah	2.9	3.4	3.9	4.2	4.5	4.8
(4)Alaqiq	14.2	16.8	18.8	20.5	22.1	23.5
(5)Qilwah	0.3	0.3	0.4	0.4	0.5	0.5
(6)Alqari	21.8	25.6	28.8	31.4	33.8	35.9
Asir(12)	**262.1**	**255.6**	**251.5**	**248.5**	**246.3**	**244.5**
(0)Abha	44.7	43.6	42.9	42.4	42.0	41.7
(1)Khamis Mushayt	24.2	23.6	23.3	23.0	22.8	22.6
(2)Bishah	81.6	79.6	78.3	77.4	76.7	76.1
(3)Annamas	12.0	11.7	11.5	11.4	11.3	11.2
(4)Muhayil	17.0	16.6	16.3	16.1	16.0	15.9
(5)Sarat Abidah	6.5	6.3	6.2	6.1	6.1	6.0
(6)Tathlith	8.2	8.0	7.9	7.8	7.7	7.7
(7)Rijal Alma	5.4	5.3	5.2	5.1	5.1	5.1
(8)Ahad Rifaydah	17.9	17.5	17.2	17.0	16.9	16.7
(9)Zahran Aljanub	6.6	6.4	6.3	6.3	6.2	6.1
(10)Balqarn	28.7	28.0	27.5	27.2	26.9	26.7
(11)Almajardah	9.2	9.0	8.8	8.7	8.7	8.6
Jazan(14)	**1,312.4**	**1,170.8**	**1,084.6**	**1,024.5**	**317.2**	**943.4**
(0)Jazan	41.5	37.0	34.3	32.4	10.0	29.8
(1)Sabya	263.3	234.9	217.6	205.6	63.7	189.3
(2)Abu Arish	108.6	96.9	89.7	84.8	26.2	78.1
(3)Samtah	325.6	290.5	269.1	254.2	78.7	234.1
(4)Alharth	97.7	87.1	80.7	76.3	23.6	70.2
(5)Damad	43.9	39.2	36.3	34.3	10.6	31.5
(6)Arrayth	67.5	60.2	55.8	52.7	16.3	48.5
(7)Baysh	6.7	6.0	5.6	5.3	1.6	4.9
(8)Farasan	8.3	7.4	6.9	6.5	2.0	6.0
(9)Addair	4.7	4.2	3.9	3.7	1.1	3.4
(10)Ahad Almusarihah	260.5	232.4	215.3	203.3	63.0	187.3
(11)Alidabi	9.4	8.4	7.8	7.3	2.3	6.7
(12)Alaridah	49.6	44.2	41.0	38.7	12.0	35.6
(13)Addarb	25.2	22.4	20.8	19.6	6.1	18.1
Najran(8)	**225.8**	**223.5**	**222.2**	**221.4**	**220.8**	**220.3**
(0)Najran	160.6	159.0	158.1	157.5	157.0	156.7
(1)Sharurah	0.0	0.0	0.0	0.0	0.0	0.0
(2)Hubuna	25.9	25.6	25.5	25.4	25.3	25.2
(3)Badr Aljanub	25.9	25.6	25.5	25.4	25.3	25.2
(4)Yadamah	8.1	8.0	7.9	7.9	7.9	7.9
(5)Thar	5.4	5.4	5.3	5.3	5.3	5.3

Case-2	2010	2015	2020	2025	2030	2035
(6)Khubash	0.0	0.0	0.0	0.0	0.0	0.0
(7)Alkharkhir	0.0	0.0	0.0	0.0	0.0	0.0

Table B.3-41 Governorate basis Water Demand (Case-3)

Unit: (MCM)

Case-3	2010	2015	2020	2025	2030	2035
Makkah(12)	750.5	750.5	750.5	750.5	750.5	750.5
(0)Makkah Almukarramah	80.8	80.8	80.8	80.8	80.8	80.8
(1)Jiddah	54.5	54.5	54.5	54.5	54.5	54.5
(2)Altaif	156.1	156.1	156.1	156.1	156.1	156.1
(3)Alqunfidhah	174.6	174.6	174.6	174.6	174.6	174.6
(4)Allith	30.9	30.9	30.9	30.9	30.9	30.9
(5)Rabigh	14.7	14.7	14.7	14.7	14.7	14.7
(6)Aljumum	0.0	0.0	0.0	0.0	0.0	0.0
(7)Khulays	85.7	85.7	85.7	85.7	85.7	85.7
(8)Alkamil	41.1	41.1	41.1	41.1	41.1	41.1
(9)Alkhurmah	28.0	28.0	28.0	28.0	28.0	28.0
(10)Ranyah	51.6	51.6	51.6	51.6	51.6	51.6
(11)Turubah	32.3	32.3	32.3	32.3	32.3	32.3
Al Baha(7)	53.9	53.9	53.9	53.9	53.9	53.9
(0)Albaha	6.8	6.8	6.8	6.8	6.8	6.8
(1)Biljurashi	5.9	5.9	5.9	5.9	5.9	5.9
(2)Almandaq	7.1	7.1	7.1	7.1	7.1	7.1
(3)Almukwah	2.5	2.5	2.5	2.5	2.5	2.5
(4)Alaqiq	12.4	12.4	12.4	12.4	12.4	12.4
(5)Qilwah	0.3	0.3	0.3	0.3	0.3	0.3
(6)Alqari	18.9	18.9	18.9	18.9	18.9	18.9
Asir(12)	268.4	268.4	268.4	268.4	268.4	268.4
(0)Abha	45.8	45.8	45.8	45.8	45.8	45.8
(1)Khamis Mushayt	24.8	24.8	24.8	24.8	24.8	24.8
(2)Bishah	83.5	83.5	83.5	83.5	83.5	76.2
(3)Annamas	12.3	12.3	12.3	12.3	12.3	8.2
(4)Muhayil	17.4	17.4	17.4	17.4	17.4	17.4
(5)Sarat Abidah	6.6	6.6	6.6	6.6	6.6	6.6
(6)Tathlith	8.4	8.4	8.4	8.4	8.4	8.4
(7)Rijal Alma	5.5	5.5	5.5	5.5	5.5	5.5
(8)Ahad Rifaydah	18.4	18.4	18.4	18.4	18.4	16.8
(9)Zahran Aljanub	6.8	6.8	6.8	6.8	6.8	6.8
(10)Balqarn	29.4	29.4	29.4	29.4	29.4	29.4
(11)Almajardah	9.4	9.4	9.4	9.4	9.4	9.4
Jazan(14)	1,501.9	1,501.9	1,501.9	1,501.9	1,501.9	1,501.9
(0)Jazan	47.5	47.5	47.5	47.5	47.5	47.5
(1)Sabya	301.3	301.3	301.3	301.3	301.3	301.3
(2)Abu Arish	124.3	124.3	124.3	124.3	124.3	124.3
(3)Samtah	372.6	372.6	372.6	372.6	372.6	372.6
(4)Alharth	111.8	111.8	111.8	111.8	111.8	111.8
(5)Damad	50.2	50.2	50.2	50.2	50.2	50.2
(6)Arrayth	77.2	77.2	77.2	77.2	77.2	77.2
(7)Baysh	7.7	7.7	7.7	7.7	7.7	7.7
(8)Farasan	9.5	9.5	9.5	9.5	9.5	9.5
(9)Addair	5.4	5.4	5.4	5.4	5.4	5.4
(10)Ahad Almusarihah	298.1	298.1	298.1	298.1	298.1	298.1
(11)Alidabi	10.7	10.7	10.7	10.7	10.7	10.7
(12)Alaridah	56.7	56.7	56.7	56.7	56.7	56.7
(13)Addarb	28.8	28.8	28.8	28.8	28.8	28.8
Najran(8)	216.5	216.5	216.5	216.5	216.5	216.5
(0)Najran	154.0	154.0	154.0	154.0	154.0	154.0
(1)Sharurah	0.0	0.0	0.0	0.0	0.0	0.0
(2)Hubuna	24.8	24.8	24.8	24.8	24.8	24.8
(3)Badr Aljanub	24.8	24.8	24.8	24.8	24.8	24.8
(4)Yadamah	7.7	7.7	7.7	7.7	7.7	7.7
(5)Thar	5.2	5.2	5.2	5.2	5.2	5.2
(6)Khubash	0.0	0.0	0.0	0.0	0.0	0.0
(7)Alkharkhir	0.0	0.0	0.0	0.0	0.0	0.0

Table B.3-42 Water Demand of Major Governorate in a Target Planned Year 2035

(Unit : MCM)

Region	1st				2nd				3rd			
	Governorate	C-1	C-2	C-3	Governorate	C-1	C-2	C-3	Governorate	C-1	C-2	C-3
Makkah	Alqunfidhah	204.3	162.3	174.6	Altaif	182.7	145.0	156.1	Khulays	100.3	79.7	85.7
Al Baha	Alquari	22.0	35.9	18.9	Alaqiq	14.4	23.5	12.4	Almandaq	8.3	13.6	7.1
Asir	Bisha	110.7	76.1	83.5	Abha	60.7	41.7	45.8	Balqarn	38.9	26.7	29.4
Jazan	Samtah	448.2	234.1	372.6	Sabya	362.4	189.3	301.3	Ahad al Musarihah	358.5	187.3	298.1
Najran	Najran	188.2	156.7	154.0	Hubawnah	30.3	25.2	24.8	Badr al Janub	30.3	25.2	24.8

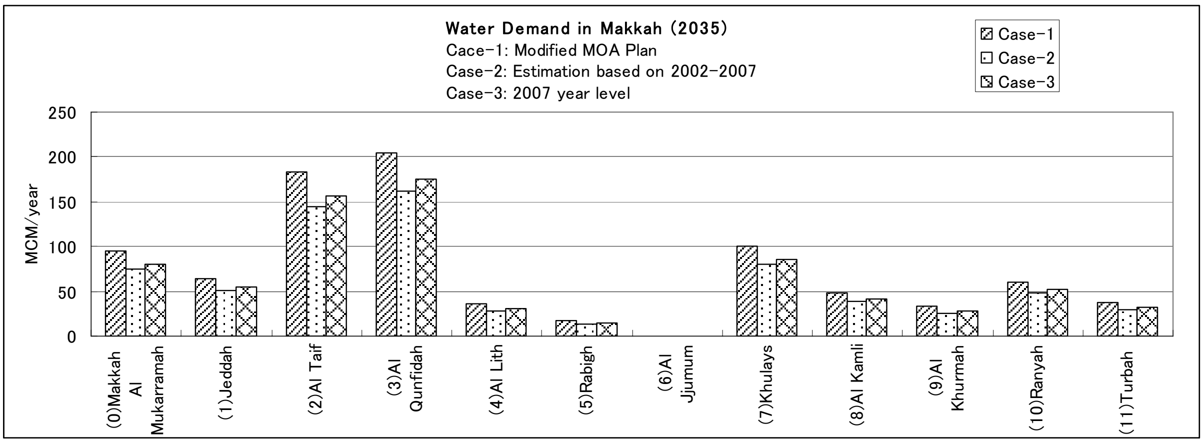


Figure B.3-16 Water Demand Classified by Governorate in 2035 in Makkah Region

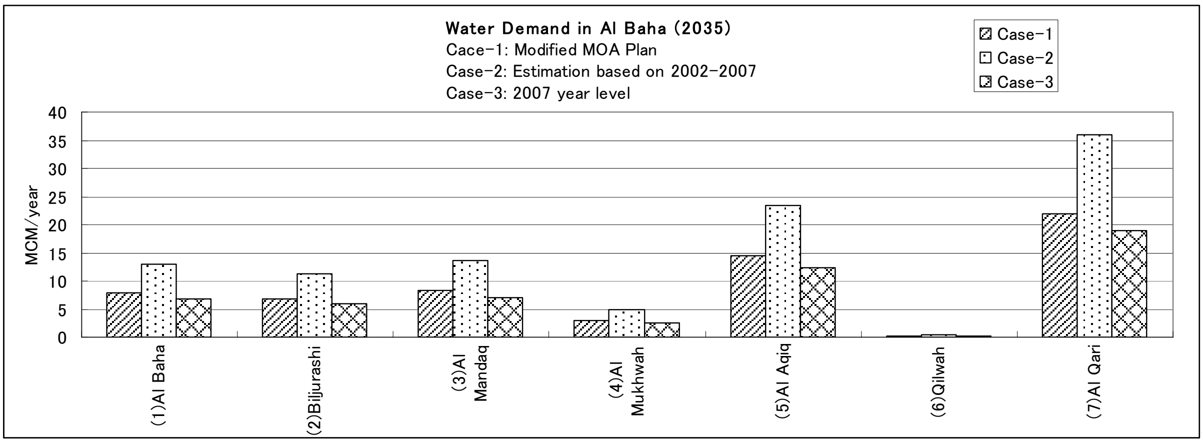


Figure B.3-17 Water Demand classified by Governorate in 2035 in Al Baha Region

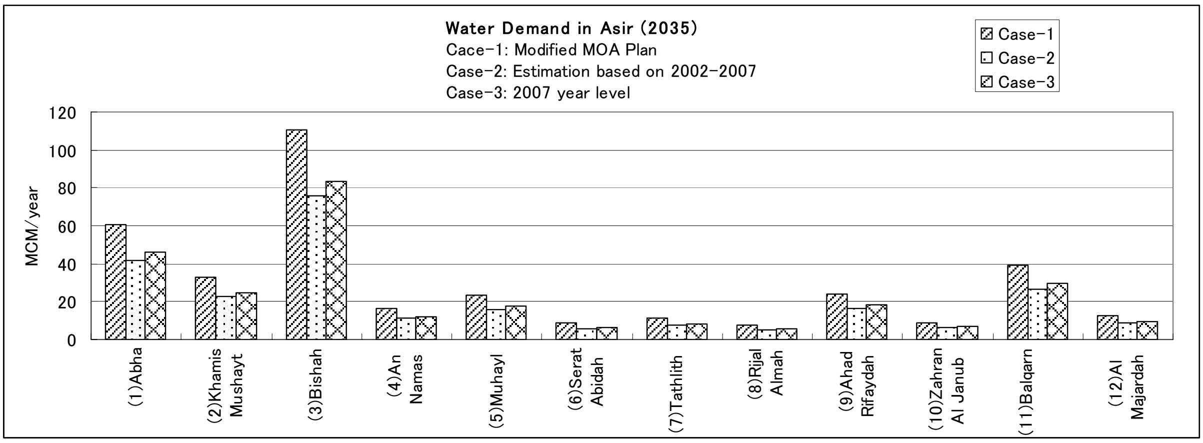


Figure B.3-18 Water Demand Classified by Governorate in 2035 in Asir Region

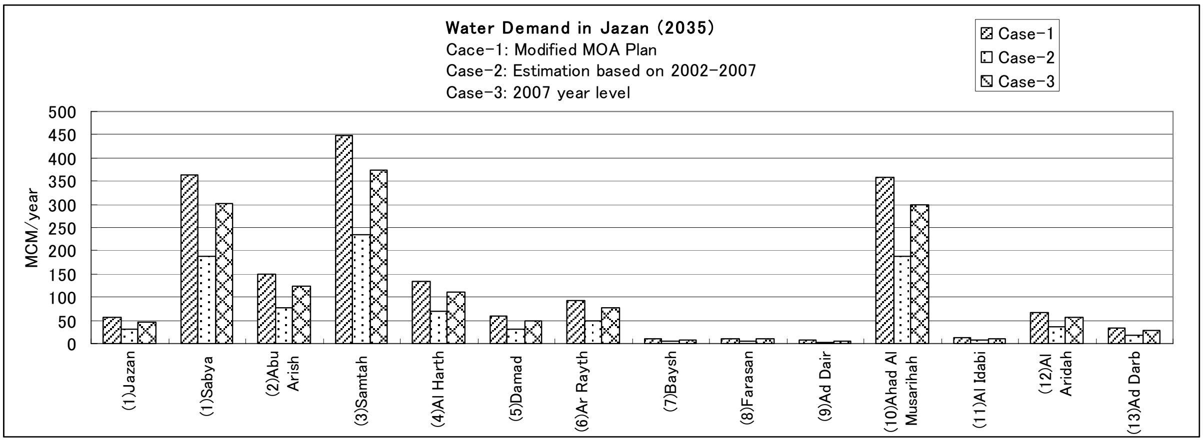


Figure B.3-19 Water Demand Classified by Governorate in 2035 in Jazan Region

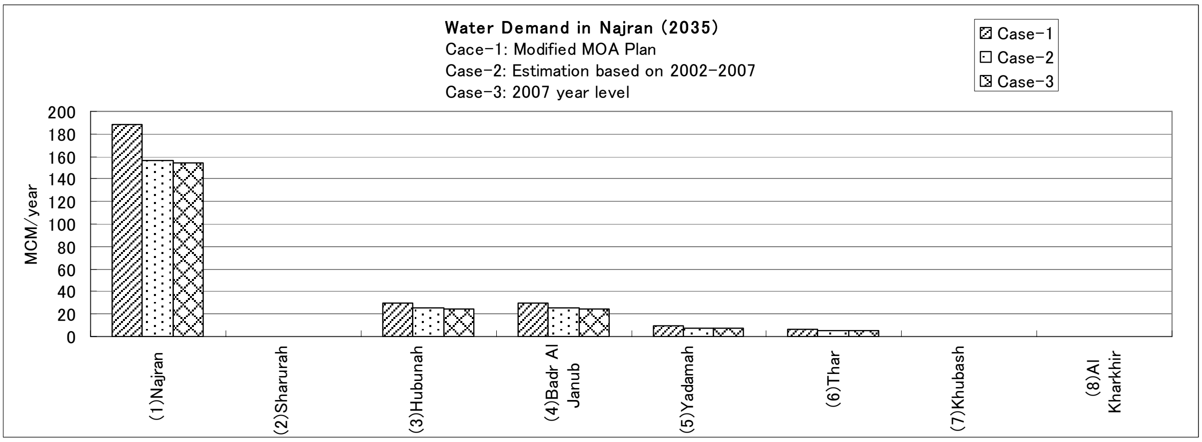


Figure B.3-20 Water Demand Classified by Governorate in 2035 in Najran Region

3.2.4 Sensitivity Analysis on Water Supply and Demand

Since the absolute quantity of renewable water resources is insufficient while the supply-demand gap is large, concerning water for agricultural use, reduction of the planted area serves as a pressing need. The government issued Decision 335 in 2008 to carrying out the policy shift from that of 100% self-support policy of agricultural product to the sustainable agriculture development by rational use of water for agriculture purposes.

The basic agricultural policy is as follows.

- Renewable water (groundwater and surface water) and re-use of wastewater are the main water resources for agricultural use.
- By considering the various usages of reusable treated wastewater, the improvement in use is aimed at and decreases the dependence to renewable water resources.
- The KSA government (Decision 335) aim in the agricultural policy is to convert agricultural development from the present 100% self-sufficient policy in agricultural products into one of sustainability. It is premised on observing this in future agricultural development.
- Continue agriculture development within the limits of potential renewable water resources while taking into consideration the present conditions.
- Agricultural rationing is aimed at the measure of preventing all agricultural output increases.

The following action plan can be considered as a policy for carrying out these basic policies.

- Introduction of saved-water type modern irrigation technology
- Positive use of treated wastewater in the agricultural field.
- Reduction of planted areas in consideration of the potential of renewable water-resources.
- Promote cultivation of vegetable and fruit trees in the city suburbs from the viewpoint of

preservation of the food self-sufficiency ratio.

Therefore, the planted area that can be irrigated and calculated based on the sensitivity analysis, considered the above-mentioned action plan in examination of the supply-demand balance. In addition, the items taken into consideration in the sensitivity analysis are as follows.

(1) Calculation of the renewable water-resources potential according to governorate

(2) Priority is given to water supply.

(3) Introduction of water saving by modern irrigation institution.

(4) Re-use of treated wastewater.

(1) Basic Frame Work for Sensitivity Analysis

So far, although 3 cases of water demand was examined such as a modified MOA plan (Case 1), 2002 to 2007 trend (Case 2), and 2007-year level (Case 3), the Case 1 which added correction to prediction of MOA can be taken for reality having deviated clearly as compared with agricultural-statistics data. On the other hand, since it can observe converging the increase and decrease of a tendency of the planted area on the value in 2007 from agricultural-statistics data, it is simple to perform examination of a demand restraint measure on a "Case 3:2007-year level", and it is intelligible (Case 3 is with the statistical data itself). Since it is judged for not processing regressive prediction etc., examination after this (water balance) is performed about a Case 3 (2007 level).

(2) Procedure of Water Demand and Supply Balance

The following procedures perform examinations on the supply-demand balance of water for agricultural use. The Water supply is part of the renewable water resources and is divided into surface water and groundwater. Shown below is the amount of water saving, treated wastewater for reuse, and the return flow from irrigation water that is added as a water resources. Since the above water supply is considered as the water resource, when a water shortage occurs, it is necessary to take into consideration water control for irrigation alone even if used. Moreover, the water supply priority is to first deduct from the renewable amount of water resources and use the remaining amounts of water resources to examine the areas that can be irrigated.

(3) Renewable Water Resources (Surface Water and Groundwater)

According to each governorate, the water resources potential is calculated based on the catchment areas of 31 Wadi (21 Wadi: Red Sea side, 10 Wadi: Inland side)

(4) Crop Diversification

Although rational use of water for agricultural use is aimed at the basis of Decision335 concerning the agricultural development plan and crop diversification, the planted area shall not be increased. In addition, crop diversification should specialize in vegetables and fruit growing centering on the city suburbs from a viewpoint of preservation of food self-sufficiency, small-scale farmhouse protection, and vegetables shall double while fruit trees maintain the planted areas in 2007. Therefore, a part for the planted area of vegetables to have increased is taken as a plan to decrease the planted area of cereals and a feed crop. Therefore, as the planted area for vegetables increases, the planted areas for cereals and fodder crops will decrease.

(5) Water Saving by Modern Irrigation

The irrigation method for fruit trees and vegetables has maintained traditional methods such as furrow irrigation, and its irrigation efficiency is low in the southwest area. However, in the future, water can be saved by introducing modernistic irrigation systems, such as a sprinkler and a drip. Although the maintenance rate (the traditional irrigation method and the modernistic irrigation method) of present condition is assumed to be 50% according to the agriculture office and irrigation efficiency is made into 70% (= (55% +85%) *50%), consideration of future plans to promote modern irrigation methods and raising irrigation efficiency to 85%.

(6) Reuse of Reclaimed Waste Water

In the KSA from 1982, National Irrigation Authority (NIA) built a large-scale irrigation institution that reused reclaimed wastewater in the suburb of Riyadh. However, although wastewater is limited to cereal crop, fruit trees and fodder crops are not part of the country and application is not performed, it is necessary to aim at use expansion to the water for irrigation of reuse of treated wastewater positively for effective use of water resources. Since ITAL CONSULT established the development plan[1] in the whole KSA about the reuse plan of reclaimed waste water in 2009, this report refers to that study.

(7) Return Flow of Irrigation Water

Although portions for net water requirement is absorbed by plants in the water for irrigation (gross water requirement), it is thought that a portion of the irrigation loss returns into the ground and recharge the groundwater. This is counted and referred to as return flow. The net water requirement in the southwest area in 2007 is 1,675MCM, and the gross water requirement is 2,791MCM. Therefore, 40% (= (2,791-1675) /2791)) of gross water requirement can be reused for irrigation as return flow.

(8) Water Balance in 5 Regions

The Water balance result shown in Table B.3-43, reflects the above-mentioned water balance computational procedure uses the renewable water resources in the five regions. In a planned target year, whole balances are positive in the four regions except Jazan. However, since the water-resource potential of sewage water, and agricultural water areas are unevenly distributed in the region, it is necessary to check them according to governorates and Wadi basin classifications.

Table B.3-43 Water Balance in 5 Regions

(Unit: MCM)

Region	Renewable Water Resource	Water Supply	Available Water	Agriculture Demand	Balance①	Water Saving	Reuse of Reclaimed Water	Return Flow	Balance②
Makkah	782.0	180.2	601.8	750.5	-148.7	80.2	28.0	300.2	287.7
Al Baha	99.4	16.4	83.0	53.9	29.1	8.2	4.1	21.6	67.1
Asir	380.5	20.4	360.1	268.4	91.7	27.2	62.1	107.4	350.5
Jazan	322.9	106.9	216.0	1,501.9	-1,285.9	24.0	28.0	600.8	-605.1
Najran	401.1	72.7	328.4	216.5	111.9	24.9	28.4	86.6	280.2
Total	1,985.9	396.6	1,589.3	2,791.2	-1,201.9	164.5	150.6	1,116.5	380.3

Balance① : Renewable Water – (Water Supply ; Agriculture Demand)

Balance② : ①+(Water Saving + Reuse of Treated Water + Return Flow)

(9) Water Demand Control Measures in 5 Regions

Although the planted area of the Southwest Region in 2007 is 192,000ha, it is necessary to decrease it from the standpoint of preservation of renewal water resources potential to 101,150 ha about half of 2007 levels. When water resources reach their potential and after deducting water supply is maximized, calculations for possible planted areas in each region and governorate are as follows.

Makkah Region

When the maximum amount of renewable water is set to 782.0 MCM, the possible planted area in the target year, 2035 becomes 39,293 ha, which is 93% of 2007 levels (42,077 ha). Figure B.3-21 shows the calculated results.

Almost the same planted areas are possible to use. Because drawdown of groundwater levels and deterioration of groundwater quality is already observed, monitoring the planted areas and groundwater to analyze relationships is recommended to control the proper planted areas.

[1] Investigation and Engineering Design for Treated Wastewater Reuse in the Kingdom of Saudi Arabia

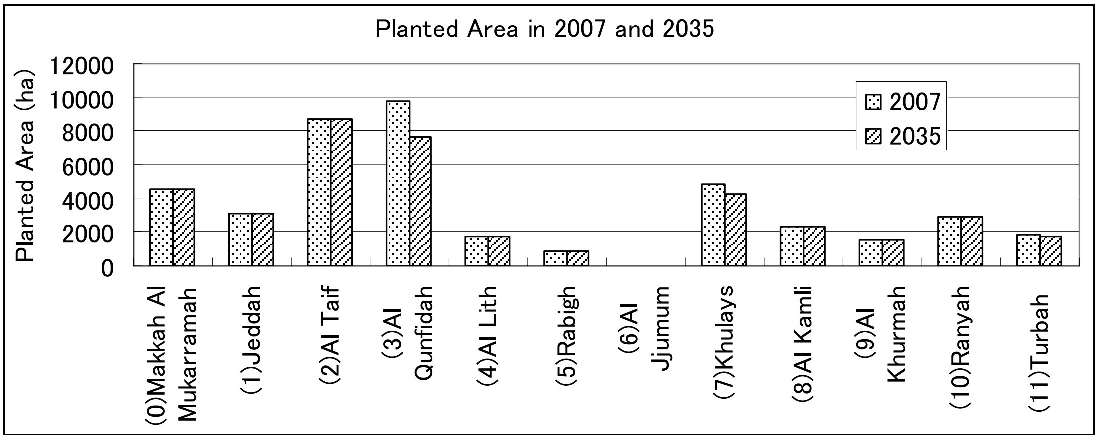


Figure B.3-21 Planted Area in 2007 and 2035 in Makkah Region

<u>Al Baha Region</u>

When the maximum amount of renewable water is set to 99.4 MCM, possible planted area in target year, 2035 becomes 4,425 ha, which is 99% of the 2007 level (4,450 ha). Figure B.3-22 shows the calculated result.

Almost the same planted area is possible to use. Because drawdown of groundwater level and deterioration of groundwater quality is already observed, monitoring of planted areas and groundwater to analyze relationships is recommended to control the proper planted areas.

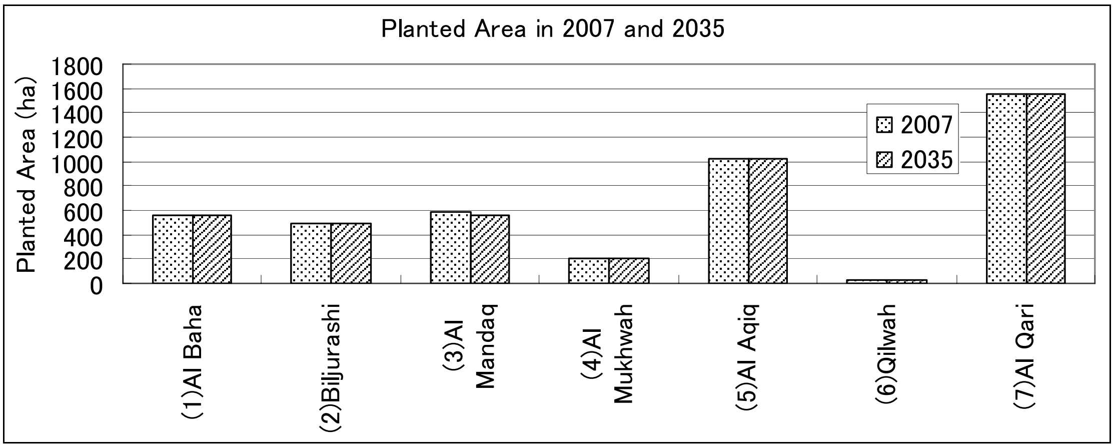


Figure B.3-22 Planted Area in 2007 and 2035 in Al Baha Region

<u>Asir Region</u>

When the maximum amount of renewable water is set to 329.4 MCM, it is necessary to reduce by 20,759 ha, which is 99% of the 2007 level (21,054 ha). Figure B.3-23 shows the calculated result.

Almost the same planted area is possible to use. Because drawdown of groundwater level and deterioration of groundwater quality is already observed, monitoring of planted areas and groundwater to analyze relationships is recommended to control the proper planted areas.

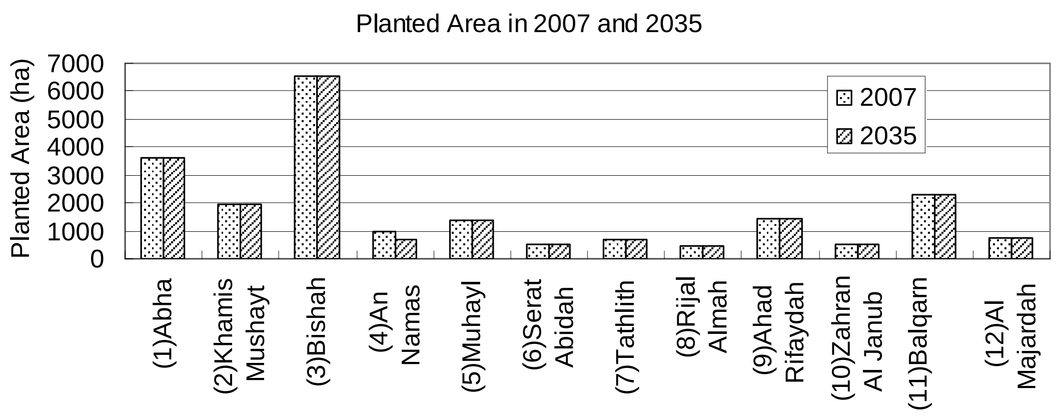


Figure B.3-23 Planted Area in 2007 and 2035 in Asir Region

<u>Jazan Region</u>

When the maximum amount of renewable water is set to 322.9 MCM, possible planted area in target year, 2035 becomes 28,540 ha, which is 25% of the 2007 level (113,558 ha). Figure B.3-24 shows the calculated result.

It seems very severe to keep the present level of planted areas from the point of view of availability of renewable water resources. However, it is important to carry out monitoring of groundwater and planted area, analyzing and grasping relations and managing proper, planted area before decreasing planted areas in the Region. As many conditions are assumed to analyze renewable water resources potential and to estimate the amount of irrigation water, which is calculated based on planning standards, it is important to monitor the situation and verify the assumptions.

The Following governorates have large gaps between present, planted areas and projected future possible planted areas. It is recommended to monitor and evaluate the results carefully in these governorates to grasp the relationship between planted areas and groundwater.

Table B.3-44 Planted Area in 2007 and 2035

Governorate	Present Planted Area in 2007 (ha)	Estimation of Planted Area in 2035 (ha)
Sabya	22.785	6,348
Abu Arith	9,395	2,292
Samtah	28,175	1,393.
Alrth	8,452	171
Damad	3,797	1,457
Arrayth	5,839	3,784
Ad Almusarih	22,540	2,561
Alaridah	4,290	2,465
Addarb	2,176	1,960

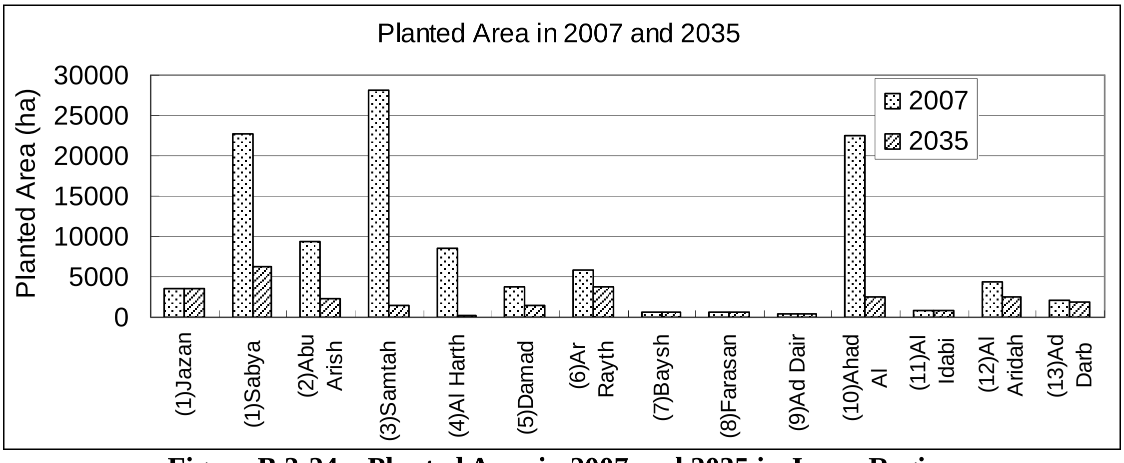


Figure B.3-24 Planted Area in 2007 and 2035 in Jazan Region

Najran Region

When the maximum amount of renewable water is set to 401.1 MCM, possible planted area in target year, 2035 becomes 8,134 ha, which is 71% of the 2007 level (11,430 ha). Figure B.3-25 shows the calculated result.

It seems very severe to keep the present level of planted areas from the point of view of availability of renewable water resources. However, it is important to carry out monitoring of groundwater and planted area, analyzing and grasping relations and managing proper, planted areas before decreasing planted areas in the Region. As many conditions are assumed to analyze renewable water resources potential and to estimate the amount of irrigation water, which is calculated based on planning standards, it is important to monitor the situation and verify the assumptions.

Some governorates have large gaps between present, planted areas and projected future possible planted areas. It is recommended to monitor and evaluate the result carefully in these governorates to grasp the relationship between planted area and groundwater.

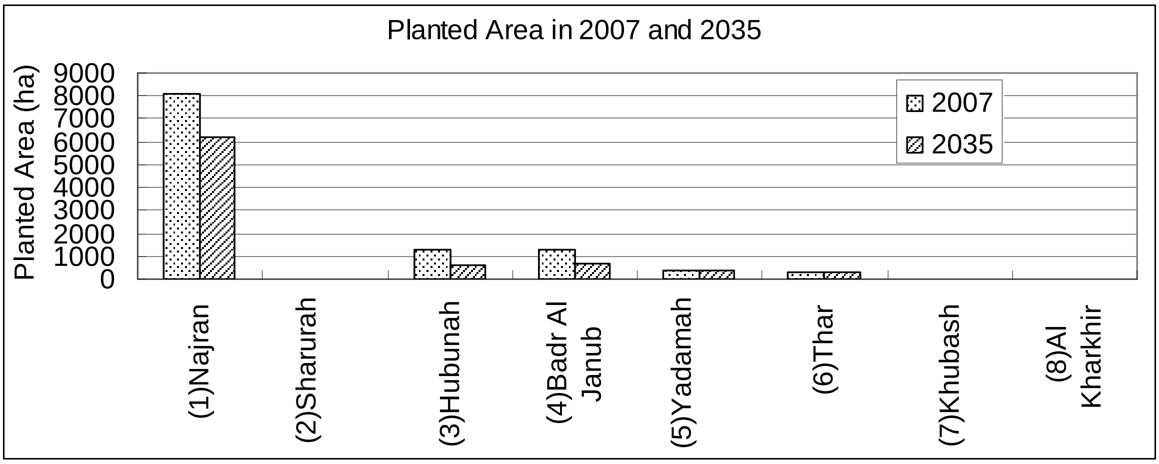


Figure B.3-25 Planted Area in 2007 and 2035 in Najran Region

As mentioned above, the reduction of the planted areas in the five regions corresponding to renewable water resources is summarized in Table B.3-45. As compared with the planted areas in 2007, the reduction area especially in Jazan Region is large, and it is necessary to formulate a radical reduction plan concerning the Jazan region. (Refer to Chapter 5)

Table B.3-45 Planted Area in 2007 and Calculated Planted Area in 2035 in Five Regions

Name of Region	Planted Area in 2007 (ha)	Planted Area in 2035 (ha)	Reduced Area for 2007 in percentage (%)
Makkah	42,077	39,293	93
Al Baha	4,450	4,425	99
Asir	21,054	20,759	99
Jazan	113,558	28,559	25
Najran	11,430	8,134	71

CHAPTER 4 WATER RESOURCES POTENTIAL

4.1 Outline of Water Balance Model

Using SWAT (Soil and Water Assessment Tool), the water balance was estimated for 30 years from 1975 to 2004. The model area was 161,000 km^2, and the monthly discharge and groundwater recharge were calculated and arranged as basin's water balance. The physical processes to analyze the water balance are summarized in the following sub-sections.

(1) Catchments Delineation

Prior to modeling, the model area was partitioned into 1,269 sub-basins (Called 'catchments' in SWAT) with the use of 30-arc grids (90m) of DEM (Digital Elevation Model).

(2) Preparation of Input Information

As necessary data set for SWAT, the meteorological and hydrological information were prepared, and input information for each sub-basin was grouped into the following categories:

a. climate data
b. land use map and soil taxonomy map
c. hydrologic response units (HRUs)

Input information (a – c), the actual data applied to the analysis is described in the following sub-sections.

<u>Climate</u>

The climate of a watershed provides the moisture and energy inputs that control the water balance and determine the relative importance of the different components of the hydrologic cycle. The climatic variables required by SWAT consist of daily records of precipitation, maximum / minimum air temperature, solar radiation, wind speed and relative humidity.

In the analysis, the data from 85 stations, selected among MOWE's 135 stations and PME's eight(8) stations (Abha, Al baha, Bisha, Jizan, Khamis Mushayt, Makkah, Najran, Jeddah) were processed, and 30 years of records from 1975 to 2004 were applied to SWAT.

The location of rain gauge station and the period of records are shown in Figure B.4-1 and Figure B.4-2.

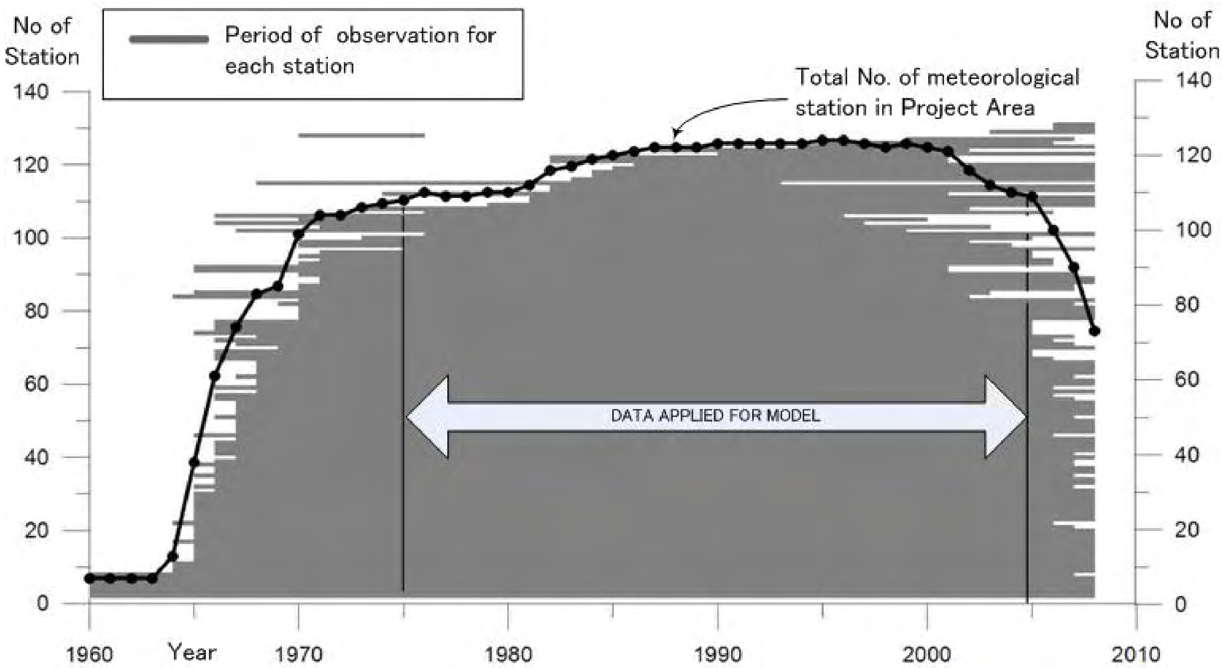


Figure B.4-1 Period of Observation for Rain Gauge Station

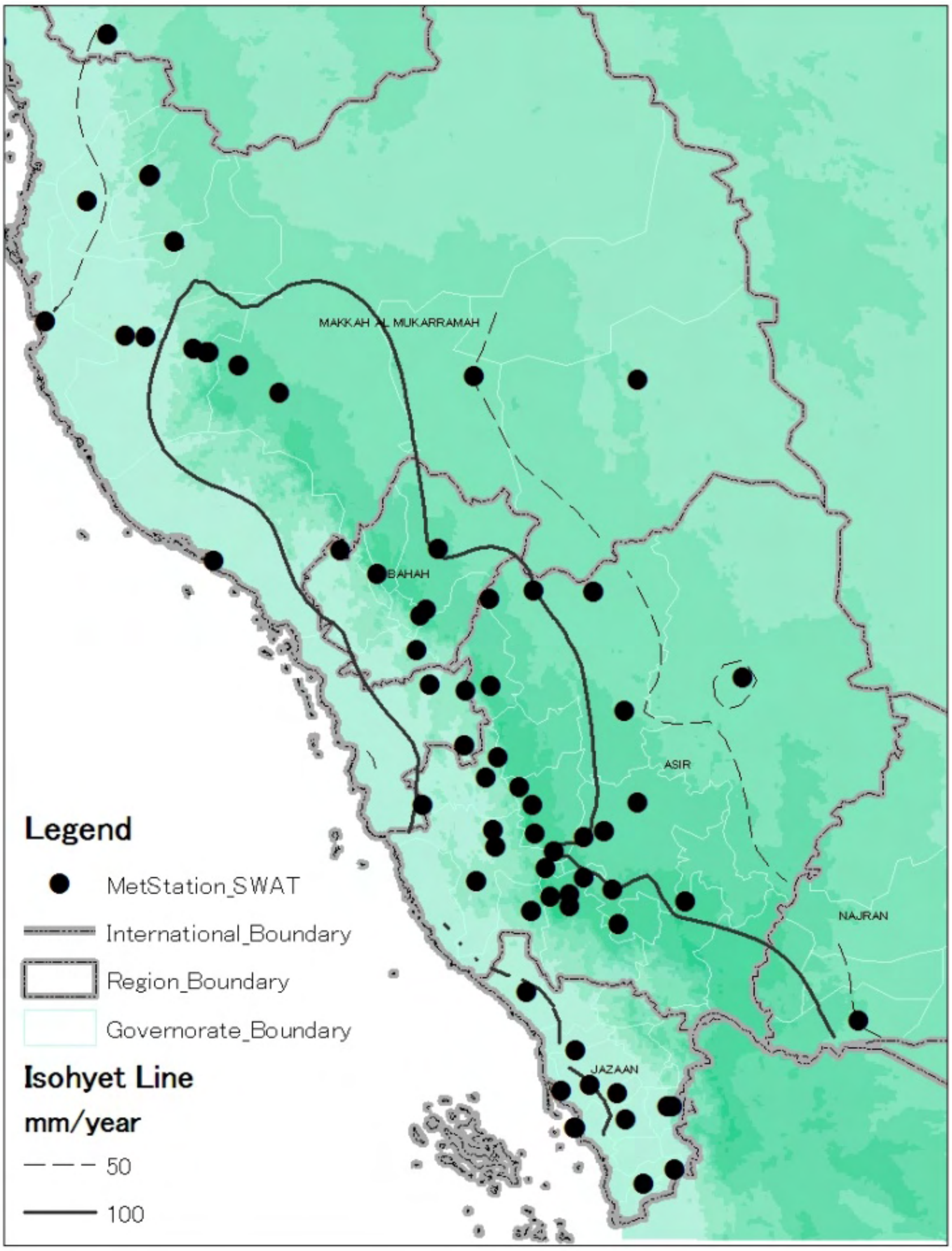


Figure B.4-2 Location Map of Rain Gauge Station (Input data of Model)

Land Use Map and Soil Taxonomy Map

The Land use map and soil characterization map were made as GIS themes. They were used to load land use and soil themes into the study areas and determine the land use/soil class combinations and distributions for the delineated watershed (s) and each respective catchments. The land use and soil themes were once imported and linked to the SWAT databases, the criteria of superficial condition was specified in determining the calculation units (hydrologic response units or HRUs) distribution. Then, one or more unique land use/soil combinations were created for each sub-basin.

In actual processing, the land use and soils classification was overlain each other and determine land use/soil class combinations and distributes for the delineated watershed(s) and each catchments. As for calculation, SWAT requires the hydrologic parameters of each land-soil category simulated within each catchment. To provide necessary hydrologic information for the calculations, personal soil database was developed with existing soil data.

Hydrologic Response Units (HRUs)

The calculation of the water balance was based on Hydrologic Response Unit (HRU). HRU are portions of catchments that possess unique landuse / management / soil attribute. Subdividing the watershed into areas having unique land use and soil combinations enables the model to reflect differences in evapotranspiration and other hydrologic conditions for different land covers/crops and soils.

Hydrologic items of groundwater recharge and runoff were predicted separately for each HRU and routed to obtain the total amount for the watershed. Table B.4-1 shows the major water balance items of SWAT output (files) and was processed for respective catchments.

Table B.4-1 Major Water Balance Items of SWAT

Variable Name	Definition
PRECIP/ PRECEP	**Precipitation:** Total amount of precipitation falling on the sub-basin during one year (mm H2O), which is showing annual average rainfall applied to SWAT, and is calculated from 30 years (1975- 2004) daily records of 85 MOWE and 8 PME stations).
PET	**Potential evapotranspiration (PET):** Potential evapotranspiration from the sub-basin during one year (mm H2O).
ET	**Actual evaporation(ET):** Output of SWAT.
SW	**Soil water contents:** Soil water content (mm). Amount of water in the soil profile at the end of the time period (Dec.31, 2004).
PERC	**Percolation:** Water that percolates past the root zone during one year (mm). There is potentially a lag between the time the water leaves the bottom of the root zone and reaches the shallow aquifer. Over a long period of time, this variable should equal groundwater percolation.
SURQ	**Surface Runoff:** Surface runoff contribution to stream flow during one year (mm H2O).
GW_Q	**Base flow:** Groundwater contribution to stream flow (mm). Water from the shallow aquifer that returns to the reach during one year.
WYLD	**Water Yield:** Water yield (mm H2O). The net amount of water that leaves the sub-basin and contributes to stream flow in the reach during one year (WYLD = SURQ + LATQ + GWQ – TLOSS – pond abstractions).
GW_RECHG	**Shallow Aquifer Recharge:** Recharge entering aquifers during time step (total amount of water entering shallow and deep aquifers during time step).
DA_RECHG	**Deep Aquifer Recharge:** The amount of water from the root zone that recharges the deep aquifer during the time step (shallow aquifer recharge = GW_RCHG-DA_RCHG).
REVAP	**Return Flow:** Water in shallow aquifer returning to root zone in response to a moisture deficit during the time step The valuable also include water uptake directly from the shallow aquifer by deep tree and shrub roots.
SA_ST	**Shallow Aquifer Storage:** Amount of water in shallow aquifer at the end of the time step.
DA_ST	**Deep Aquifer Storage:** Amount of water in deep aquifer at the end of the time step.
TLOSS	**Transmission Loss:** Water lost form tributary channels in HRU via transmission through the bed. This water becomes recharge for the shallow aquifer during time step. Net surface runoff contribution to the main channel stream flow is calculated by subtracting.
LATQ	**Lateral Flow:** Lateral flow contribution to stream flow. Water flowing laterally within the soil profile that enters the main channel during time step.
RECHG	**Groundwater Recharge:** Gross amount of groundwater recharge to shallow aquifer calculated from SWAT water balance (groundwater recharge = PRECP – ET – DRCHG - WYLDO). Negative value shows the upward (return) flow from shallow aquifer to surface or roots zone.

(3) Model Calibration

Sensitivity Analysis and Parameter Calibration

Model calibration was made with 9 records of Rabigh, Al lith, Hali, Baysh, Jizan, Ranyah (Aqiq), Talabah, Bisha, Ranya, Maruwani basin (refer to Figure B.4-3) to determine the model parameters through the correlation between model calculations. The period of calibration was applied from 1969 to 1985 using with annual and monthly records.

Prior to calibrating the model, Sensitivity Analysis was made to obtain sensitive factors from around 60 parameters. At the beginning of calibration, Auto Calibration tools were tried to find the best value as a minimum difference between calculated and observed values. Unless the best fitting from Auto Calibration was obtained, manual adjustment was then followed with trial runs.

By both Auto Calibration and trial, the model parameters were consequently verified within 5 percent error.

In Figure B.4-4 and B.4-5, the calibration results for the 9 basins are indicated. Both figures show the results for a 10 to 15 year period since the 1970's. However in some parts in particularly 1972 and 1973, the differences were large. It is not to be adjusted by handling parameter due to inconsistency of records between precipitation and river discharge. Some records may contain missing information.

For daily calibration, it was also tried to be adjusted within less than 5 % of error. However, acceptable results were not obtained due to poor the relationship between the precipitation and river discharge data. It may be affected by local climatic condition of showery rainfall.

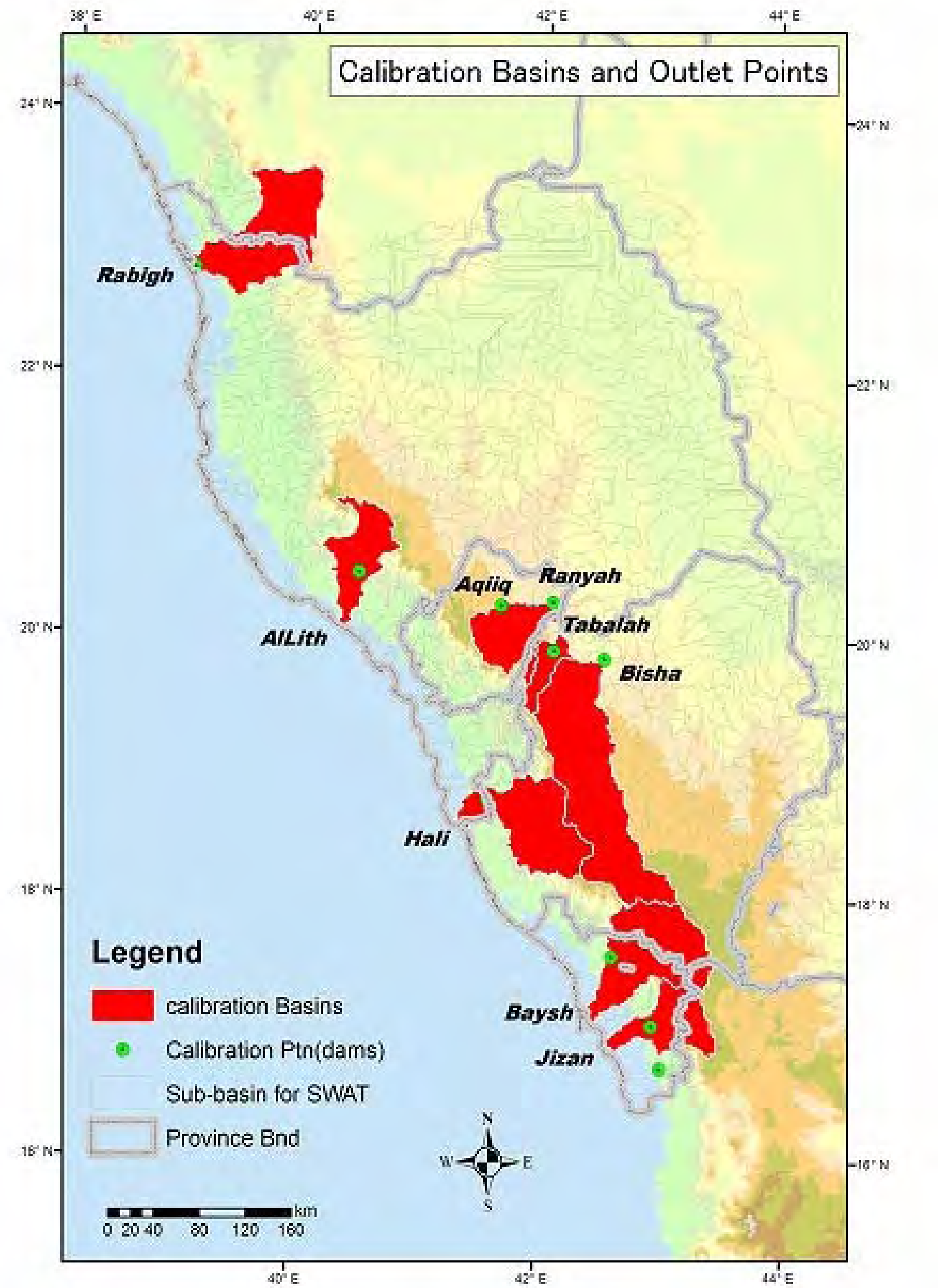


Figure B.4-3 Basin for Model Calibration

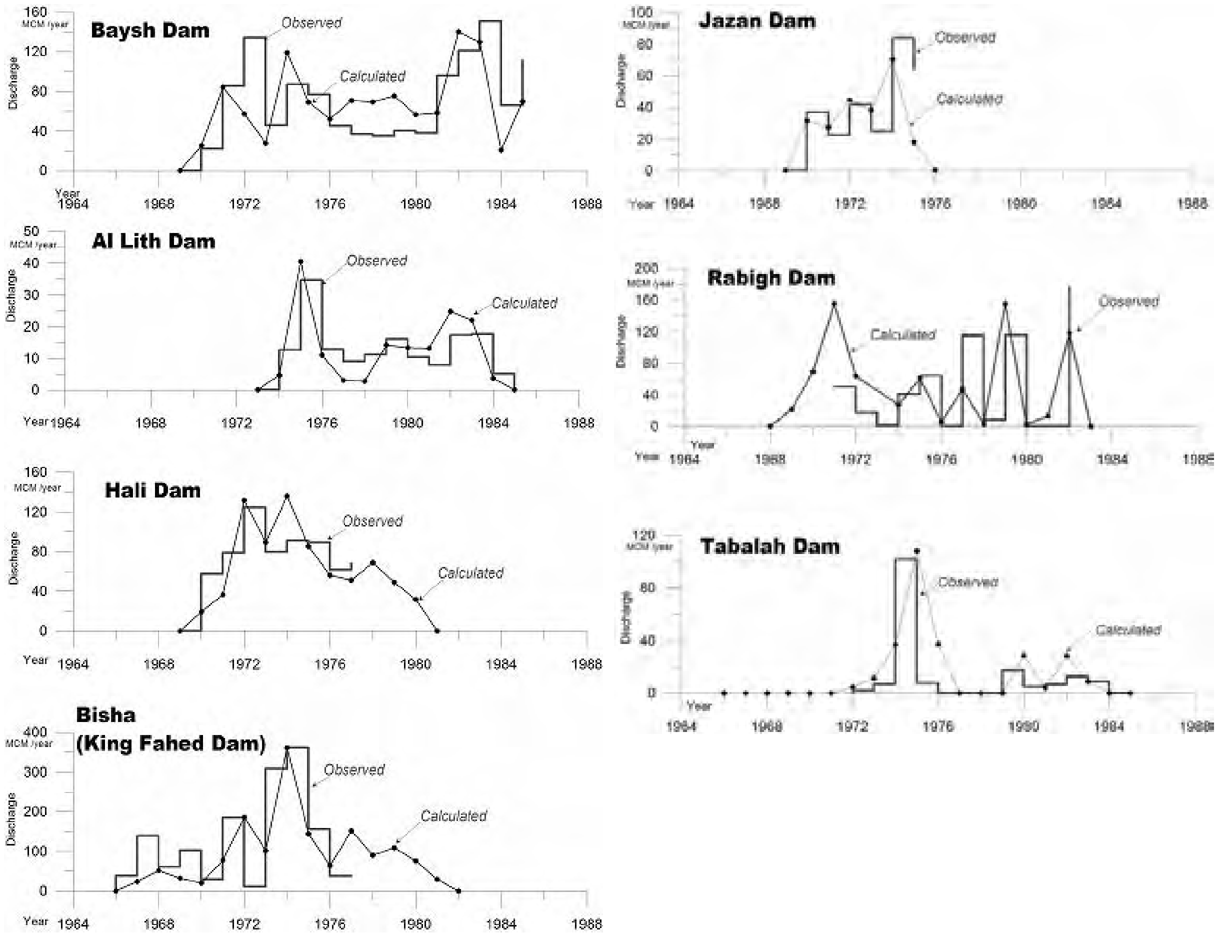


Figure B.4-4 Calibration Result (Annual Discharge)

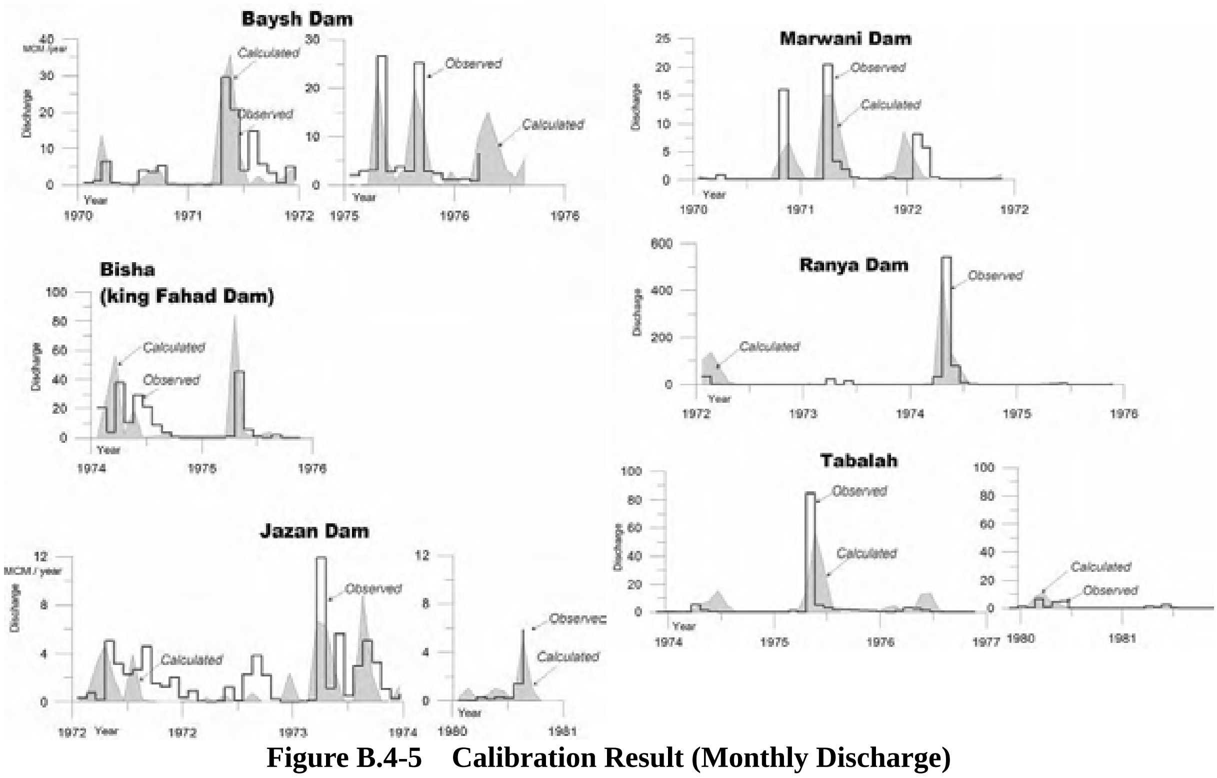


Figure B.4-5 Calibration Result (Monthly Discharge)