In residential areas, large sized projects makes the residential environmental condition be worse. In the central business district, these generate a large amount of traffic, and it means the traffic condition shall become worse.

To avoid the traffic congestion, it should be needed to improve the road network and mass transportation condition. But also, it is necessary to control the zoning and the increasing building volume, so that the traffic amount does not concentrate into one area more than the capacity of the transportation planning, through adequate land use control and limitation of building volume.

(2) Industrial Development

Industrialization and urbanization are closely related. Industries are attracted to urban centers, especially Bangkok and its satellite provinces, because of the availability of infrastructure and services, and the proximity to markets and ports. The rural population is attracted to urban centers because of the availability of employment in industry and services.

The industrial development in Thailand began to take shape in 1958. The strong governmental support was instrumental in the widespread development of industries. The industrial sector is the most significant contributor to the Thailand economy. During the period 1970-1990, the number of industrial factories in Thailand has increased from a few hundred to over fifty thousand.

At present, there are 5 industrial estates in the Greater Bangkok namely: Bang Chan I.S. (Minburi), Lat Krabang I.S. (Lat Krabang), Bang Poo I.S. (Samut Prakarn), Bang Phlee I.S. (Samut Prakarn), Samut Sakhon I.S. (Samut Sakhon), and many large and medium scale industries in Phra Pradaeng industrial area.

4.7.3 Metropolitan Growth Plan

The vision of a desirable future is shaped by the present action through well-meaningful plan. The plan must consider the long term needs and projects, to anticipate needs and demands of the growing population in relation to land, land use, economy, accessibility, and environmental quality.

Through a framework of development or a structure plan which is concerned with spatial or locational arrangements of functional areas and the desired pattern of growth in the years to come, such needs and demands are translated into physical terms and given a geographical dimension. There is then formulated a unified vision for metropolitan (city) of a desired direction of growth, form, and substance.

On this basis, the framework of planned metropolitan development proceeds from the establishment of the regional goals in terms of achieving full development potential for economic growth; improving the quality of life by making available opportunities and benefits of development.

In this regard, the future pattern of the urban growth area based on three development principles:

- decentralization of concentration
- expansion and distribution of opportunities, and
- improved accessibility

Decentralization of concentration of activities in the inner urban core should encourage concentration around emerging centers of activity rather than directionless sprawl. This effects greater opportunities for rehabilitation of older areas and balancing population densities. Such concentrations, achieve economies of scale in the provision of services such as transportation and utilities.

To attain the first two principles, it is necessary to improve the transportation system to provide for efficient access, especially to the centers of activity. Also, job opportunities, social services, cultural and educational facilities should be available to residents in various parts of the activity area.

METROPOLITAN REGIONAL STRUCTURE PLAN

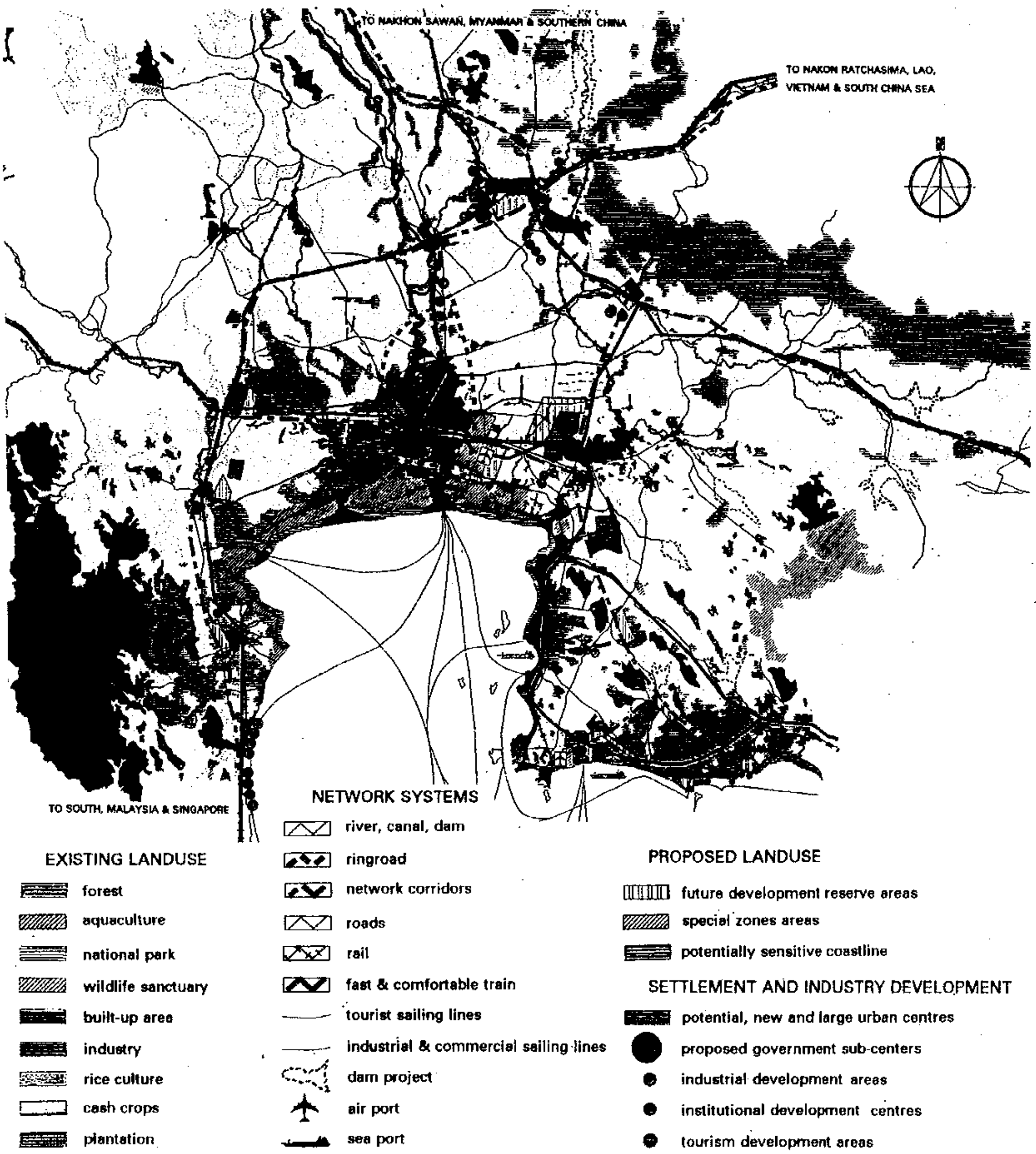

Figure 4.7.1 Metropolitan Regional Structure Plan

4.8 Conclusions and Recommendations

(1) Land Use and Zoning Regulations

At present, there is no land use zoning regulation for Bangkok and Vicinity that has been enforced. The land use shall be regulated under zoning regulation may be dictated by the regional or municipal agency. These should be strictly enforced in regard to each kind of development and any proposal shall be subjected to the stipulations. It is necessary to formulate zoning ordinances so as to encourage pertinent one and restrict the objectionable work not only to regulate the trend of the urban development but also to have plan development of town or settlement areas at different places.

Zoning protects residential areas from the harmful invasion of commercial and industrial uses while it also promotes business and industry by the nature of the planned and orderly development that it ensures. It prevents over-crowding in buildings and land, thus facilitate the provision and continued adequacy of water, sewerage, transportation, and other facilities.

Space standards for community facilities and services and all future land use shall be governed by zonal plans under the Master Plan. The zoning regulations and their administration are the major tool in carrying out the land use part of the master plan of which it is an integral part.

(2) Urban Consolidation Zone

Main built-up area. Densely populated urban area where implementation of the plan is needed to avoid water shortage, land subsidence, traffic congestion, pollution and unhealthy environment created by mixed and uncontrolled land use.

The followings are recommended:

- No more expansion,
- Land use planning and update zoning ordinance,
- Improve the standard of land subdivision standard,
- No new heavy industries,
- Upgrading of urban service,
- Provide drainage ponding areas and along the public roads.

The improvement/rehabilitation/maintenance of natural drainages courses and existing facilities particularly water supply, flood control/drainage and sewerage networks should be given priority so as prevent further deterioration of the urban ecosystem.

(3) Complementary Urban Satellites

The metropolitan concern may be mitigated through the development of growth centers outside the metropolis which will act as complementary urban satellites of Bangkok Metropolis.

In view of annual increase of population of Bangkok Metropolis pressure, population will increase in the contiguous province also. New town and city areas as proposed by BMA and NHA in different parts of the Outer Ring areas are needed in order to develop town in a planned way, controlling the haphazard urban sprawl, but taken into account the water resources and land subsidence of the area.

Loss of storage capacity in the flood plain (due to landfill for urban development), and increased runoff to change of land use shall be consider, especially in the surrounding areas of future town development and SBIA .

(4) Industrial Areas

As expansion of industrial activities within Bangkok Metropolis, particularly in the suburbs, continue to add congestion and cause environmental problems, it is deemed appropiate as proposed in the Metropolitan Regional Structure Plan to develop a new economic base in the upper central region and northeastern region to serve as a centers for relocation of industrial activities from Bangkok Metropolis and vicinity towns. These centers will also serve as a connecting point with the Eastern Seaboard for transportation of agricultural products for export to avoid going through Bangkok, reducing congestion in the city.

(5) Highways

The highway development should be emphasized on responding to the demand of the people in the regions because good economics means the production for export to bring income into the country. The goods transportation should be rapid and in time. Thus, the highway network in the future should be developed to be high standard for the convenience in journeys and transportation especially the highway leading to the special regions as appeared in the government's policy.

The followings are recommended:

- Propose to limit the use of private cars by turning to use the public transportation. For this to improve Mass Transit System is upmost important,
- Provide networks of public distributor/collector roads,
- To connect potential areas from economic and social point of view, to open and to develop the new areas, to solve the traffic congestion.

(6) Environment Aspects

Bangkok's congestion and environmental problems will not be solved by a single ambitious project to create a metropolitan center in the suburbs. Only a decentralization of economic activities and a system of centers connected by mass transit on and outside the Outer Ring Road, will begin to transform the form of the city into an urban realm that is capable of functioning and being managed in the future.

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CHAPTER 5 FUTURE WATER DEMAND

5.1 MWA

The MWA's Master Plan Study (1990) forecasted the total water demand in the year 2017 of its service area (see Table 5.1.1a, Table 5.1.1b and Figure 5.1.1).

According to the Master Plan Study, the assumed growth of the population of the MWA's service area is as presented in Table 5.1.2.

Table 5.1.2 POPULATION PROJECTIONS (in thousand inhabitants)

YEAR	1987	1997	2007	2017
Metropolitan Bangkok	5,739	7,481	9,182	10,616
Nonthaburi	568	965	1,568	2,398
Samut Prakarn	742	1,163	1,744	2,462
Total	7,049	9,609	12,494	15,476

Considering future urbanization, land use and location of future population, the total water demand was forecasted by using specific consumption parameters as shown in Table 5.1.3.

Table 5.1.3 FORECAST OF THE TOTAL WATER DEMAND

YEAR	1987	1997	2007	2017
Total Population (million inhab.)	7.05	9.61	12.49	15.48
growth rate	3.15%	2.66%	2.17%	
Total Water Demand(1,000CMD)				
1.Residential	1,562	2,368	3,109	3,965
2.Non-esidential	992	1,228	1,567	1,854
Total	2,554	3,596	4,676	5,819
Water Demand(lpcd)				
1.Residential	221	246	249	256
2.Non-esidential	141	128	125	120
Total	362	374	374	376

The Master Plan assumes that all elementary zones (of 2x2 km) within the area of responsibility of MWA with a projected water demand greater than 20 liter/sec will, by the year 2017, be served with piped water from the MWA central system. Therefore, 91.4 % of the total water demand (5,319,000 CMD) will be met by piped water supply. The rest, 8.6 % of the total water demand ,will be met from a variety of sources including private wells and direct local extraction from khlongs. The Master Plan assumes the private pumpage volume as follows:

Table 5.1.4 DEEP WELL PUMPAGE PREDICTION

YEAR	1997	2007	2017
Pumpage (,000 CMD)	555	450	336
% of registered capacity	58%	47%	35%

Based on the assumptions, treatment capacity and raw water requirement were estimated as follows.

Table 5.15 Treatment Plant Capacity and Raw Water Requirement

YEAR	1997	2007	2017
Treatment plant capacity(,000CMD)	4,550	6,050	7,800
Raw water requirement(CMS)	58.1	77.1	99.6

5.2 PWA Pathum Thani

According to the JICA "PWA Feasibility Study Report ,March 1990", the total water demand of the Pathum Thani waterworks was estimated as follows.

Table 5.2.1 WATER DEMAND PROJECTION OF PWA PATHUM THANI
IN CMD DAILY AVERAGE

YEAR	1995	2000	2005	2011	2017
Domestic	11,740	240,055	45,303	73,657	104,929
Institutional	6,921	9,746	16,267	21,206	25,346
Commercial	2,136	3,221	4,662	5,599	6,355
Industrial	25,750	37,500	66,637	74,130	79,380
Sub Total	46,547	74,532	132,869	174,592	216,010
Water Loss	12,568	20,124	34,546	43,648	49,682
Total Demand	59,115	94,656	167,415	218,240	265,692

Present water supply is met by groundwater source through deep wells (Table 5.2.2). However, the PWA is going to expand its production capacity to 155,650 CMD in the 1995 as Phase I project, which will meet the water demand until the year 2000 (see Figure 5.2.1). New water take will be constructed at Samkho in Pathum Thani. As a part of the expansion of PWA water works, the Pathum Thani - Rangsit Project is on going. However, due to delay of evaluation of the tender, this project has not yet commenced. After the completion of the project, the PWA will stepwise phase out its deep wells.

JICA report also proposes the Phase II expansion project which will produce 311,300 m3/day at the new intake constucted in the year 2001. It will meet the demand until the yeary 2017.

5.3 Industrial Estates

Pumpage of groundwater of 849 factories was 89,600 CMD in 1993 at 9 industrial estates, i.e., Bangchan, Lat Krabang, Bang Phli, Bang Poo, Samut Sakhon, Hi-Tech, Bang Pain, Navanakhon Co., Ltd. and Bang Kadi Park in the Study Area (see Table 5.3.1).

Future water demand of the estate was estimated by multiplying the average groundwater pumpage per factory of 100 to 108 CMD to number of factories to be increased in the feature. The total water demand will become 118,500 CMD in 2000 and 132,600 CMD in 2017 (see Table 5.3.2).

5.4 Groundwater Demand

Groundwater demand projection for wells under control of the DMR, PWA, DOH and ARD was estimated based on the trend of groundwater pumpage in past 10 years, considering the urbanization of the Study Area (see Tables 5.4.1, 5.4.2 and 5.4.3).

Table 5.1.1a WATER DEMAND PROJECTION (Ordinary Growth)

Unit = m3/day No.1

Description	1995	1996	1997	1998	1999	2000	2001	2002
1. MWA Water Demand								
a. Domestic	1,464,282	1,554,943	1,646,027	1,719,945	1,793,863	1,867,781	1,941,699	2,015,617
b. Institutional	372,800	395,836	440,796	452,232	501,616	512,058	552,821	569,527
c. Commercial	1,244,135	1,321,166	1,399,178	1,462,000	1,524,822	1,587,644	1,650,466	1,713,288
d. Industrial	99,098	105,221	117,174	119,838	124,301	132,600	145,921	149,325
sub-total	3,180,315	3,377,166	3,603,175	3,754,015	3,944,602	4,100,083	4,290,907	4,447,757
e. Water Loss	858,685	911,835	936,826	976,044	986,151	1,025,021	1,029,818	1,067,462
Total Demand	4,039,000	4,289,001	4,540,001	4,730,059	4,930,753	5,125,104	5,320,725	5,515,219
Groundwater Rate %	3	3	2	2	2	2	2	2
Groundwater Volume	121,170	107,225	90,800	94,601	98,615	102,502	106,414	110,304
Surface Water Rate %	97	97	98	98	98	98	98	98
Water Loss Rate %	27	27	26	26	25	25	24	24
Total Population × 1000	9,173	9,459	9,739	10,002	10,272	10,549	10,857	11,163
2. PWA Water Demand	Pathum	Thani						
a. Domestic	11,740	14,205	16,670	19,135	21,600	24,065	26,529	38,427
b. Institutional	6,921	7,486	8,051	8,616	9,181	9,746	10,311	11,800
c. Commercial	2,136	2,353	2,570	2,787	3,004	3,221	3,438	3,744
d. Industrial	25,750	28,100	30,450	32,800	35,150	37,500	39,851	57,289
sub-total	46,547	52,144	57,741	63,338	68,935	74,532	80,129	111,260
e. Water Loss	12,568	14,584	15,590	17,101	18,612	20,124	21,848	28,928
Total Demand	59,115	66,728	73,331	80,439	87,547	94,656	101,977	140,188
Groundwater Rate %	95	90	80	55	45	35	30	25
Groundwater Volume	56,159	60,055	58,665	44,242	39,396	33,129	30,593	35,047
Surface Water Rate %	5	10	20	45	55	65	70	75
Water Loss Rate %	27	27	27	27	27	27	27	26
Total Population	545,329	568,379	591,429	614,479	637,529	660,579	683,629	702,803
3. Industrial Estates (9 Estates)								
Groundwater Demand	100,244	102,880	105,517	109,787	114,057	118,497	119,533	120,569
4. Groundwater Demand (DMR + PWA +DOH + ARD)								
a. Domestic	400,682	405,323	409,975	414,638	419,313	423,999	428,697	433,407
b. Institutional	75,198	76,069	76,942	77,817	78,695	79,574	80,456	81,340
c. Commercial	51,628	52,226	52,826	53,427	54,029	54,633	55,238	55,845
d. Industrial	594,850	601,740	608,646	615,569	622,509	629,466	636,440	643,433
Sub-Total	1,122,358	1,135,358	1,148,388	1,161,451	1,174,545	1,187,672	1,200,831	1,214,025
Groundwater Total	1,399,931	1,405,518	1,403,370	1,410,081	1,426,613	1,441,801	1,457,372	1,479,945
Surface Water Total	3,920,786	4,188,449	4,463,867	4,671,655	4,880,289	5,084,128	5,285,694	5,510,055
Total	5,320,717	5,593,967	5,867,237	6,081,736	6,306,902	6,525,928	6,743,066	6,990,000

Water Demand Projection
(Ordinary Growth) Unit = m3/day No.2

Description	2003	2004	2005	2006	2,007	2,008	2,009	2,010
1. MWA Water Demand								
a. Domestic	2,089,535	2,163,453	2,237,371	2,311,289	2,385,205	2,437,013	2,488,821	2,540,629
b. Institutional	614,590	625,078	638,436	694,378	716,585	767,665	784,213	810,534
c. Commercial	1,776,110	1,838,932	1,901,754	1,964,576	2,027,397	2,071,424	2,115,451	2,159,478
d. Industrial	162,505	173,722	181,798	189,874	190,523	204,023	205,409	206,623
sub-total	4,642,740	4,801,185	4,959,359	5,160,117	5,319,710	5,480,125	5,593,894	5,717,264
e. Water Loss	1,067,830	1,104,273	1,140,653	1,135,226	1,170,336	1,150,826	1,174,718	1,200,625
Total Demand	5,710,570	5,905,458	6,100,012	6,295,343	6,490,046	6,630,951	6,768,612	6,917,889
Groundwater Rate %	2	1	1	1	1	0	0	0
Groundwater Volume	114,211	59,055	61,000	62,953	64,900	0	0	0
Surface Water Rate %	98	99	99	99	100	100	100	100
Water Loss Rate %	23	23	23	22	22	21	21	21
Total Population × 1000	11,442	11,728	11,787	11,846	11,905	11,964	12,024	12,084
2. PWA Water Demand	Pathum	Thani						
a. Domestic	40,719	43,011	45,303	47,595	52,809	58,021	63,233	68,445
b. Institutional	13,289	14,778	16,267	17,756	18,446	19,136	19,826	20,516
c. Commercial	4,050	4,356	4,662	4,968	5,094	5,220	5,346	5,472
d. Industrial	60,405	63,521	66,637	69,753	70,630	71,505	72,380	73,255
sub-total	118,463	125,666	132,869	140,072	146,979	153,882	160,785	167,688
e. Water Loss	30,800	32,673	34,546	35,896	36,745	38,471	40,196	41,922
Total Demand	149,263	158,339	167,415	175,968	183,724	192,353	200,981	209,610
Groundwater Rate %	20	18	17	16	15	14	13	12
Groundwater Volume	29,853	28,501	28,461	28,155	27,559	26,929	26,128	25,153
Surface Water Rate %	80	82	83	84	85	86	87	88
Water Loss Rate %	26	26	26	25	25	25	25	26
Total Population	721,977	741,151	760,325	779,499	798,673	817,847	837,021	856,195
3. Industrial Estates (9 Estates)								
Groundwater Demand	121,605	122,642	123,679	124,716	125,753	126,790	127,827	128,864
4. Groundwater Demand (DMR + PWA +DOH + ARD)								
a. Domestic	438,129	442,864	447,611	452,371	457,144	461,930	466,729	471,541
b. Institutional	82,226	83,115	84,005	84,899	85,795	86,693	87,593	88,497
c. Commercial	56,464	57,064	57,675	58,289	58,904	59,520	60,139	60,759
d. Industrial	650,444	657,473	664,521	671,588	678,673	685,778	692,903	700,047
Sub-Total	1,227,263	1,240,516	1,253,813	1,267,147	1,280,515	1,293,921	1,307,364	1,320,844
Groundwater Total	1,492,922	1,450,714	1,466,953	1,482,971	1,498,727	1,447,640	1,461,319	1,474,861
Surface Water Total	5,715,770	5,976,241	6,177,966	6,380,202	6,581,311	6,796,374	6,943,465	7,102,346
Total	7,208,692	7,426,955	7,644,919	7,863,174	8,080,038	8,244,015	8,404,784	8,577,207

Table 5.1.1a (Continuation)

Water Demand Projection
(Ordinary Growth) Unit = m3/day No. 3

Description	2011	2012	2013	2014	2015	2016	2017
1. MWA Water Demand							
a. Domestic	2,592,437	2,644,245	2,696,053	2,747,861	2,799,669	2,851,477	2,903,287
b. Institutional	827,124	883,256	900,678	917,918	935,340	952,756	969,900
c. Commercial	2,203,505	2,247,532	2,291,569	2,335,586	2,379,613	2,423,640	2,467,671
d. Industrial	206,762	220,811	225,144	229,477	233,810	238,143	242,475
sub-total	5,829,828	5,995,844	6,113,434	6,230,842	6,348,432	6,466,016	6,583,333
e. Water Loss	1,224,264	1,199,169	1,222,687	1,246,168	1,269,686	1,293,203	1,316,667
Total Demand	7,054,092	7,195,013	7,336,121	7,477,010	7,618,118	7,759,219	7,900,000
Groundwater Rate %	0	0	0	0	0	0	0
Groundwater Volume	0	0	0	0	0	0	0
Surface Water Rate %	100	100	100	100	100	100	100
Water Loss Rate %	21	20	20	20	20	20	20
Total Population × 1000	12,108	12,169	12,229	12,291	12,352	12,414	12,476
2. PWA Water Demand	Pathum	Thani					
a. Domestic	73,657	78,869	84,081	89,293	94,505	99,717	104,929
b. Institutional	21,206	21,896	22,586	23,276	23,966	24,656	25,346
c. Commercial	5,599	5,725	5,851	5,977	6,103	6,229	6,355
d. Industrial	74,130	75,005	75,880	76,755	77,630	78,505	79,380
sub-total	174,592	181,495	188,398	195,301	202,204	209,107	216,010
e. Water Loss	43,648	43,559	45,216	46,872	48,529	48,095	49,682
Total Demand	218,240	225,054	233,614	242,173	250,733	257,202	265,692
Groundwater Rate %	12	12	11	11	10	10	10
Groundwater Volume	26,189	27,006	25,697	26,639	25,073	25,720	26,569
Surface Water Rate %	88	88	89	89	90	90	90
Water Loss Rate %	25	24	24	24	24	23	23
Total Population	875,369	894,533	913,697	932,861	952,025	971,189	990,353
3. Industrial Estates (9 Estates)							
Groundwater Demand	129,396	129,928	130,460	130,992	131,524	132,056	132,586
4. Groundwater Demand (DMR + PWA +DOH + ARD)							
a. Domestic	476,368	481,208	486,062	490,931	495,814	500,712	505,625
b. Institutional	89,402	90,311	91,222	92,136	93,052	93,971	94,893
c. Commercial	61,381	62,004	62,630	63,257	63,886	64,518	65,151
d. Industrial	707,213	714,399	721,605	728,833	736,083	743,355	750,648
Sub-Total	1,334,365	1,347,922	1,361,519	1,375,157	1,388,835	1,402,556	1,416,317
Groundwater Total	1,489,950	1,504,856	1,517,878	1,532,788	1,545,432	1,560,332	1,576,472
Surface Water Total	7,246,143	7,393,060	7,544,037	7,692,546	7,843,778	7,990,701	8,139,123
Total	8,736,093	8,897,917	9,061,713	9,225,333	9,389,210	9,551,033	9,714,595

Source : M W A, P W A, I E A T, D M R

Table 5.1.1b WATER DEMAND PROJECTION (Extraordinary Growth)

Unit = m3/day No.1

Description	1995	1996	1997	1998	1999	2000	2001	2002
1. MWA Water Demand								
a. Domestic	1,464,282	1,554,943	1,648,518	1,742,093	1,835,668	1,929,243	2,022,818	2,116,393
b. Institutional	372,800	395,836	425,733	455,630	485,527	515,424	545,321	575,218
c. Commercial	1,244,135	1,321,166	1,400,797	1,480,428	1,560,059	1,639,690	1,719,321	1,798,952
d. Industrial	99,098	106,221	112,696	120,171	127,646	135,121	142,596	150,071
sub-total	3,180,315	3,377,166	3,587,744	3,798,322	4,008,900	4,219,478	4,430,056	4,640,634
e. Water Loss	954,095	1,013,150	1,076,323	1,101,513	1,162,581	1,223,649	1,240,416	1,299,378
Total Demand	4,134,410	4,390,316	4,664,067	4,899,835	5,171,481	5,443,127	5,670,472	5,940,012
Groundwater Rate %	3	3	3	4	4	5	6	7
Groundwater Volume	124,032	131,709	139,922	195,993	206,859	272,156	340,228	415,801
Surface Water Rate %	95	97	97	96	96	95	94	93
Water Loss Rate %	30	30	30	29	29	29	28	28
Total Population×1000	9,173	9,459	9,739	10,002	10,272	10,549	10,857	11,163
2. PWA Water Demand								
a. Domestic	20,535	26,559	32,583	38,606	46,314	54,022	61,730	69,438
b. Institutional	10,427	12,617	14,808	16,998	19,801	22,604	25,407	28,210
c. Commercial	4,473	5,933	7,394	8,854	10,723	12,591	14,460	16,328
d. Industrial	32,469	37,580	42,691	47,802	54,342	60,882	67,422	73,962
sub-total	67,904	82,690	97,475	112,261	131,180	150,100	169,019	187,938
e. Water Loss	18,334	22,326	26,318	30,311	35,419	40,527	45,635	48,864
Total Demand	86,238	105,016	123,794	142,572	166,599	190,626	214,654	236,802
Groundwater Rate %	100	100	100	50	40	20	10	5
Groundwater Volume	86,238	105,016	123,794	71,286	66,640	38,125	21,465	11,840
Surface Water Rate %	0	0	0	50	60	80	90	95
Water Loss Rate %	27	27	27	27	27	27	27	26
Total Population	613,799	675,029	718,619	762,209	805,799	849,389	892,979	927,107
3. Industrial Estates (9 Estates)								
Groundwater Demand	100,244	105,256	110,519	116,045	121,847	127,940	134,337	141,053
4. Groundwater Demand (DMR + PWA +DOH + ARD)								
a. Domestic	400,682	409,812	418,942	428,073	437,203	446,333	455,463	464,594
b. Institutional	75,198	76,912	78,625	80,339	82,052	83,766	85,479	87,193
c. Commercial	51,628	52,806	53,981	55,158	56,334	57,511	58,687	59,864
d. Industrial	594,850	608,404	621,959	635,514	649,069	662,623	676,178	689,733
Sub-Total	1,122,358	1,147,933	1,173,508	1,199,083	1,224,658	1,250,233	1,275,808	1,301,383
Groundwater Total	1,432,872	1,489,916	1,547,743	1,582,407	1,620,004	1,688,454	1,771,838	1,870,077
Surface Water Total	4,010,377	4,258,605	4,524,145	4,775,128	5,064,581	5,323,471	5,523,432	5,749,172
Total	5,443,250	5,748,521	6,071,888	6,357,535	6,684,585	7,011,926	7,295,270	7,619,250

Water Demand Projection
(Extraordinary Growth) Unit = m3/day No.2

Description	2003	2004	2005	2006	2007	2008	2009	2010
1. MWA Water Demand								
a. Domestic	2,178,949	2,241,505	2,304,061	2,366,617	2,429,173	2,491,729	2,554,285	2,616,841
b. Institutional	614,590	645,017	675,444	705,871	736,298	766,725	797,152	827,579
c. Commercial	1,857,515	1,916,077	1,974,639	2,033,201	2,091,763	2,150,325	2,208,887	2,267,449
d. Industrial	162,505	173,722	181,798	189,874	190,523	204,023	205,409	206,623
sub-total	4,813,559	4,976,321	5,135,942	5,295,563	5,447,757	5,612,802	5,765,733	5,918,492
e. Water Loss	1,347,797	1,393,370	1,438,064	1,482,758	1,470,894	1,515,457	1,556,748	1,597,993
Total Demand	6,161,356	6,369,691	6,574,006	6,778,321	6,918,651	7,128,259	7,322,481	7,516,485
Groundwater Rate %	7	7	7	7	7	7	7	8
Groundwater Volume	431,295	445,878	460,180	474,482	484,306	498,978	512,574	601,319
Surface Water Rate %	93	93	93	93	93	93	93	92
Water Loss Rate %	28	28	28	28	27	27	27	27
Total Population×1000	11,442	11,728	11,787	11,846	11,906	11,964	12,024	12,084
2. PWA Water Demand	Pathum	Thani						
a. Domestic	77,121	84,100	91,079	98,059	105,038	112,017	118,996	125,975
b. Institutional	30,872	33,410	35,948	38,486	41,024	43,561	46,099	48,637
c. Commercial	18,162	19,854	21,546	23,238	24,930	26,622	28,314	30,006
d. Industrial	79,763	85,685	91,606	97,528	103,450	109,372	115,293	121,215
sub-total	205,918	223,049	240,179	257,310	274,441	291,571	308,702	325,833
e. Water Loss	53,539	57,993	62,447	64,328	68,610	72,893	77,176	81,458
Total Demand	259,457	281,041	302,626	321,638	343,051	364,464	385,878	407,291
Groundwater Rate %	5	5	5	5	10	14	18	23
Groundwater Volume	12,973	14,052	15,131	16,082	34,305	51,025	69,458	93,677
Surface Water Rate %	95	95	95	95	90	86	82	77
Water Loss Rate %	26	26	26	25	25	25	25	25
Total Population	961,235	995,363	1,029,491	1,063,619	1,097,747	1,131,875	1,166,003	1,200,131
3. Industrial Estates (9 Estates)								
Groundwater Demand	143,874	146,751	149,687	152,680	155,734	158,849	162,025	165,266
4. Groundwater Demand (DMR + PWA +DOH + ARD)								
a. Domestic	473,724	482,854	491,985	501,115	510,245	519,375	528,506	537,636
b. Institutional	88,906	90,620	92,333	94,047	95,760	97,474	99,187	100,901
c. Commercial	61,040	62,217	63,393	64,569	65,746	66,922	68,099	69,275
d. Industrial	703,288	716,842	730,397	743,952	757,507	771,061	784,616	798,171
Sub-Total	1,326,958	1,352,533	1,378,108	1,403,683	1,429,258	1,454,833	1,480,408	1,505,983
Groundwater Total	1,916,100	1,959,215	2,003,106	2,046,928	2,103,603	2,163,685	2,224,465	2,366,245
Surface Water Total	5,976,544	6,190,802	6,401,320	6,609,394	6,743,092	6,942,720	7,126,327	7,228,780
Total	7,891,644	8,150,017	8,404,426	8,656,321	8,846,694	9,106,404	9,350,792	9,595,025

Table 5.1.1b (Continuation)

Water Demand Projection
(Extraordinary Growth) Unit : m3/day No.3

Description	2011	2012	2013	2014	2015	2016	2017
1. MWA Water Demand							
a. Domestic	2,666,057	2,715,273	2,764,489	2,813,705	2,862,921	2,912,137	2,961,353
b. Institutional	849,296	871,013	892,730	914,447	936,164	957,881	979,598
c. Commercial	2,313,678	2,359,907	2,406,136	2,452,366	2,498,594	2,544,823	2,591,052
d. Industrial	206,762	220,811	225,144	229,477	233,810	238,143	242,476
sub-total	6,035,793	6,167,004	6,288,499	6,409,994	6,531,489	6,652,984	6,774,478
e. Water Loss	1,629,664	1,603,421	1,635,010	1,666,698	1,632,872	1,663,246	1,693,620
Total Demand	7,666,457	7,770,425	7,923,509	8,076,692	8,164,361	8,316,230	8,468,098
Groundwater Rate %	8	8	8	7	7	7	7
Groundwater Volume	613,237	621,634	633,881	566,361	571,505	582,136	592,767
Surface Water Rate %	92	92	92	93	93	93	93
Water Loss Rate %	27	26	26	26	25	25	25
Total Population×1000	12,108	12,169	12,229	12,291	12,352	12,414	12,476
2. PWA Water Demand	Pathum	Thani					
a. Domestic	130,567	134,938	139,308	143,679	148,049	152,420	156,790
b. Institutional	50,325	51,914	63,604	65,093	56,682	68,271	69,861
c. Commercial	31,164	32,224	33,283	34,343	35,402	36,462	37,521
d. Industrial	123,963	127,671	131,380	135,088	138,796	142,505	146,213
sub-total	336,019	346,747	357,474	368,202	378,930	389,657	400,385
e. Water Loss	84,005	86,687	89,369	92,050	94,732	97,414	100,096
Total Demand	420,024	433,433	446,843	460,252	473,662	487,072	500,481
Groundwater Rate %	25	27	29	31	33	35	37
Groundwater Volume	106,006	117,027	129,584	142,678	156,308	170,475	185,178
Surface Water Rate %	75	73	71	69	67	65	63
Water Loss Rate %	25	25	25	25	25	25	25
Total Population	1,234,258	1,268,385	1,302,512	1,336,639	1,370,766	1,404,893	1,439,020
3. Industrial Estates (9 Estates)							
Groundwater Demand	166,092	166,922	167,757	168,696	169,439	170,285	171,137
4. Groundwater Demand (DMR + PWA +DOH + ARD)							
a. Domestic	546,766	555,896	565,027	574,157	583,287	592,418	601,548
b. Institutional	102,614	104,328	106,041	107,766	109,468	111,182	112,896
c. Commercial	70,452	71,628	72,805	73,981	75,157	76,334	77,510
d. Industrial	811,726	825,280	838,836	852,390	865,945	879,499	893,054
Sub-Total	1,531,558	1,557,133	1,582,708	1,608,283	1,633,858	1,659,433	1,685,008
Groundwater Total	2,415,893	2,462,716	2,513,930	2,484,919	2,531,111	2,582,330	2,634,090
Surface Water Total	7,367,238	7,465,197	7,606,886	7,828,805	7,910,209	8,050,690	8,190,634
Total	9,783,131	9,927,914	10,120,817	10,313,724	10,441,320	10,633,021	10,824,724

Source : M W A, P W A, I E A T, D M R

Table 5.2.2 PWA WATER SUPPLY DATA

Description	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
1) Total Water Production (1000 m3)	1099.9	1597.5	2155.3	2238.6	2236.3	2281.2	3421.5	5420.1	8266.5	10231.7	13834.7
Increase %	21.1	31.1	25.9	3.7	-0.1	2.0	33.5	36.9	34.4	19.2	26.0
2) Total Water Comsumption Water Sales (1000 m3)	523.7	869.0	1107.2	1151.2	1277.9	1441.7	2333.5	3941.3	5332.1	7886.4	8453.6
Increase %	23.5	39.7	21.5	3.8	9.9	11.4	38.2	40.8	26.1	32.4	6.7
3) Water Loss (1000 m3)	576.2	728.5	1048.1	1087.4	958.4	839.5	1088	1478.8	2934.4	2345.3	5381.1
Water Sales Ratio %	47.6	54.4	51.4	51.4	57.1	63.2	68.2	72.7	64.5	77.1	61.1
4) Total Customers	1229	2181	2475	2741	3180	5019	5901	7120	13179	14867	22037
Increase %	31.2	43.6	11.9	9.7	13.8	36.6	14.9	17.1	46.0	11.4	32.5
5) Population in Service Area (1000 persons)	357.8	366.8	384.7	402.0	415.2	435.4	441.9	452.7	465.9	480.4	493.7
Increase %	2.6	2.5	4.7	4.3	3.2	4.6	1.5	2.4	2.8	3.0	2.7
6) Water Supply Ratio %	2.1	2.5	3.5	4.2	5.7	10.2	11.5	12.2	12.8	13.5	15.8
7) Service Area km2	30	36	45	50	80	140	161	172	180	205	228
8) Water Use Ratio Lit./Person/Day	66.8	90.9	78.9	65.4	51.8	31.1	44.0	68.4	85.7	116.6	103.9
9) Groundwater Supply Ratio %	100	100	100	100	100	100	100	100	100	100	100

Table 5.3.1 INDUSTRIAL ESTATES WATER CONSUMPTION DATA

Industrial Name	1989	1990	1991	1992	1993	1994
1) Bangchan Industrial	Estate					
Groundwater Use m3/day	6,850	7,000	7,000	7,000	7,000	7,000
Groundwater Use m3/year	2,000,200	2,044,000	2,044,000	2,044,000	2,044,000	2,044,000
Number of Wells	4	4	4	4	4	6
Number of Factories	73	74	74	74	74	74
2) Lat Krabang Industrial	Estate					
Groundwater Use m3/day	9,000	9,900	11,600	15,300	16,700	17,100
Groundwater Use m3/year	2,656,500	2,898,000	3,346,500	4,485,000	4,884,000	5,007,600
Number of Wells	10	10	10	10	10	10
Number of Factories	77	84	97	130	139	147
3) Bangplee Industrial	Estate					
Groundwater Use m3/day	4,000	4,200	4,800	5,400	6,500	6,900
Groundwater Use m3/year	1,164,400	1,235,400	1,405,800	1,576,800	1,604,600	1,723,300
Number of Wells	4	4	3	3	3	3
Number of Factories	82	87	99	112	113	121
4) Bangpoo Industrial	Estate					
Groundwater Use m3/day	15,200	17,600	21,000	26,500	27,000	27,500
Groundwater Use m3/year	4,438,400	6,139,200	6,132,000	7,738,000	7,870,200	8,044,200
Number of Wells	19	19	19	19	19	19
Number of Factories	152	176	210	270	270	275
5) Samut Sakhon Industrial	Estate					
Groundwater Use m3/day	-	-	-	370	1,900	2,300
Groundwater Use m3/year	-	-	-	109,150	564,000	684,000
Number of Wells	-	-	-	15	15	15
Number of Factories	-	-	-	6	12	18
6) Hi-Tech Industrial	Estate					
Groundwater Use m3/day	-	-	-	1,900	2,000	2,100
Groundwater Use m3/year	-	-	-	660,000	564,000	613,200
Number of Wells	-	-	-	3	3	3
Number of Factories	-	-	-	9	11	11
7) Bang Pain Industrial	Estate					
Groundwater Use m3/day	-	-	-	400	500	700
Groundwater Use m3/year	-	-	-	116,800	146,000	204,400
Number of Wells	-	-	-	9	9	9
Number of Factories	-	-	-	5	15	19
8) Navanakhon Co., LTD						
Groundwater Use m3/day	24,400	24,600	24,800	25,000	25,200	25,100
Groundwater Use m3/year	7,126,000	7,163,200	7,244,600	7,326,000	7,358,400	7,340,200
Number of Wells	9	9	9	9	9	9
Number of Factories	176	176	178	180	180	180
9) Bang Kadi Industrial	Park					
Groundwater Use m3/day	-	-	2,400	3,600	3,800	4,000
Groundwater Use m3/year	-	-	700,800	1,062,000	1,109,600	1,168,000
Surface Water Use m3/day	-	-	6,500	8,400	7,200	8,200
Number of Wells			2	2	2	2
Number of Factories	-	-	20	30	35	40
Total of wells	46	46	47	74	74	76
Total of Factories	560	597	678	815	849	885
Total of Groundwater Consumption m3/day	59,450	63,200	71,600	85,470	89,600	91,700

Source : I E A T

Table 5.3.2 INDUSTRIAL ESTATES WATER DEMAND PROJECTION

Industrial Name	1995	1997	1999	2000	2010	2017
1) Bangchan Industrial Estate						
Groundwater Use m3/day	7,000	7,150	7,150	7,200	7,250	7,300
Groundwater Use m3/year	2,044,000	2,087,800	2,087,800	2,102,400	2,117,000	2,131,600
Number of Wells	6	6	6	8	8	8
Number of Factories	75	75	75	75	75	75
Capacity of Factories	75	75	75	75	75	75
2) Lat Krabang Industrial Estate						
Groundwater Use m3/day	18,000	19,251	20,796	21,628	23,767	23,767
Groundwater Use m3/year	5,378,600	5,621,400	6,072,500	6,315,400	6,940,000	6,940,000
Number of Wells	10	10	10	10	12	15
Number of Factories	155	162	175	182	200	200
Capacity of Factories	200	200	200	200	200	200
3) Bangplee Industrial Estate						
Groundwater Use m3/day	6,000	6,150	6,250	6,250	6,250	6,250
Groundwater Use m3/year	1,781,200	1,795,800	1,825,000	1,825,000	1,825,000	1,825,000
Number of Wells	4	4	4	5	5	5
Number of Factories	122	123	125	125	125	125
Capacity of Factories	125	125	125	125	125	125
4) Bangpoo Industrial Estate						
Groundwater Use m3/day	30,160	30,986	32,055	33,123	35,260	36,329
Groundwater Use m3/year	8,892,000	9,048,000	9,360,000	9,672,000	10,296,000	10,608,000
Number of Wells	19	19	19	19	19	19
Number of Factories	285	290	300	310	330	340
Capacity of Factories	340	340	340	340	340	340
5) Samut Sakhon Industrial Estate						
Groundwater Use m3/day	5,620	7,288	10,411	11,973	14,966	16,267
Groundwater Use m3/year	1,710,000	2,128,000	3,040,000	3,496,000	4,370,000	4,750,000
Number of Wells	15	15	15	15	15	15
Number of Factories	45	56	80	92	115	125
Capacity of Factories	125	125	125	125	125	125
6) Hi-Tech Industrial Estate						
Groundwater Use m3/day	1,863	2,521	4,164	4,603	5,479	5,479
Groundwater Use m3/year	544,000	736,000	1,216,000	1,344,000	1,600,000	1,600,000
Number of Wells	3	3	3	3	3	3
Number of Factories	17	23	38	42	50	60
Capacity of Factories	70	70	70	70	70	70
7) Bang Pain Industrial Estate						
Groundwater Use m3/day	2,003	2,564	3,205	3,366	5,209	6,411
Groundwater Use m3/year	585,000	748,800	936,000	982,800	1,521,000	1,872,000
Number of Wells	9	9	9	9	12	15
Number of Factories	25	32	40	42	65	80
Capacity of Factories	100	100	100	100	100	100
8) Navanakhon Co., LTD						
Groundwater Use m3/day	25,507	25,507	25,925	26,204	26,483	26,483
Groundwater Use m3/year	7,448,100	7,448,100	7,570,200	7,651,600	7,733,000	7,733,000
Number of Wells	9	9	9	9	9	9
Number of Factories	183	183	186	188	190	190
Capacity of Factories	190	190	190	190	190	190
9) Bang Kadi Industrial Park						
Groundwater Use m3/day	4,100	4,100	4,100	4,150	4,200	4,300
Groundwater Use m3/year	1,197,200	1,197,200	1,197,200	1,211,800	1,226,400	1,255,600
Number of Wells	2	2	2	2	2	2
Number of Factories	40	40	40	40	40	40
Capacity of Factories	40	40	40	40	40	40
Total of wells	77	77	77	80	85	91
Total of Factories	947	984	1,059	1,096	1,190	1,225
Total Groundwater Consumption m3/day	100,244	105,517	114,057	118,497	128,864	132,586

Table 5.4.1 TOTAL GROUNDWATER PUMPAGE DATA IN THE STUDY AREA

Year	Well Number	Domestic m3/day	Institut- ional m3/day	Commercial m3/day	Industrial m3/day	Total m3/day
1982	7,416	545,588	105,592	75,255	694,171	1,420,606
1983	7,753	582,671	112,795	77,841	732,370	1,505,677
1984	8,050	519,399	105,138	73,826	734,099	1,432,462
1985	8,387	586,323	117,672	77,930	788,660	1,570,585
1986	8,700	557,888	116,081	76,779	800,032	1,550,780
1987	8,958	573,630	118,827	77,335	825,429	1,595,221
1988	9,171	590,460	118,968	78,617	860,033	1,648,078
1989	7,793	559,207	104,446	74,414	909,531	1,647,598
1990	4,621	393,018	66,326	47,385	757,397	1,264,126
1991	4,764	456,479	71,653	52,374	793,918	1,374,424
1992	4,486	470,740	57,783	53,698	768,851	1,351,072

Source : DMR, PWD, MWA, PWA, DOH, ARD, IEAT

Groundwater Pumpage Data (Registered at D M R)

Year	Well Number	Domestic m3/day	Institut- ional m3/day	Commercial m3/day	Industrial m3/day	Total m3/day
1980	6,517	207,990	54,028	51,639	500,060	813,717
1981	7,019	225,632	64,298	57,547	531,595	879,072
1982	7,155	227,897	67,068	58,133	566,862	919,960
1983	7,450	243,126	73,158	60,225	601,722	978,231
1984	7,763	262,454	80,875	63,043	649,574	1,055,946
1985	8,022	272,132	88,700	65,054	687,070	1,112,956
1986	8,312	287,265	95,180	67,490	718,665	1,168,600
1987	8,540	302,556	98,995	68,472	746,938	1,216,961
1988	8,743	326,836	100,695	70,496	785,297	1,283,324
1989	7,323	294,128	87,751	66,994	799,997	1,248,870
1990	4,149	177,575	58,944	44,104	672,051	952,674
1991	4,262	210,591	61,509	47,866	691,986	1,011,952
1992	3,916	205,388	46,686	48,766	650,089	950,929

Source : DMR

Table 5.4.2 ECONOMIC GROWTH TREND

Year	Groth Rate (%) GDP	Manufacturing Industry	Trade Million B Export	Import
1971	4.96	11.07	17,275	26,794
1972	4.07	13.24	22,491	30,875
1973	9.86	15.74	32,226	42,184
1974	4.35	6.18	49,799	64,044
1975	4.85	5.80	45,007	66,835
1976	9.38	15.32	60,797	72,877
1977	9.90	14.30	71,198	94,177
1978	10.44	8.73	83,065	108,899
1979	5.31	8.27	108,179	146,161
1980	4.78	2.88	133,197	188,686
1981	6.33	6.29	153,001	216,746
1982	4.06	2.54	169,728	196,616
1983	7.25	8.40	146,472	236,606
1984	7.13	6.76	175,237	245,155
1985	3.51	-0.61	193,366	251,169
1986	4.90	9.60	233,383	241,358
1987	9.50	13.60	299,853	334,209
1988	13.23	12.40	403,570	513,114
1989	12.20	14.90	515,745	656,428
1990	10.00	13.70	589,813	844,448
1991	7.50	10.00	725,630	958,832
1995	6.90	9.50	1,141,000	1,508,740
2000	7.30	10.00	1,277,920	1,659,614
2005	8.10	11.00	1,431,270	1,825,575
2010	8.70	10.00	1,603,023	2,008,133
2017	9.00	10.50	1,795,386	2,208,946

Source : NESDB

Table 5.4.3 TREND OF GROUNDWATER DEMAND

Year	PWD m3/day	DOH m3/day	ARD m3/day	DMR m3/day	Total m3/day	Total m3/day
1982	48,995	0	0	919,960	968,955	
1983	60,925	0	0	978,231	1,039,156	
1984	76,350	0	0	1,055,946	1,132,296	
1985	97,260	64	0	1,112,956	1,210,280	
1986	106,620	64	0	1,168,600	1,275,284	
1987	115,700	64	0	1,216,851	1,332,615	
1988	118,930	64	0	1,283,324	1,402,318	
1989	123,265	64	0	1,248,870	1,372,199	
1990	124,645	104	64	952,674	1,077,487	
1991	131,045	136	73	1,011,952	1,143,206	
1992	132,355	136	118	950,929	1,083,538	
1993	134,340	136	119	961,852	1,096,447	
1994	136,355	137	121	972,775	1,109,388	
1995	138,401	137	122	983,698	1,122,358	1,122,358
1996	140,477	138	122	994,621	1,135,358	1,147,933
1997	142,584	138	122	1,005,544	1,148,388	1,173,508
1998	144,723	138	123	1,016,467	1,161,451	1,199,083
1999	146,894	138	123	1,027,390	1,174,545	1,224,658
2000	149,097	139	123	1,038,313	1,187,672	1,250,233
2001	151,333	139	123	1,049,236	1,200,831	1,275,808
2002	153,603	140	123	1,060,159	1,214,025	1,301,383
2003	155,907	140	124	1,071,082	1,227,253	1,326,958
2004	158,246	140	125	1,082,005	1,240,516	1,352,533
2005	160,620	140	125	1,092,928	1,253,813	1,378,108
2006	163,029	142	125	1,103,851	1,267,147	1,403,683
2007	165,474	142	125	1,114,774	1,280,515	1,429,258
2008	167,957	142	125	1,125,697	1,293,921	1,454,833
2009	170,476	142	126	1,136,620	1,307,364	1,480,408
2010	173,033	142	126	1,147,543	1,320,844	1,505,983
2011	175,629	142	128	1,158,466	1,334,365	1,531,558
2012	178,263	142	128	1,169,389	1,347,922	1,557,133
2013	180,937	142	128	1,180,312	1,361,519	1,582,708
2014	183,651	143	128	1,191,235	1,375,157	1,608,283
2015	186,406	143	128	1,202,158	1,388,835	1,633,858
2016	189,202	143	130	1,213,081	1,402,556	1,659,433
2017	192,040	143	130	1,224,004	1,416,317	1,685,008

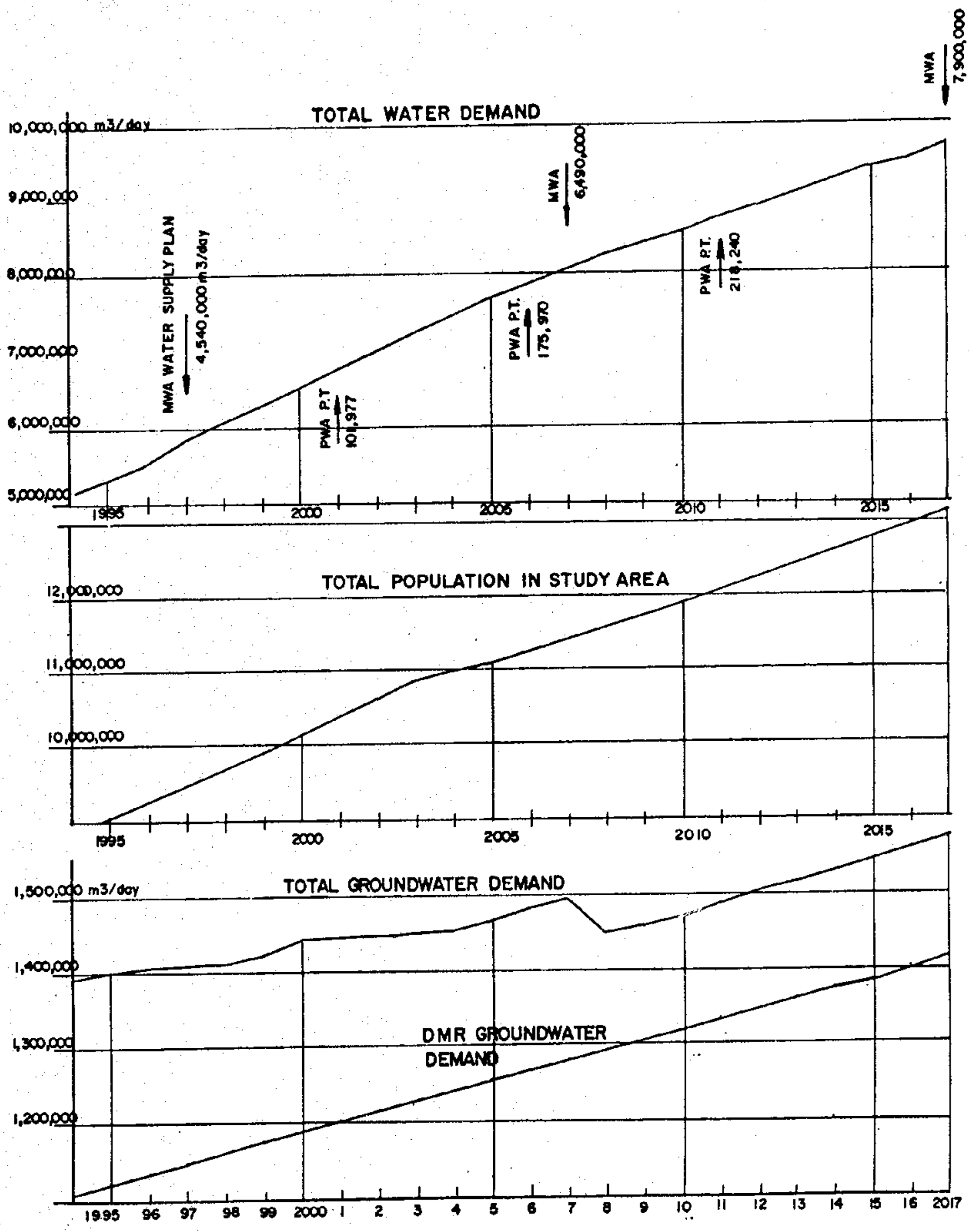

Figure 5.1.1	WATER DEMAND PROJECTION
THE STUDY ON MANAGEMENT OF GROUNDWATER AND LAND SUBSIDENCE IN THE BANGKOK METROPOLITAN AREA AND ITS VICINITY	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	KOKUSAI KOGYO CO., LTD.

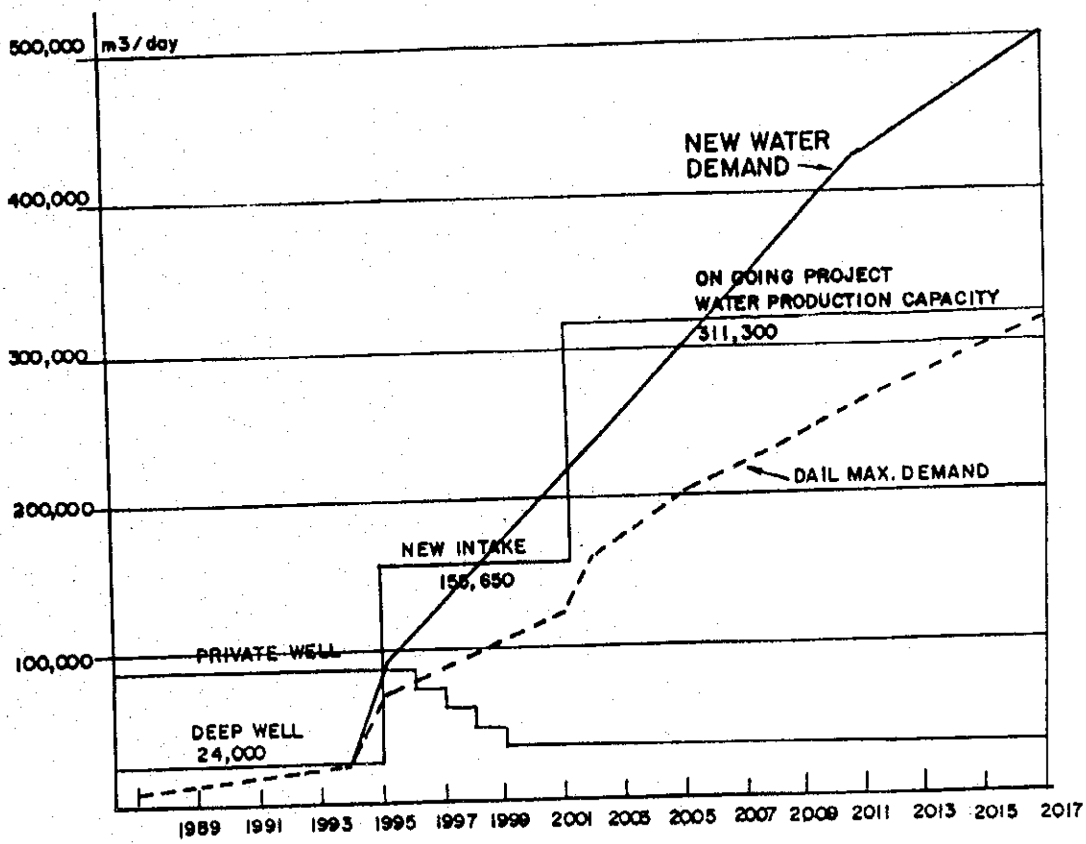

Figure 5.2.1	PWA PATHUM THANI WATER DEMAND PROJECTION
THE STUDY ON MANAGEMENT OF GROUNDWATER AND LAND SUBSIDENCE IN THE BANGKOK METROPOLITAN AREA AND ITS VICINITY	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	KOKUSAI KOGYO CO., LTD.

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CHAPTER 6 GROUNDWATER LEVELS AND LAND SUBSIDENCE

6.1 Records of JICA Monitoring Stations

Groundwater levels and land subsidence have been monitored at the JICA monitoring stations (see Figure 6.1.1) since July 1993. The monitoring equipment installed at the stations have been recording data at an interval of one (1) hour.

6.1.1 Site-A (Lat Krabang)

The groundwater levels and land subsidence at eight (8) monitoring wells have been recorded. The groundwater levels and land subsidence for a period from July 1993 to November 1994 are summarized in Figure 6.1.2 and Figure 6.1.3, respectively. The groundwater level and land subsidence at each monitoring well are shown from Figure 6.1.4 to Figure 6.1.11.

(1) Groundwater level

The deepest groundwater level was observed at A-6 well (depth = 145m, Nakhon Luang aquifer) at the station, ranging from -55.5m to -61.0m in elevation. The groundwater levels of A-5 well (depth = 215m, Nonthaburi aquifer) and A-7 well (depth = 108m, Phra Pradaeng aquifer) were ranging from -42.0m to -52.0m. The groundwater levels of A-2 well (depth = 437m, Phayathai aquifer), A-3 well (depth = 360m, Sam Khok aquifer), A-4 well (depth = 302m, Sam Khok aquifer), and A-8 well (depth = 48m, Bangkok aquifer) were located between -16.0m and -26.0m in elevation. The groundwater level of A-1 well (depth = 574m, Pak Nam aquifer) has gradually recovered, then the present groundwater level becomes higher than the ground elevation.

The features of groundwater level change at each monitoring well are as follows:

<u>A-1 well [depth = 574m, Pak Nam aquifer] (refer to Figure 6.1.4)</u>

The groundwater level was not able to be measured during the well construction time due to low permeability of the aquifer. The water level was located below -6m in elevation in July 1993. But the level has been recovered and reached sea level in March 1994. Now the well is a artesian well, but the amount of flow is very small.

<u>A-2 well [depth = 437m, Phayathai aquifer] (refer to Figure 6.1.5)</u>

The groundwater level was gradually declined from -19.6m to -21.0m for the past year. Strange water level fluctuations were recorded from September to October 1993 due to the sensor failure. A new sensor was installed in December 1993.

<u>A-3 well [depth = 360m, Sam Khok aquifer] (refer to Figure 6.1.6)</u>

The groundwater level has dropped from -19.9m to -21.5m in elevation for the period from July 1993 to July 1994. The level was almost stable from August to September 1993, but it started to decline from October 1993. The groundwater level was not recorded from December 1993 to May 1994 due to the sensor failure.

<u>A-4 well [depth = 302m, Sam Khok aquifer] (refer to Figure 6.1.7)</u>

The pattern of groundwater level changes is similar to that of A-3 well. The groundwater level has declined from -24.4m to -26.4m in elevation for the past one (1) year. The monitoring was interrupted due to the sensor failure.

A-5 well [depth = 215m, Nonthaburi aquifer] (refer to Figure 6.1.8)
The groundwater level has dropped from -41.7m to -51.8m for the one (1) year. The water level may be affected by nearby wells because typical drawdown curves and recovery curves can be observed. The level was recovered about 4m in early March 1994, but it dropped again from mid-March 1994.

A-6 well [depth = 145m, Nakhon Luang aquifer] (refer to Figure 6.1.9)
The aquifer is intensively used in the area so that the water level shows the deepest in the station. Daily fluctuations and recoveries on holidays are clearly observed. The level ranged between -55.5m and -57.5m from July 1993 to February 1994, but it has dropped from -57.5m to -61.0 m since March 1994 to July 1994.

A-7 well [depth = 108m, Phra Pradaeng aquifer] (refer to Figure 6.1.10)
The groundwater levels was located around -49.5m in elevation from September to December 1993. Then the water level was recovered about 2m by the end of February 1994. But the water level started to drop by stepwise pattern from March 1994. The water level in July 1994 is 1.5m lower than that in July 1993. The records were disturbed in March 1994 due to the sensor error.

A-8 well [depth = 48m, Bangkok aquifer] (refer to Figure 6.1.11)
The well shows the annual fluctuation of groundwater level was only 0.5m. But clear water level rise from -16.3m to -15.9m was observed from September to October 1993. The water level was remaining at higher level until November 1993, but it declined from December 1993 to March 1994. The recession curve has almost become a flat line from March to July 1994. This annual fluctuation pattern may correspond to the occurrence of rainfall and changes in surface water level over the year.

(2) Land subsidence
The maximum land subsidence of 83 mm, which is the compression between the ground surface and the bottom of a well, was recorded at A-2 well for the period from July 1993 to November 1994. Even though the subsidence rates may be affected by each monitoring well's condition, it can be seen that the subsidence rate increases with increasing well depth.

If it is assumed that the total compression between the ground surface and the depth at 574m is 75.0 mm as measured at A-1 well, the compression between the ground surface and the depth at 48m, that is the total compression of Bangkok Clay and Bangkok aquifer, contributes 45% of the total compression. Similarly the compression between 48m depth and 145m depth, that approximately belongs to Phra Pradaeng aquifer and Nakhon Luang aquifer, occupies 37% of the total compression. The subsiding rate at each well has decreased since March 1994. This phenomenon may correspond to the stop of groundwater level drop in the Bangkok aquifer, which was monitored at A-8 well.

Figure 6.1.12 shows the relation between the compression and piezometric head using the monitoring record at A-8 well and A-6 well. The upper graph clearly shows the cyclic compression process at A-8 well from July 1993 to November 1994. When the piezometric level of Bangkok aquifer declines from -15.90 masl to -16.36 masl, the compression increases from 6 mm to 25 mm. During the period of water level's recovery, the compression rate becomes gentle, but rebound does not occur. The apparent volume compressibility can be obtained from the graph, drawing a straight line as shown in the graph. The obtained value is 8.38E-03 cm^2/kgf.

The lower graph in Figure 6.1.12 also shows the linear relation between the piezometric head of A-6 well and the compression at depths from 108m to 145m during the declining of piezometric level. The obtained apparent volume compressibility is 4.22E-04 cm^2/kgf.

It is noted that apparent volume compressibility obtained from monitoring records shows smaller values compared with the values obtained by consolidation tests. Because the apparent volume compressibility uses the thickness including sandy layers. However, the apparent volume compressibility is useful to examine consolidation properties, and to prepare input data for land subsidence simulation models.

(3) Elevation of benchmarks

Benchmarks in the monitoring station were measured by the Study Team on 05 July 1993 and 20 July 1994. An existing benchmark of DMR36 at station No. 41 was used as a starting benchmark for both leveling surveys. Besides these surveys, the DMR Surveying Division has conducted leveling survey on 26 November 1993.

The results of leveling survey are summarized in Table 6.1.1. It is noted that the elevation of benchmarks in July 1994 were computed by using the same elevation value of DMR36 benchmark in 1993, because the latest elevation of DMR36 is not yet known. Therefore, the data can be used to know the relative difference between the starting benchmark and the benchmarks in the station so far. The absolute elevation of each benchmark should be recalculated after examining the movement of the starting benchmark. Further, it is needed to check the surveying route, origin, and date of measurement of the DMR leveling survey to compare the results with those of the Study Team.

(4) Pore water pressure

Pore water pressures in shallow clayey layers have been monitored in the station every one (1) week. The sensors were set at depths of 5m, 10m, 15, 25m, and 34m. The changes in pore water pressure at each measuring point are shown in Figure 6.1.13. The changes over time were small. The pore water pressures in the Bangkok Soft Clay (5m, 10m, and 15m) are almost equal to the ideal hydrostatic pressure in which the groundwater level is assumed to be 0m in elevation. On the other hand, the pore water pressures at depths of 25m and 34m are about 1.5 kgf/cm^2 smaller than the ideal hydrostatic pressures at the same depth (Figure 6.1.14).

6.1.2 Site-B (AIT)

The groundwater levels and land subsidence at five (5) monitoring wells have been recorded. The groundwater levels and land subsidence for the past one (1) year are summarized in Figure 6.1.15 and Figure 6.1.16, respectively. The groundwater level and land subsidence at each monitoring well are shown from Figure 6.1.17 to Figure 6.1.21.

(1) Groundwater level

The deepest groundwater level was observed at B-1 well (depth = 272m, Nonthaburi aquifer), ranging from -34.5m to -37.5m in elevation. The groundwater levels at B-2 well (depth = 192m, Nakhon Luang aquifer) and B-3 well (depth = 153m, Nakhon Luang aquifer) were located between -29.0m to -33.0m. B-4 well (depth = 94m, Phra Pradaeng aquifer) had a groundwater level ranging from -22.2m to -23.9m. The shallowest groundwater level was observed at B-5 well (depth = 47m, Bangkok aquifer) ranging from -3.8m to -4.5m in elevation.

The features of groundwater level change at each monitoring well are as follows:

B-1 well [depth = 272m, Nonthaburi aquifer] (refer to Figure 6.1.17)
Groundwater level has dropped from -35.0m to -36.9m for a period from July 1993 to July 1994. The highest water level was recorded in August 1993, then the water level declined gradually with gentle fluctuation. The rate of water level drop increased from January to March 1994. The level was slightly recovered in mid-April, but it dropped again from May to July 1994. The minor daily fluctuation can be observed at a cycle of two (2) weeks, which may be influenced by the tidal movement.

B-2 well [depth = 192m, Nakhon Luang aquifer] (refer to Figure 6.1.18)
The groundwater level has dropped from -30.8m to -32.3m for the past one (1) year. Daily and weekly fluctuations are clearly observed from the records. The water level was recovered about 2.0m and 1.0m during the holidays in January 1994 and April 1994, respectively.

B-3 well [depth = 153m, Nakhon Luang aquifer] (refer to Figure 6.1.19)
The pattern of water level changes is similar to that of B-2 well. Daily fluctuation is about 0.5m. The water level was clearly recovers during the holidays in January 1994 and April 1994. The base line of the hydrograph declined from -30.0m in January 1994 to -32.0m in July 1994.

B-4 well [depth = 94m, Phra Pradaeng aquifer] (refer to Figure 6.1.20)
The annual groundwater level drop was 0.9m from July 1993 to July 1994. The level ranged from -22.7m to -23.0m in elevation from July 1993 to January 1994, then it started to decline from -22.7m to -23.8m from January to July 1994.

B-5 well [depth = 47m, Bangkok aquifer] (refer to Figure 6.1.21)
The pattern of groundwater level change is similar to that of A-8 well at Site-A. The water level was recovered from -4.2m to -3.8m for the period from August 1993 to October 1993. Then it dropped continuously from November 1993 to March 1994. The lowest water level of -4.46m was recorded in May 1994. The level has been recovered since June 1994. This pattern may correspond to the occurrence of rainfall and surface water level changes.

(2) Land subsidence

The records show the station was rebounded about 1.0 mm from July 1993 to early November 1993. But all monitoring wells indicated subsidence from mid-November 1993 when the water level of Bangkok aquifer started to drop as monitored in B-5 well. The curves of land subsidence graphs and the hydrograph of B-5 well show good agreements. There was a slight rebound in March 1994, but the maximum subsidence at B-2 well reached 11.0 mm in May 1994. After this, all monitoring wells shows rebound until July 1994.

(3) Elevation of benchmarks

Benchmarks in the monitoring station were measured by the Study Team on 13 July 1993 and 28 June 1994. An existing benchmark of BM25 at CI station No. 25 was used as a starting benchmark for both leveling surveys. Besides these surveys, the DMR Surveying Division has conducted leveling survey on 26 November 1993.

The results of leveling survey are summarized in Table 6.1.2. It is noted that the elevation of benchmarks in July 1993 and June 1994 were computed by using the same elevation value of BM25 benchmark measured on 12 October 1993, because the latest elevation of BM25 is not available yet. Therefore, the data can be used to know the relative difference between the starting benchmark and the benchmarks in the station so far. The absolute elevation of each benchmark should be recalculated after examining the movement of the starting benchmark. Further, it is needed to check the surveying route, origin, and date of measurement of the DMR leveling survey to compare the results with those of the Study Team.

6.1.3 Site-C (Samut Sakhon)

The groundwater levels and land subsidence at five (5) monitoring wells have been recorded. The groundwater levels and land subsidence for the past one (1) year are summarized in Figure 6.1.22 and Figure 6.1.23, respectively. The groundwater level and land subsidence at each monitoring well are shown from Figure 6.1.24 to Figure 6.1.28.

(1) Groundwater level

The deepest groundwater level was observed at C-2 well (depth = 212m, Nonthaburi aquifer), ranging from -57.5m to -71.5m in elevation. The groundwater levels at C-3 well (depth = 140m, Nakhon Luang aquifer) ranged from -43.0m to -55.0m. The water levels of C-2 well and C-3 well are highly affected by nearby production wells. C-1 well (depth = 320m, Sam Khok aquifer) had a water level ranging between -26.3m and -29.2m. The water levels of C-4 well (depth = 105m, Phra Pradaeng aquifer) and C-5 well (depth = 78m, Phra Pradaeng aquifer) ranged from -21.8m to -22.9m and -16.4m to -17.4m, respectively.

The features of groundwater level change at each monitoring well are as follows:

<u>C-1 well [depth = 320m, Sam Khok aquifer] (refer to Figure 6.1.24)</u>

Groundwater level has dropped from -27.3m to -29.2m for a period from July 1993 to July 1994. The highest water level of -26.3m was recorded in September 1993, then the water level declined to -28.0m for the period from September to December 1993. The water level from January to February 1994 was fluctuated between -27.3m and -27.8m, but it declined to -28.8m by April 1994. After the recovery during holidays in April, the level continued to drop until July 1994.

<u>C-2 well [depth = 212m, Nonthaburi aquifer] (refer to Figure 6.1.25)</u>

The water level changes were highly affected by nearby production wells. Daily fluctuation and weekly fluctuation were about 1m and 5m, respectively. During the holidays in January, February and April in 1994, the water level was recovered about 6m to 8m. The base line of the hydrograph was located -66.0m to -67.0m from July 1993 to March 1994, but steep drop of base line occurred from April to May 1994, then the base level reached -71.5m in July 1994.

<u>C-3 well [depth = 140m, Nakhon Luang aquifer] (refer to Figure 6.1.26)</u>

The groundwater level was also affected by nearby production wells so that the daily and weekly fluctuations as well as recovery on holidays can be clearly observed. The base line of the hydrograph was located between -49.0m and -55.0m in elevation. The decline of the base line from July 1993 to July 1994 was about 2.0m, which is smaller than that of C-2 well.

C-4 well [depth = 105m, Phra Pradaeng aquifer] (refer to Figure 6.1.27)
The groundwater level fluctuated within a range from -21.8m to -22.3m in elevation from July 1993 to April 1994. Then the level dropped sharply from mid-April and reached -22.8m in July 1994. The annual decline of the water level was 0.8m.

C-5 well [depth = 78m, Phra Pradaeng aquifer] (refer to Figure 6.1.28)
The water level had highly fluctuated in July and August 1993 due to local pumpage. But the fluctuation decreased with rising the water level from -17.3m to -16.5m during the said period. Then the level ranged between -16.4m and -16.8m from October 1993 to July 1994.

(2) Land subsidence
The measured land subsidence values in the station are larger than those in other stations because the filled up ground has not yet settled. The maximum compression was recorded at C-2 well as an annual compression of 126 mm. The subsidence curves in the station can be divided into two (2) types; one is the curves of deeper wells (C-1 well and C-2 well) which shows almost straight lines from October 1993 to July 1994, and the other is the curves of shallower wells (C-3 to C-5 wells) which shows the curves decreasing the compression rates during the said period. The true values of land subsidence should be recalculated by using the absolute elevations of benchmarks determined by leveling surveys. But the latest values of absolute elevations have not yet known.

(3) Elevation of benchmarks
Benchmarks in the monitoring station were measured by the Study Team on 05 August 1993 and 30 June 1994. An existing benchmark of DMR05 at station No. 48 was used as a starting benchmark for both leveling surveys. Besides these surveys, the DMR Surveying Division has conducted leveling survey on 09 November 1993.

The results of leveling survey are summarized in Table 6.1.3. It is noted that the elevation of benchmarks in August 1993 and June 1994 were computed by using the same elevation value of DMR05 benchmark measured on 08 July 1993, because the latest elevation of DMR25 is not available yet. Therefore, the data can be used to know the relative difference between the starting benchmark and the benchmarks in the station so far. The absolute elevation of each benchmark should be recalculated after examining the movement of the starting benchmark. Further, it is needed to check the surveying route, origin, and date of measurement of the DMR leveling survey to compare the results with those of the Study Team.

Table 6.1.1 Results of Leveling Survey at Site-A

Benchmark No.	ELEV. (m)	DATE (M/D/Y)	DONE BY:	ELEV. (m)	DATE (M/D/Y)	DONE BY:	ELEV. (m)	DATE (M/D/Y)	DONE BY:
DMR36	1.1292	07/02/93	DMR				1.1292	07/02/93	DMR
BM-A	0.58156	07/05/93	JICA	0.5813	11/26/93	DMR	0.59993	07/20/94	JICA
BM-B	0.57787	07/05/93	JICA	0.5781	11/26/93	DMR	0.59752	07/20/94	JICA
A-1/1	0.85032	07/05/93	JICA	0.8573	11/26/93	DMR	0.88623	07/20/94	JICA
A-1/2	0.95739	07/05/93	JICA	0.9643	11/26/93	DMR	0.99312	07/20/94	JICA
A-1/3	1.16268	07/05/93	JICA	1.1773	11/26/93	DMR	1.22650	07/20/94	JICA
A-1/4	1.48133	07/05/93	JICA	1.4793	11/26/93	DMR	1.49159	07/20/94	JICA
A-1/5	1.47864	07/05/93	JICA	1.4763	11/26/93	DMR	1.48626	07/20/94	JICA
A-2/1	0.84913	07/05/93	JICA	0.8553	11/26/93	DMR	0.88601	07/20/94	JICA
A-2/2	0.95879	07/05/93	JICA	0.9653	11/26/93	DMR	0.99569	07/20/94	JICA
A-2/3	1.15584	07/05/93	JICA	1.1713	11/26/93	DMR	1.22091	07/20/94	JICA
A-2/4	1.46131	07/05/93	JICA	1.4583	11/26/93	DMR	1.46522	07/20/94	JICA
A-2/5	1.45991	07/05/93	JICA	1.4563	11/26/93	DMR	1.46399	07/20/94	JICA
A-3/1	0.83227	07/05/93	JICA	0.8373	11/26/93	DMR	0.86769	07/20/94	JICA
A-3/2	0.93381	07/05/93	JICA	0.9393	11/26/93	DMR	0.97084	07/20/94	JICA
A-3/3	1.14117	07/05/93	JICA	1.1553	11/26/93	DMR	1.20671	07/20/94	JICA
A-3/4	1.46775	07/05/93	JICA	1.4663	11/26/93	DMR	1.47749	07/20/94	JICA
A-3/5	1.46585	07/05/93	JICA	1.4643	11/26/93	DMR	1.47498	07/20/94	JICA
A-4/1	0.85959	07/05/93	JICA	0.8653	11/26/93	DMR	0.89094	07/20/94	JICA
A-4/2	0.95194	07/05/93	JICA	0.9573	11/26/93	DMR	0.98524	07/20/94	JICA
A-4/3	1.17672	07/05/93	JICA	1.1913	11/26/93	DMR	1.24171	07/20/94	JICA
A-4/4	1.48198	07/05/93	JICA	1.4793	11/26/93	DMR	1.49534	07/20/94	JICA
A-4/5	1.47918	07/05/93	JICA	1.4783	11/26/93	DMR	1.49213	07/20/94	JICA
A-5/1	0.84981	07/05/93	JICA	0.8513	11/26/93	DMR	0.86880	07/20/94	JICA
A-5/2	0.95541	07/05/93	JICA	0.9623	11/26/93	DMR	0.98969	07/20/94	JICA
A-5/3	1.14934	07/05/93	JICA	1.1633	11/26/93	DMR	1.21079	07/20/94	JICA
A-5/4	1.46026	07/05/93	JICA	1.4573	11/26/93	DMR	1.46513	07/20/94	JICA
A-5/5	1.46090	07/05/93	JICA	1.4573	11/26/93	DMR	1.46651	07/20/94	JICA
A-6/1	0.83961	07/05/93	JICA	0.8413	11/26/93	DMR	0.86188	07/20/94	JICA
A-6/2	0.91638	07/05/93	JICA	0.9223	11/26/93	DMR	0.95049	07/20/94	JICA
A-6/3	1.12316	07/05/93	JICA	1.1343	11/26/93	DMR	1.17875	07/20/94	JICA
A-6/4	1.46939	07/05/93	JICA	1.4673	11/26/93	DMR	1.47889	07/20/94	JICA
A-6/5	1.46777	07/05/93	JICA	1.4663	11/26/93	DMR	1.47606	07/20/94	JICA
A-7/1	0.85074	07/05/93	JICA	0.8533	11/26/93	DMR	0.87481	07/20/94	JICA
A-7/2	0.95956	07/05/93	JICA	0.9643	11/26/93	DMR	0.98813	07/20/94	JICA
A-7/3	1.16313	07/05/93	JICA	1.1723	11/26/93	DMR	1.20737	07/20/94	JICA
A-7/4	1.46080	07/05/93	JICA	1.4593	11/26/93	DMR	1.46612	07/20/94	JICA
A-7/5	1.46375	07/05/93	JICA	1.4613	11/26/93	DMR	1.46798	07/20/94	JICA
A-8/1	0.83505	07/05/93	JICA	0.8353	11/26/93	DMR	0.86236	07/20/94	JICA
A-8/2	0.94036	07/05/93	JICA	0.9453	11/26/93	DMR	0.97228	07/20/94	JICA
A-8/3	1.14178	07/05/93	JICA	1.1473	11/26/93	DMR	1.17600	07/20/94	JICA
A-8/4	1.44987	07/05/93	JICA	1.4483	11/26/93	DMR	1.46028	07/20/94	JICA
A-8/5	1.45029	07/05/93	JICA	1.4483	11/26/93	DMR	1.46018	07/20/94	JICA

DMR36: Starting benchmark of leveling survey by JICA Study Team

Table 6.1.2 Results of Leveling Survey at Site-B

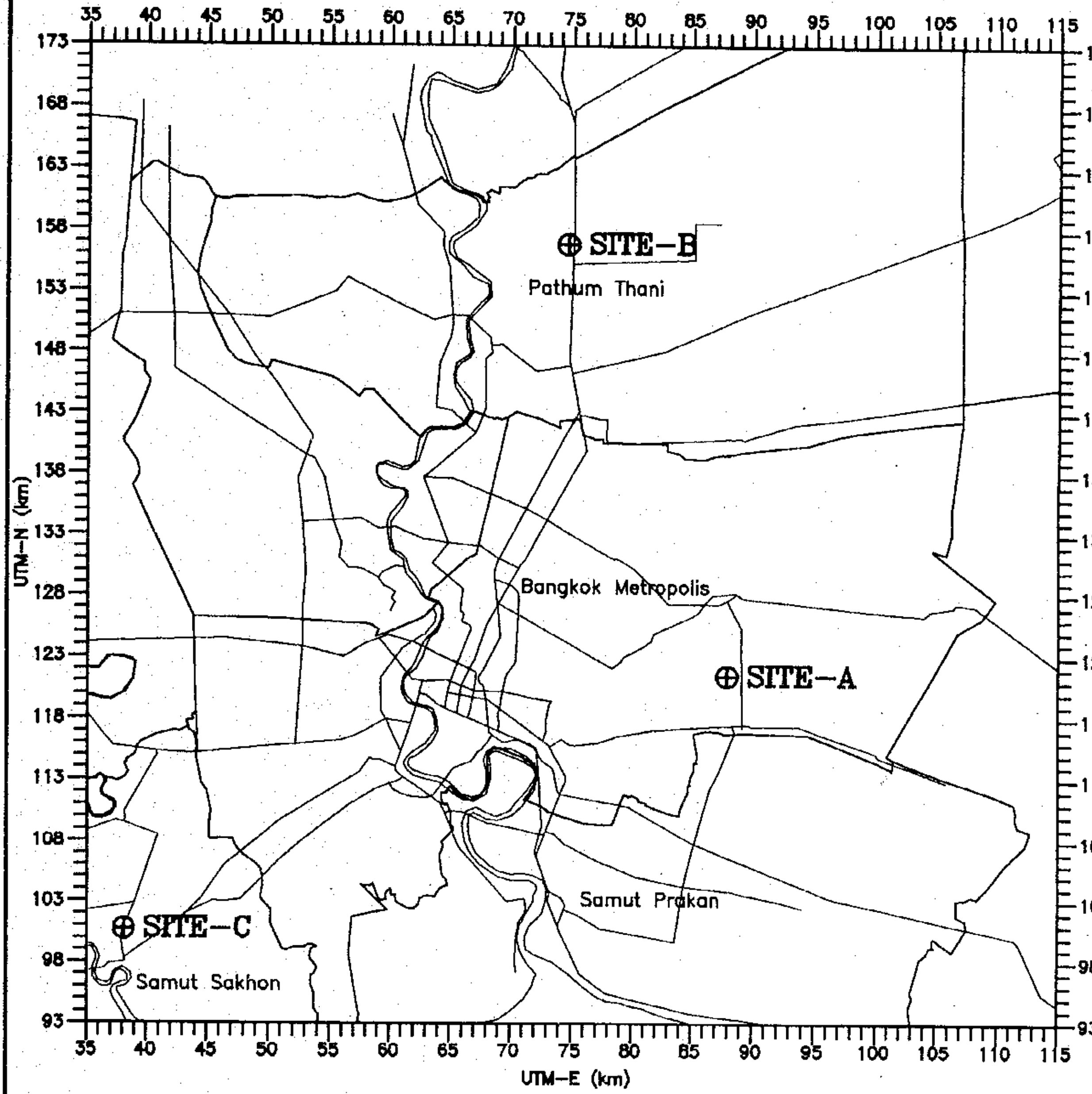
Benchmark No.	ELEV. (m)	DATE (M/D/Y)	DONE BY:	ELEV. (m)	DATE (M/D/Y)	DONE BY:	ELEV. (m)	DATE (M/D/Y)	DONE BY:
BM25	2.0107	10/12/93	DMR	2.0107	10/12/93	DMR	2.0107	10/12/93	DMR
BM-A	1.72057	07/13/93	JICA	1.7293	10/12/93	DMR	1.72778	06/28/94	JICA
BM-B	1.71828	07/13/93	JICA	1.7256	10/12/93	DMR	1.72251	06/28/94	JICA
B-1/1	2.01831	07/13/93	JICA	2.0227	11/26/93	DMR	2.02820	06/28/94	JICA
B-1/2	2.11431	07/13/93	JICA	2.1180	11/26/93	DMR	2.12393	06/28/94	JICA
B-1/3	2.36973	07/13/93	JICA	2.3732	11/26/93	DMR	2.38260	06/28/94	JICA
B-1/4	2.64157	07/13/93	JICA	2.6488	11/26/93	DMR	2.64839	06/28/94	JICA
B-1/5	2.64343	07/13/93	JICA	2.6460	11/26/93	DMR	2.65148	06/28/94	JICA
B-2/1	2.00745	07/13/93	JICA	2.0119	11/26/93	DMR	2.01497	06/28/94	JICA
B-2/2	2.11425	07/13/93	JICA	2.1187	11/26/93	DMR	2.12370	06/28/94	JICA
B-2/3	2.40343	07/13/93	JICA	2.4066	11/26/93	DMR	2.41459	06/28/94	JICA
B-2/4	2.63985	07/13/93	JICA	2.6447	11/26/93	DMR	2.64523	06/28/94	JICA
B-2/5	2.63718	07/13/93	JICA	2.6414	11/26/93	DMR	2.64187	06/28/94	JICA
B-3/1	2.01841	07/13/93	JICA	2.0227	11/26/93	DMR	2.02816	06/28/94	JICA
B-3/2	2.12518	07/13/93	JICA	2.1289	11/26/93	DMR	2.13485	06/28/94	JICA
B-3/3	2.34664	07/13/93	JICA	2.3501	11/26/93	DMR	2.35891	06/28/94	JICA
B-3/4	2.64924	07/13/93	JICA	2.6520	11/26/93	DMR	2.65496	06/28/94	JICA
B-3/5	2.64759	07/13/93	JICA	2.6539	11/26/93	DMR	2.65308	06/28/94	JICA
B-4/1	2.01173	07/13/93	JICA	2.0162	11/26/93	DMR	2.01889	06/28/94	JICA
B-4/2	2.11478	07/13/93	JICA	2.1186	11/26/93	DMR	2.12380	06/28/94	JICA
B-4/3	2.42119	07/13/93	JICA	2.4245	11/26/93	DMR	2.43101	06/28/94	JICA
B-4/4	2.64288	07/13/93	JICA	2.6479	11/26/93	DMR	2.64907	06/28/94	JICA
B-4/5	2.63624	07/13/93	JICA	2.6478	11/26/93	DMR	2.64220	06/28/94	JICA
B-5/1	2.00719	07/13/93	JICA	2.0122	11/26/93	DMR	2.01586	06/28/94	JICA
B-5/2	2.11250	07/13/93	JICA	2.1161	11/26/93	DMR	2.12161	06/28/94	JICA
B-5/3	2.36767	07/13/93	JICA	2.3709	11/26/93	DMR	2.37662	06/28/94	JICA
B-5/4	2.63958	07/13/93	JICA	2.6436	11/26/93	DMR	2.64566	06/28/94	JICA
B-5/5	2.63676	07/13/93	JICA	2.6448	11/26/93	DMR	2.64472	06/28/94	JICA

BM25: Starting benchmark of leveling survey by JICA Study Team

Table 6.1.3 Results of Leveling Survey at Site-C

Benchmark No.	ELEV. (m)	DATE (M/D/Y)	DONE BY:	ELEV. (m)	DATE (M/D/Y)	DONE BY:	ELEV. (m)	DATE (M/D/Y)	DONE BY:
DMR05	1.3878	07/08/93	DMR				1.3878	07/08/93	DMR
BM-A	2.53832	08/05/93	JICA	2.4900	10/06/93	DMR	2.43829	06/30/94	JICA
BM-B	2.54694	08/05/93	JICA	2.5022	11/07/93	DMR	2.45417	06/30/94	JICA
C-1/1	2.84698	08/05/93	JICA	2.8163	11/09/93	DMR	2.80848	06/30/94	JICA
C-1/2	2.96564	08/05/93	JICA	2.9613	11/09/93	DMR	2.96234	06/30/94	JICA
C-1/3	3.16964	08/05/93	JICA	3.1788	11/09/93	DMR	3.20103	06/30/94	JICA
C-1/4	3.46708	08/05/93	JICA	3.4328	11/09/93	DMR	3.39080	06/30/94	JICA
C-1/5	3.46557	08/05/93	JICA	3.4322	11/09/93	DMR	3.39158	06/30/94	JICA
C-2/1	2.85967	08/05/93	JICA	2.8515	11/07/93	DMR	2.84292	06/30/94	JICA
C-2/2	2.97925	08/05/93	JICA	2.9748	11/07/93	DMR	2.97134	06/30/94	JICA
C-2/3	3.17609	08/05/93	JICA	3.1832	11/07/93	DMR	3.19906	06/30/94	JICA
C-2/4	3.45212	08/05/93	JICA	3.4089	11/07/93	DMR	3.65850	06/30/94	JICA
C-2/5	3.45138	08/05/93	JICA	3.4114	11/07/93	DMR	3.36166	06/30/94	JICA
C-3/1	2.86717	08/05/93	JICA	2.8601	11/09/93	DMR	2.85301	06/30/94	JICA
C-3/2	2.98036	08/05/93	JICA	2.9774	11/09/93	DMR	2.97627	06/30/94	JICA
C-3/3	3.18142	08/05/93	JICA	3.1833	11/09/93	DMR	3.19000	06/30/94	JICA
C-3/4	3.47558	08/05/93	JICA	3.4341	11/09/93	DMR	3.38991	06/30/94	JICA
C-3/5	3.47147	08/05/93	JICA	3.4351	11/09/93	DMR	3.39011	06/30/94	JICA
C-4/1	2.85883	08/05/93	JICA	2.8568	11/09/93	DMR	2.85460	06/30/94	JICA
C-4/2	2.96245	08/05/93	JICA	2.9604	11/09/93	DMR	2.95896	06/30/94	JICA
C-4/3	3.16952	08/05/93	JICA	3.1695	11/09/93	DMR	3.17212	06/30/94	JICA
C-4/4	3.45456	08/05/93	JICA	3.4154	11/09/93	DMR	3.37447	06/30/94	JICA
C-4/5	3.45484	08/05/93	JICA	3.4170	11/09/93	DMR	3.37157	06/30/94	JICA
C-5/1	2.82772	08/05/93	JICA	2.7869	11/09/93	DMR	2.74106	06/30/94	JICA
C-5/2	2.95357	08/05/93	JICA	2.9521	11/09/93	DMR	2.95294	06/30/94	JICA
C-5/3	3.15912	08/05/93	JICA	3.1588	11/09/93	DMR	3.16135	06/30/94	JICA
C-5/4	3.46813	08/05/93	JICA	3.4285	11/09/93	DMR	3.37563	06/30/94	JICA
C-5/5	3.47029	08/05/93	JICA	3.4238	11/09/93	DMR	3.38178	06/30/94	JICA

DMR05: Starting benchmark of leveling survey by JICA Study Team



	UTM GRID	LONGITUDE	LATITUDE	LOCATION
SITE-A:	879215	100°44'17"	13°45'26"	ROM KLAO VILLAGE, NHA, LAT KRABANG
SITE-B:	746568	100°37'02"	14°04'41"	AIT CAMPUS, PATHUM THANI
SITE-C:	381007	100°16'35"	13°34'23"	RON RIAN WAT KLONG KRU, SAMUT SAKHON

Figure 6.1.1	LOCATION OF JICA MONITORING STATIONS
THE STUDY ON MANAGEMENT OF GROUNDWATER AND LAND SUBSIDENCE IN THE BANGKOK METROPOLITAN AREA AND ITS VICINITY	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	KOKUSAI KOGYO CO., LTD.

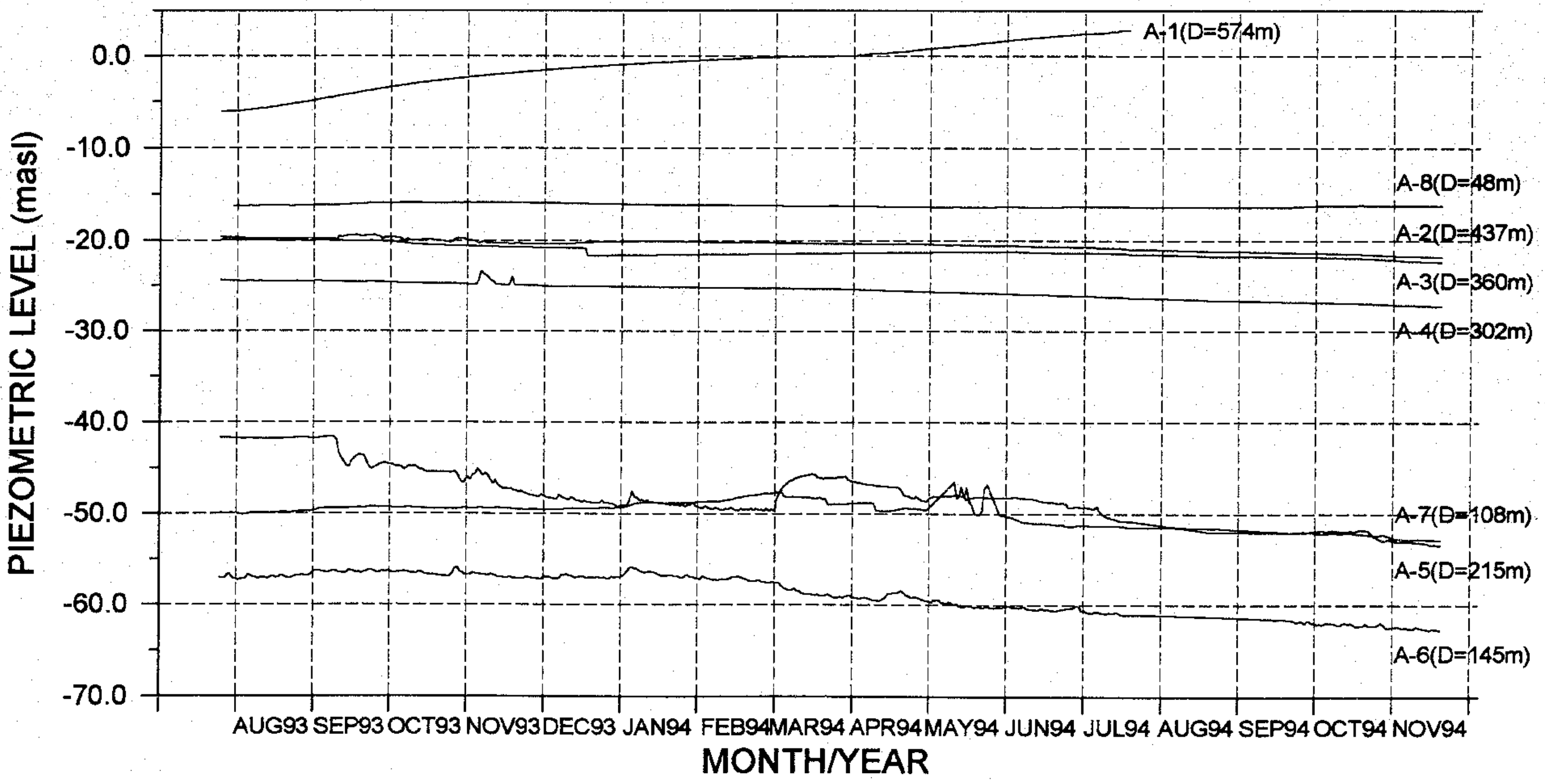


Figure 6.1.2	PIEZOMETRIC LEVELS MONITORED AT SITE-A
THE STUDY ON MANAGEMENT OF GROUNDWATER AND LAND SUBSIDENCE IN THE BANGKOK METROPOLITAN AREA AND ITS VICINITY	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	KOKUSAI KOGYO CO., LTD.

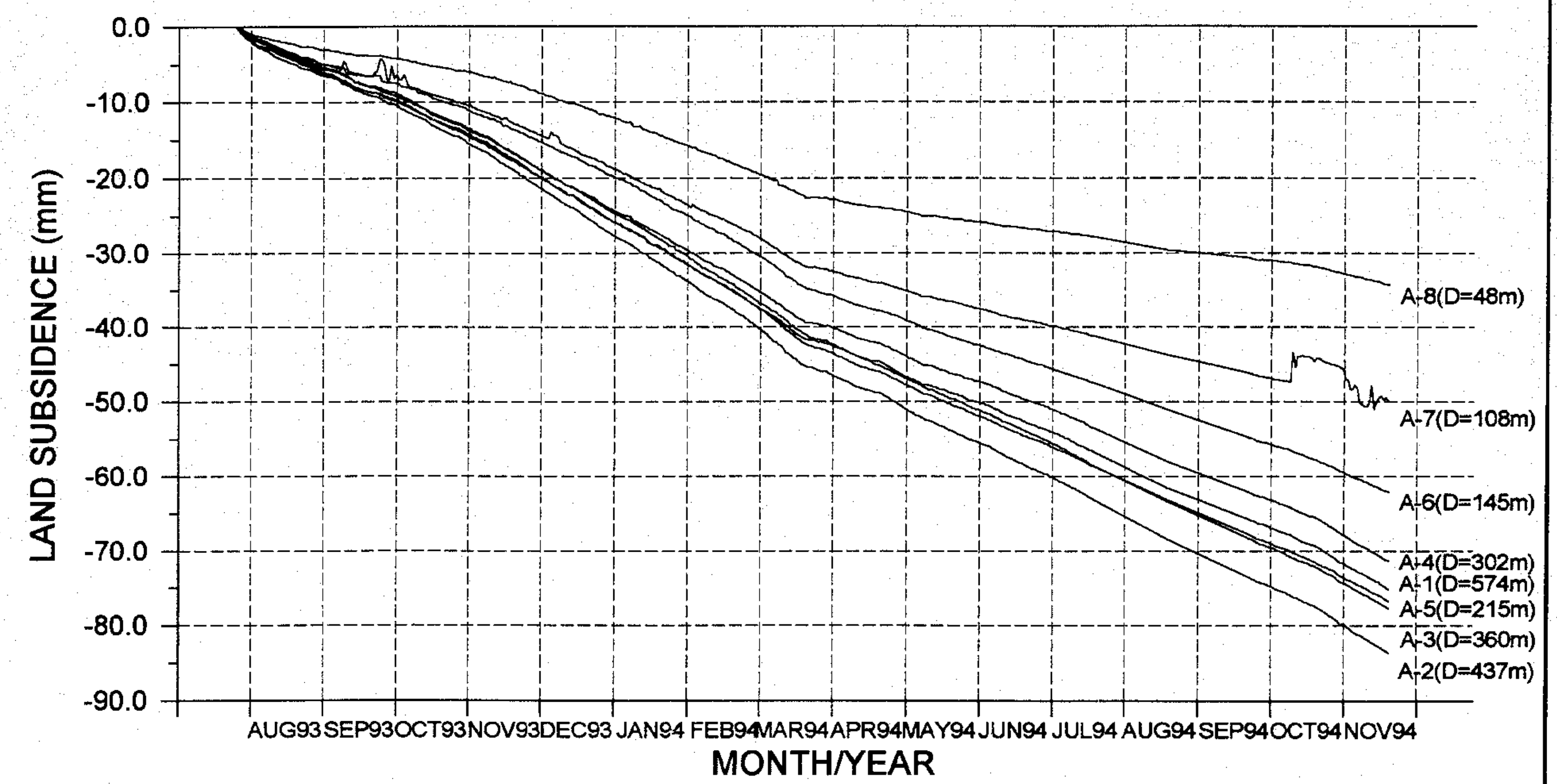
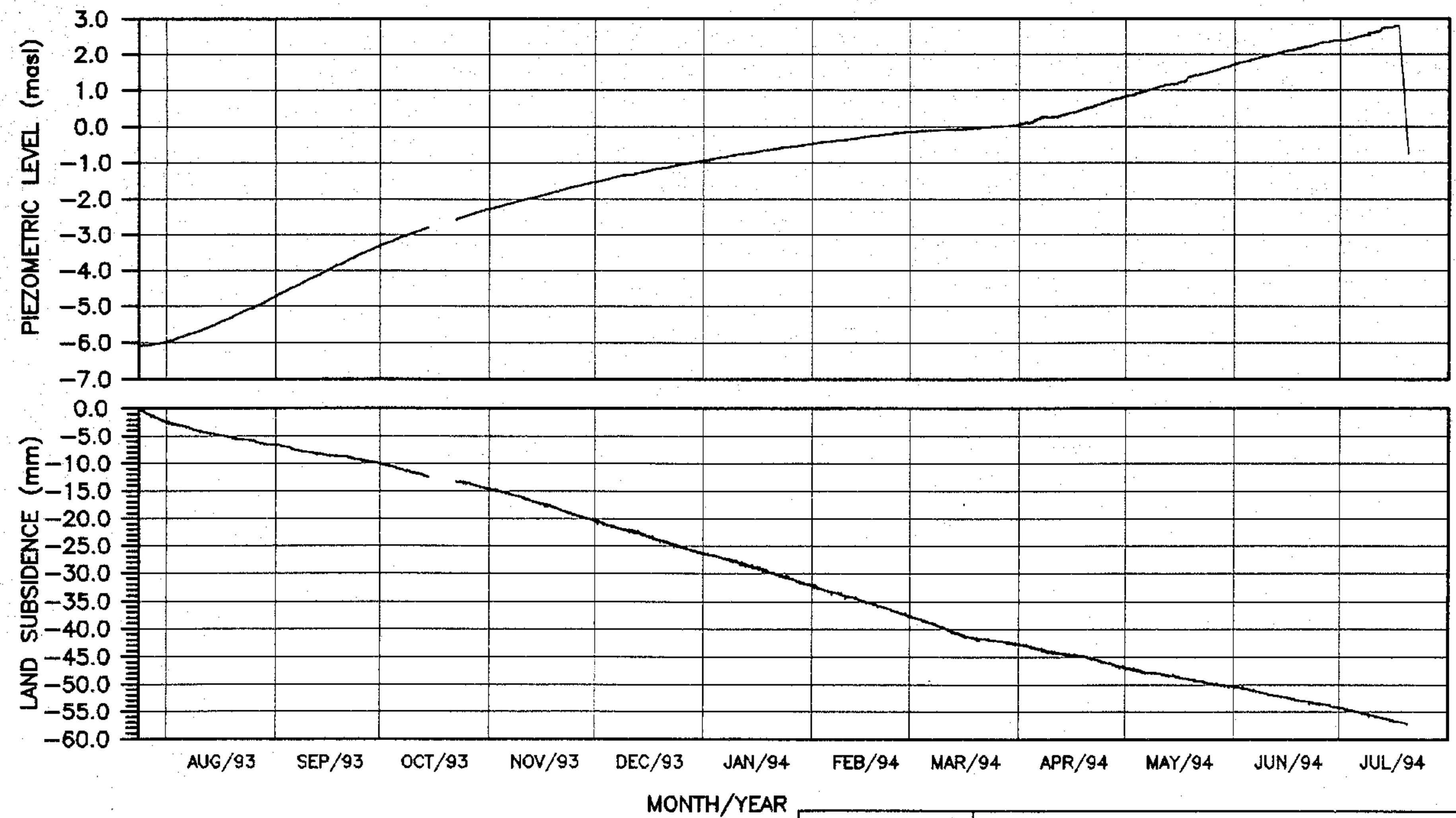


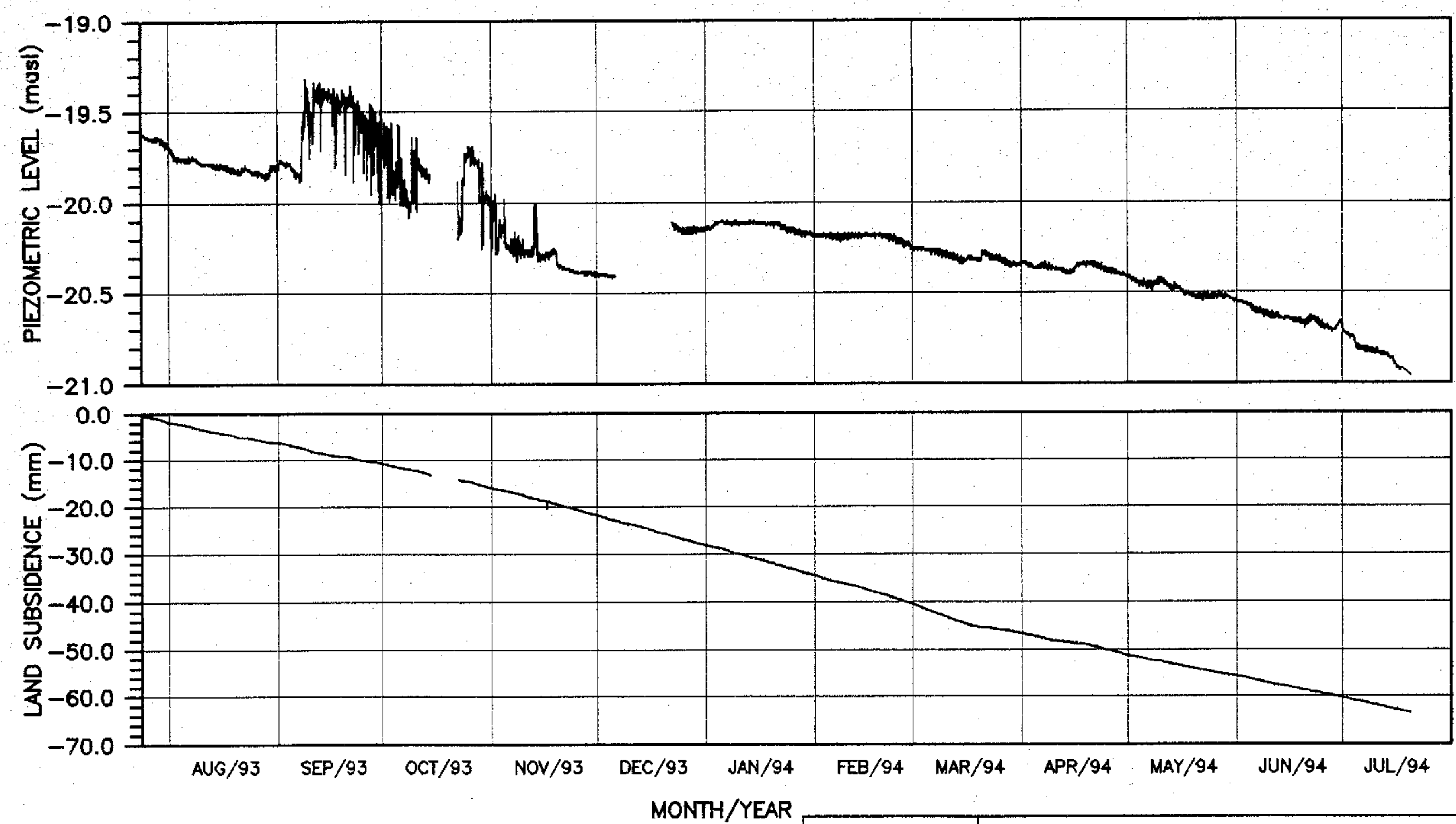
Figure 6.1.3	LAND SUBSIDENCE MONITORED AT SITE-A
THE STUDY ON MANAGEMENT OF GROUNDWATER AND LAND SUBSIDENCE IN THE BANGKOK METROPOLITAN AREA AND ITS VICINITY	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	KOKUSAI KOGYO CO., LTD.



WELL NO.: JICA A−1
LOCATION: LAT KRABANG
UTM GRID: 879215

WELL DEPTH: 574m
SCREEN DEPTH: 555.800−574.000m
SCREEN LENGTH: 16.50m
AQUIFER TAPPED: PAK NAM AQUIFER

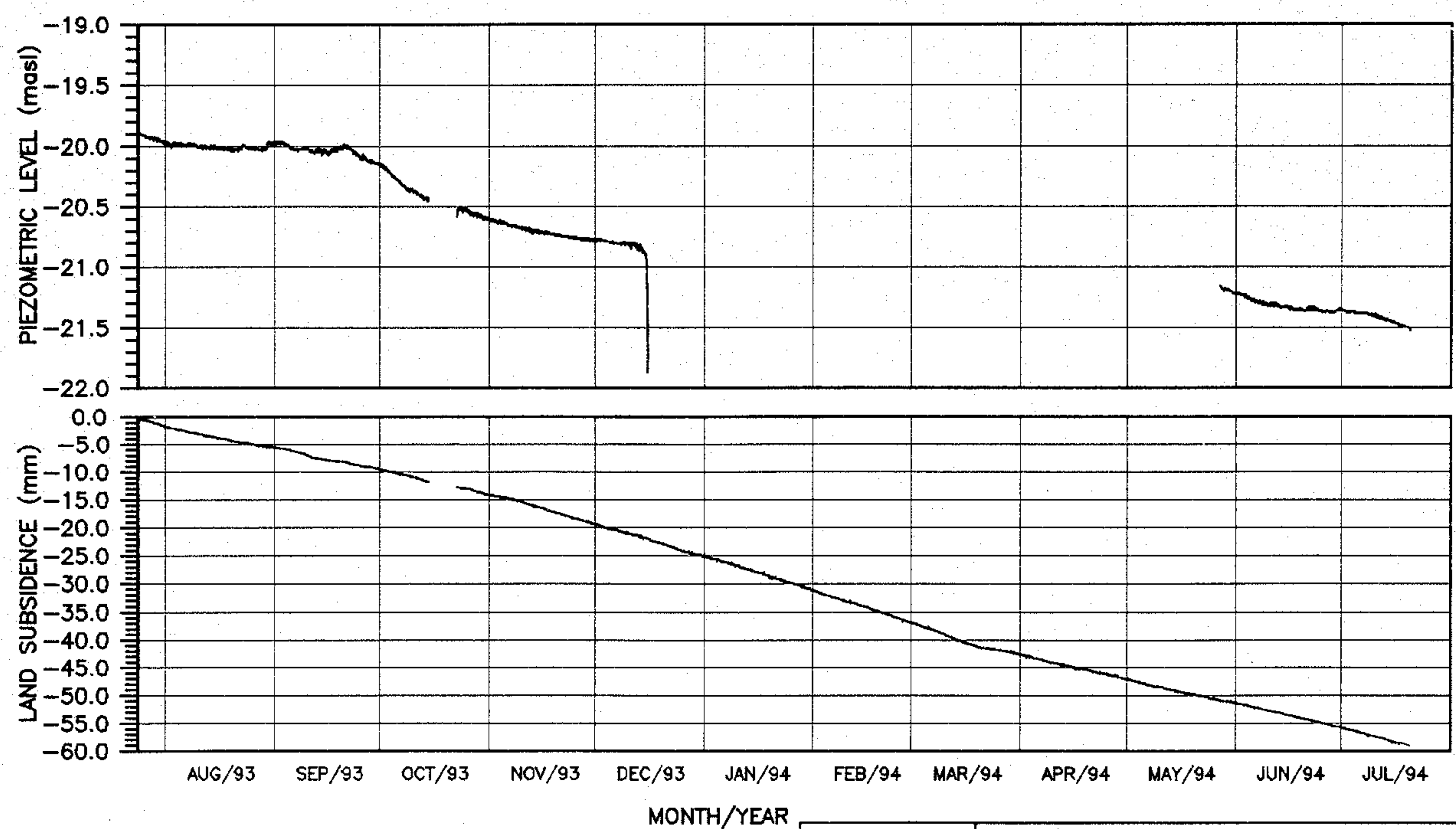
Figure 6.1.4	PIEZOMETRIC LEVEL AND LAND SUBSIDENCE AT JICA A−1 WELL
THE STUDY ON MANAGEMENT OF GROUNDWATER AND LAND SUBSIDENCE IN THE BANGKOK METROPOLITAN AREA AND ITS VICINITY	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	KOKUSAI KOGYO CO., LTD.



WELL NO.: JICA A-2
LOCATION: LAT KRABANG
UTM GRID: 879215

WELL DEPTH: 437m
SCREEN DEPTH: 428.190-436.495m
SCREEN LENGTH: 7.25m
AQUIFER TAPPED: PHAYATHAI AQUIFER

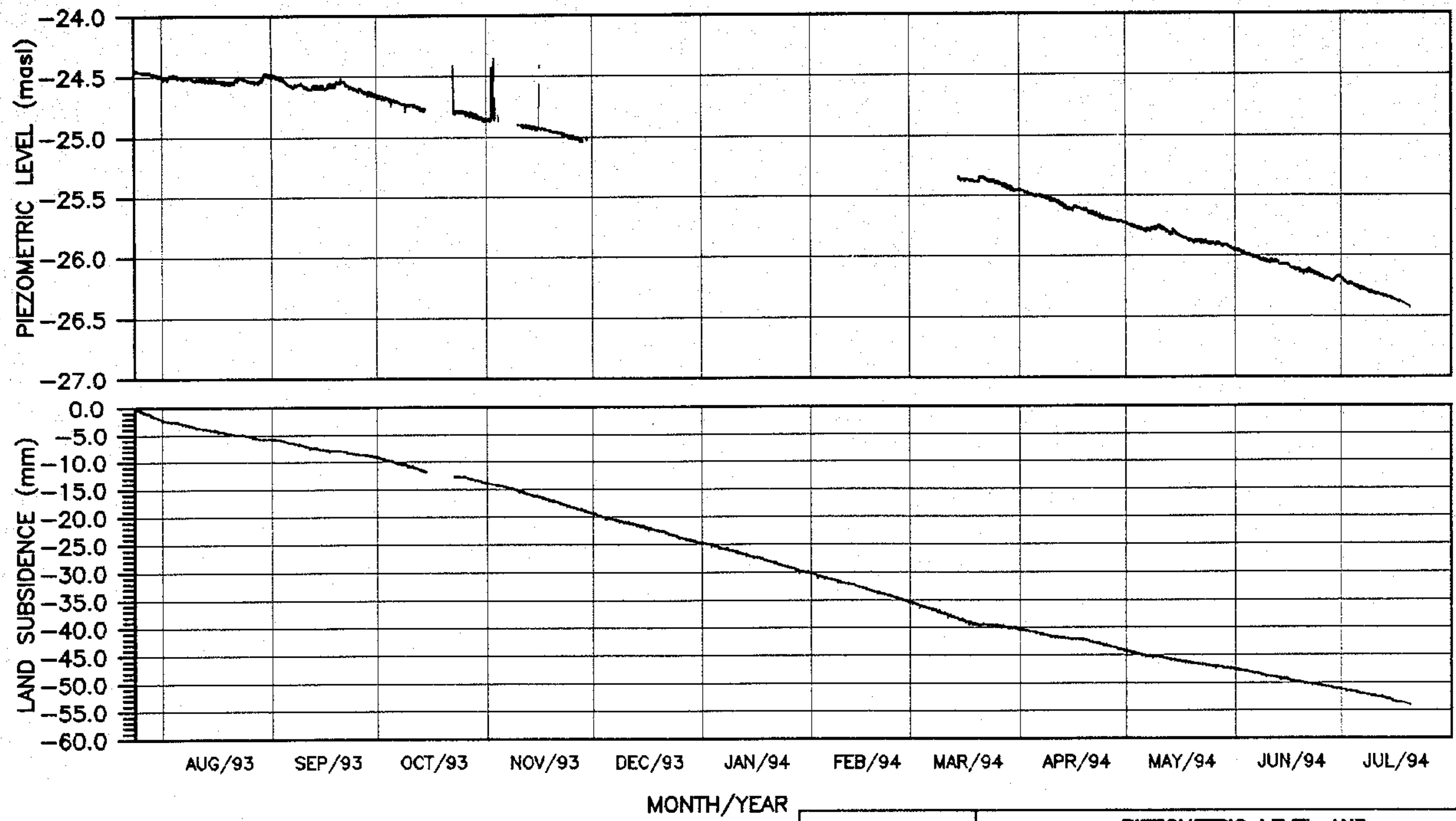
Figure 6.1.5	PIEZOMETRIC LEVEL AND LAND SUBSIDENCE AT JICA A-2 WELL
THE STUDY ON MANAGEMENT OF GROUNDWATER AND LAND SUBSIDENCE IN THE BANGKOK METROPOLITAN AREA AND ITS VICINITY	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	KOKUSAI KOGYO CO., LTD.



WELL NO.: JICA A-3
LOCATION: LAT KRABANG
UTM GRID: 879215

WELL DEPTH: 360m
SCREEN DEPTH: 351.190-359.495m
SCREEN LENGTH: 7.25m
AQUIFER TAPPED: SAM KHOK AQUIFER

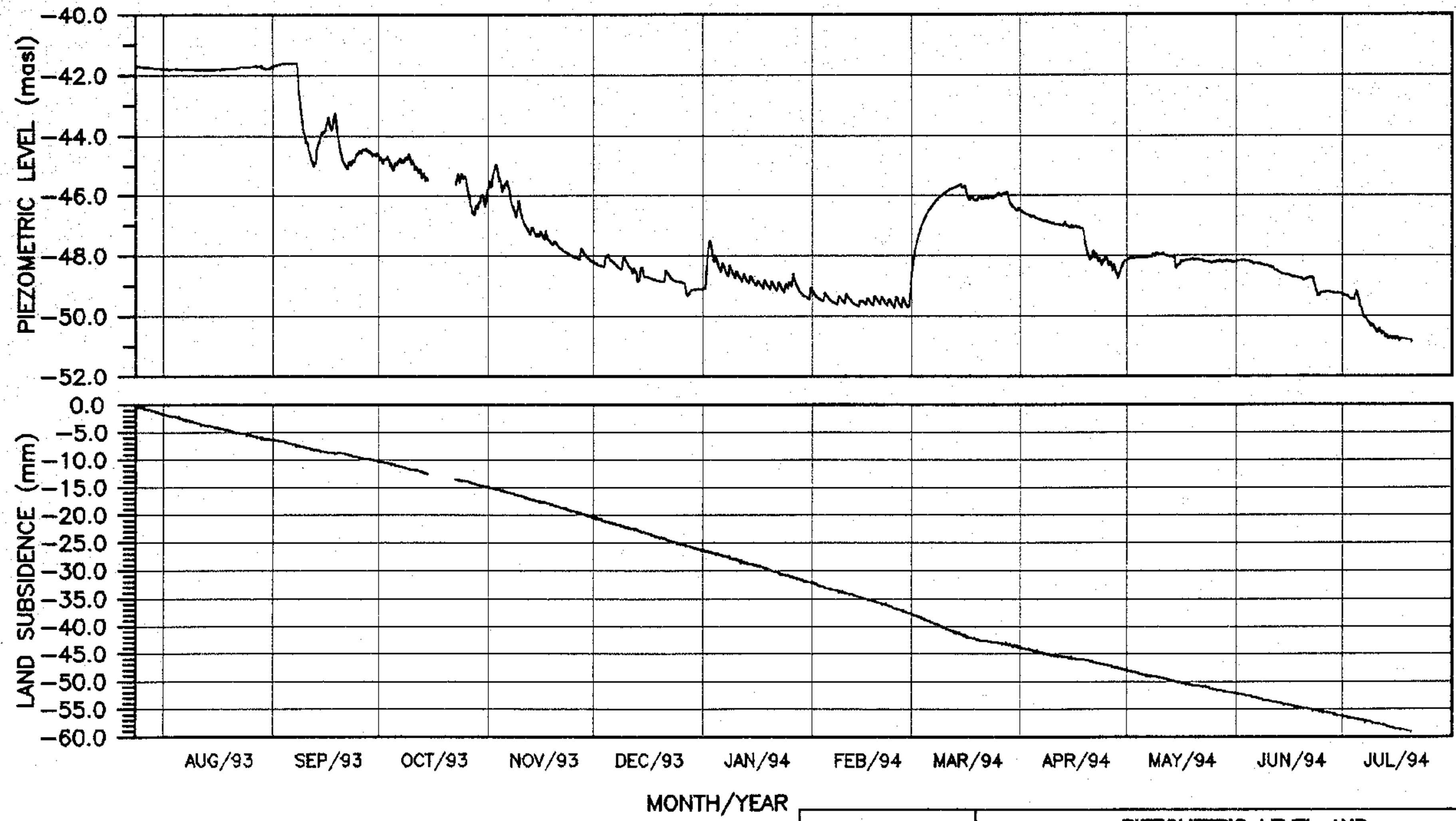
Figure 6.1.6	PIEZOMETRIC LEVEL AND LAND SUBSIDENCE AT JICA A-3 WELL
THE STUDY ON MANAGEMENT OF GROUNDWATER AND LAND SUBSIDENCE IN THE BANGKOK METROPOLITAN AREA AND ITS VICINITY	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	KOKUSAI KOGYO CO., LTD.



WELL NO.: JICA A-4
LOCATION: LAT KRABANG
UTM GRID: 879215

WELL DEPTH: 302m
SCREEN DEPTH: 293.190-301.495m
SCREEN LENGTH: 7.25m
AQUIFER TAPPED: SAM KHOK AQUIFER

Figure 6.1.7	PIEZOMETRIC LEVEL AND LAND SUBSIDENCE AT JICA A-4 WELL
THE STUDY ON MANAGEMENT OF GROUNDWATER AND LAND SUBSIDENCE IN THE BANGKOK METROPOLITAN AREA AND ITS VICINITY	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	KOKUSAI KOGYO CO., LTD.



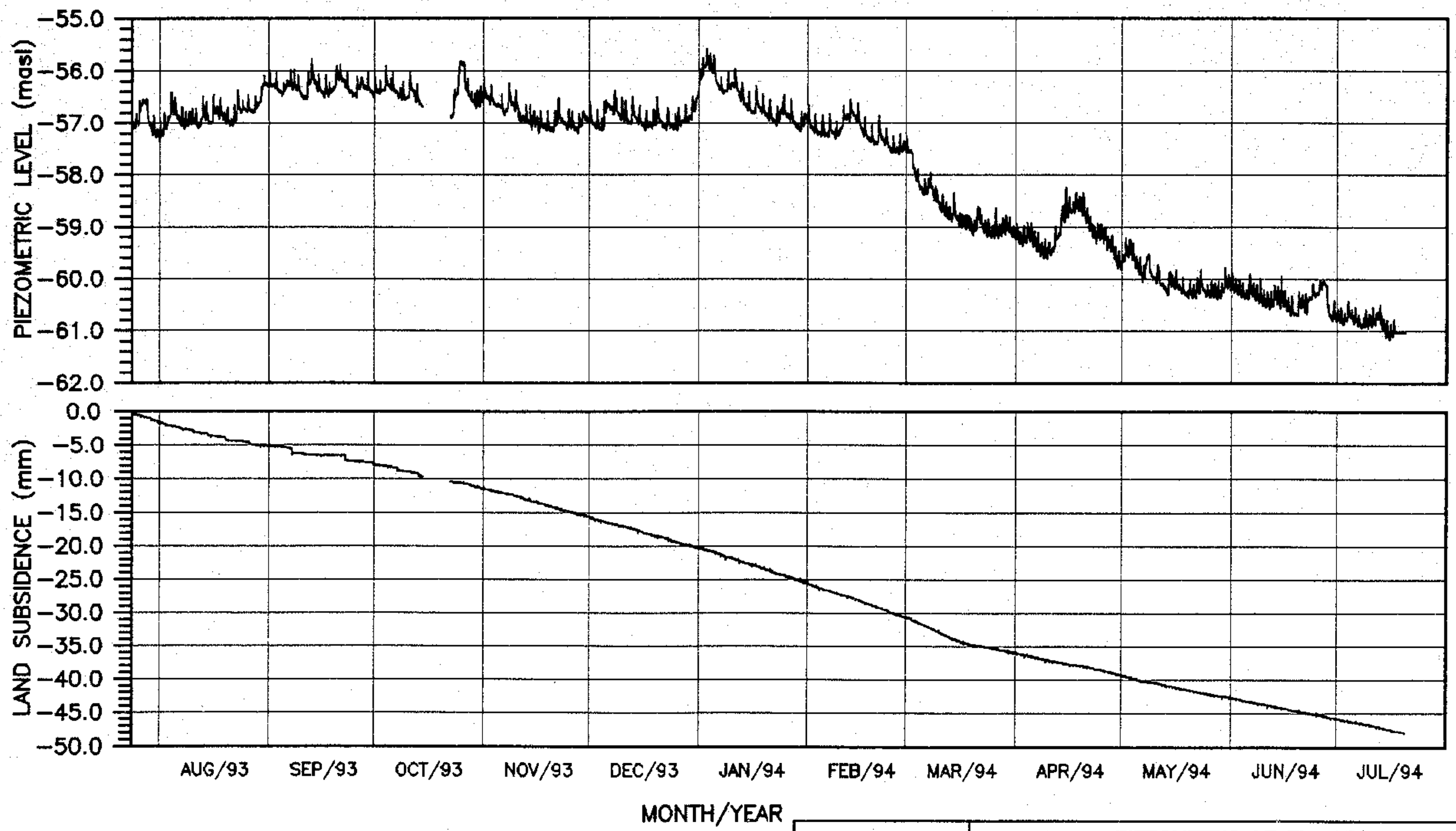
WELL NO.: JICA A-5
LOCATION: LAT KRABANG
UTM GRID: 879215

WELL DEPTH: 215m
SCREEN DEPTH: 206.190-214.495m
SCREEN LENGTH: 7.25m
AQUIFER TAPPED: NONTHABURI AQUIFER

Figure 6.1.8 PIEZOMETRIC LEVEL AND LAND SUBSIDENCE AT JICA A-5 WELL

THE STUDY ON MANAGEMENT OF GROUNDWATER AND LAND SUBSIDENCE IN THE BANGKOK METROPOLITAN AREA AND ITS VICINITY

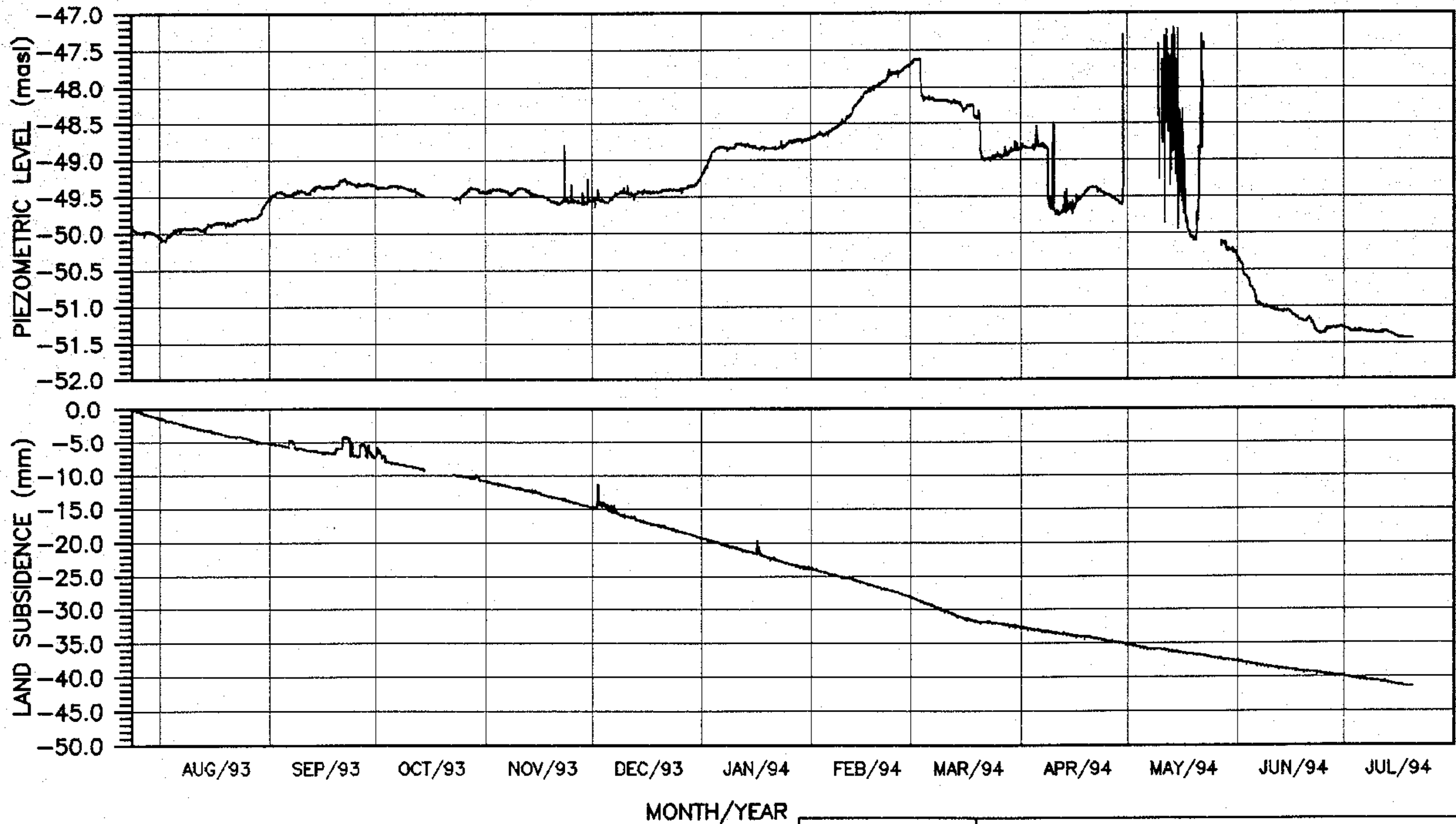
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA) | KOKUSAI KOGYO CO., LTD.



WELL NO.: JICA A-6
LOCATION: LAT KRABANG
UTM GRID: 879215

WELL DEPTH: 145m
SCREEN DEPTH: 136.190-144.495m
SCREEN LENGTH: 7.25m
AQUIFER TAPPED: NAKHON LUANG AQUIFER

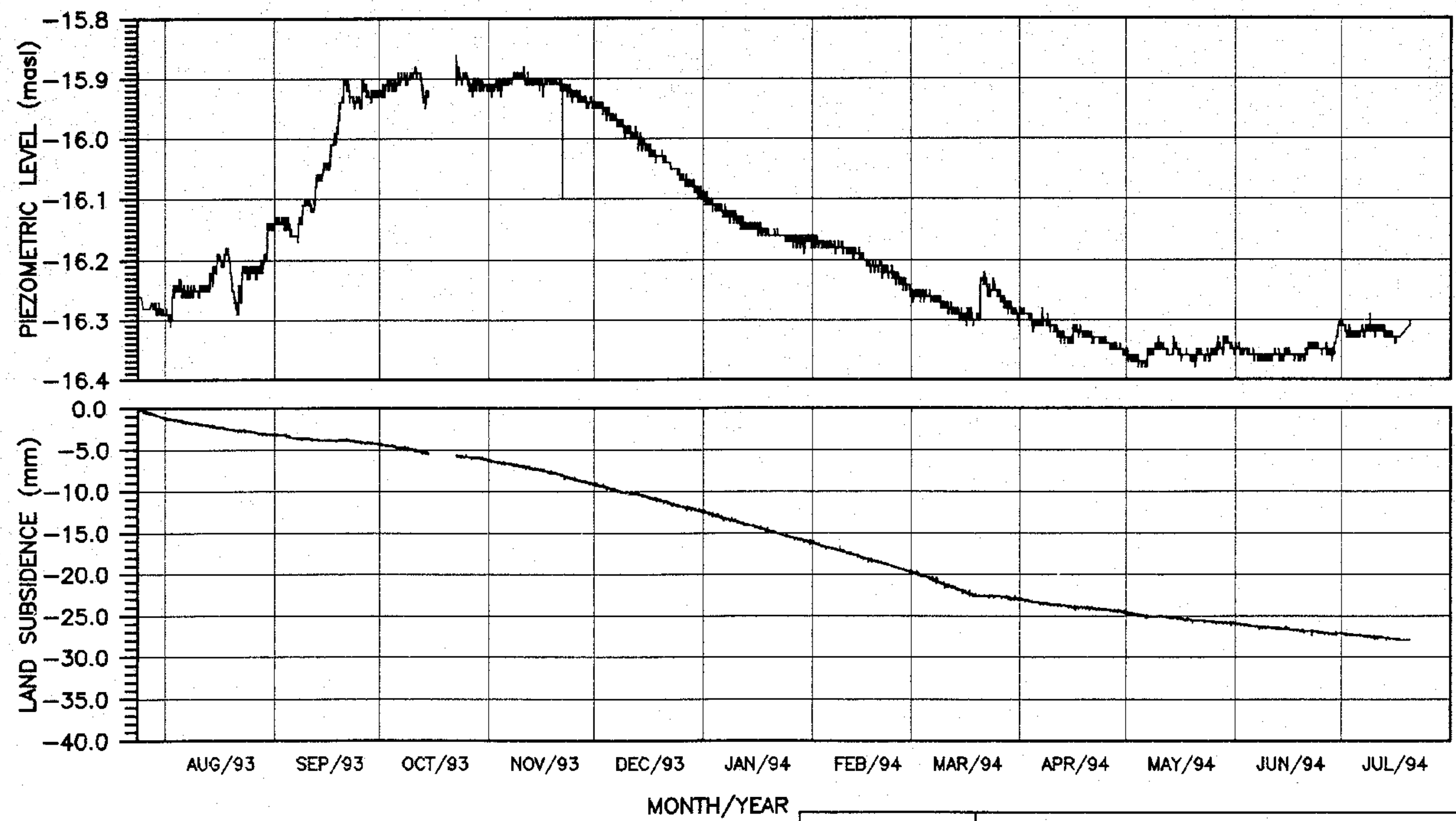
Figure 6.1.9	PIEZOMETRIC LEVEL AND LAND SUBSIDENCE AT JICA A-6 WELL
THE STUDY ON MANAGEMENT OF GROUNDWATER AND LAND SUBSIDENCE IN THE BANGKOK METROPOLITAN AREA AND ITS VICINITY	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	KOKUSAI KOGYO CO., LTD.



WELL NO.: JICA A-7
LOCATION: LAT KRABANG
UTM GRID: 879215

WELL DEPTH: 108m
SCREEN DEPTH: 101.960-107.495m
SCREEN LENGTH: 5.00m
AQUIFER TAPPED: PHRA PRADAENG AQUIFER

Figure 6.1.10	PIEZOMETRIC LEVEL AND LAND SUBSIDENCE AT JICA A-7 WELL
THE STUDY ON MANAGEMENT OF GROUNDWATER AND LAND SUBSIDENCE IN THE BANGKOK METROPOLITAN AREA AND ITS VICINITY	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	KOKUSAI KOGYO CO., LTD.

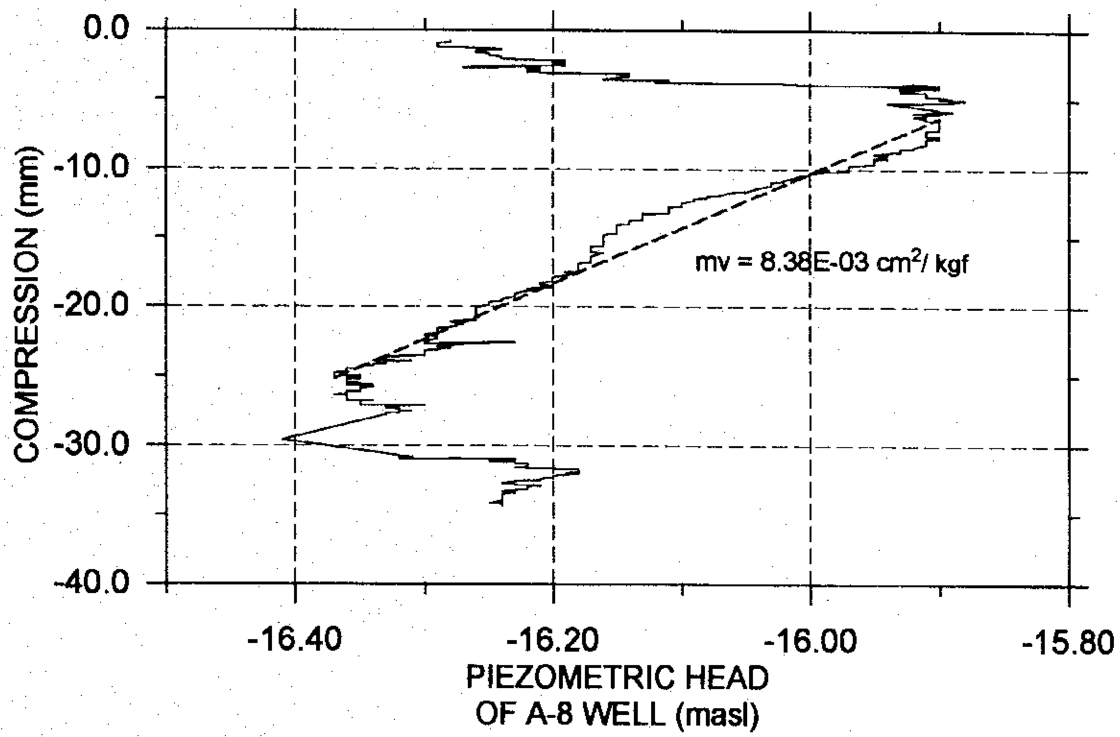


WELL NO.: JICA A−8
LOCATION: LAT KRABANG
UTM GRID: 879215

WELL DEPTH: 48m
SCREEN DEPTH: 41.960−47.495m
SCREEN LENGTH: 5.00m
AQUIFER TAPPED: BANGKOK AQUIFER

Figure 6.1.11	PIEZOMETRIC LEVEL AND LAND SUBSIDENCE AT JICA A−8 WELL
THE STUDY ON MANAGEMENT OF GROUNDWATER AND LAND SUBSIDENCE IN THE BANGKOK METROPOLITAN AREA AND ITS VICINITY	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	KOKUSAI KOGYO CO., LTD.

ANALISYS OF MONITORING RECORDS
(A-8 Well, Depth from 0m to 48m)



ANALYSIS OF MONITORING RECORDS
(A-6 Well, Depth from 108m to 145m)

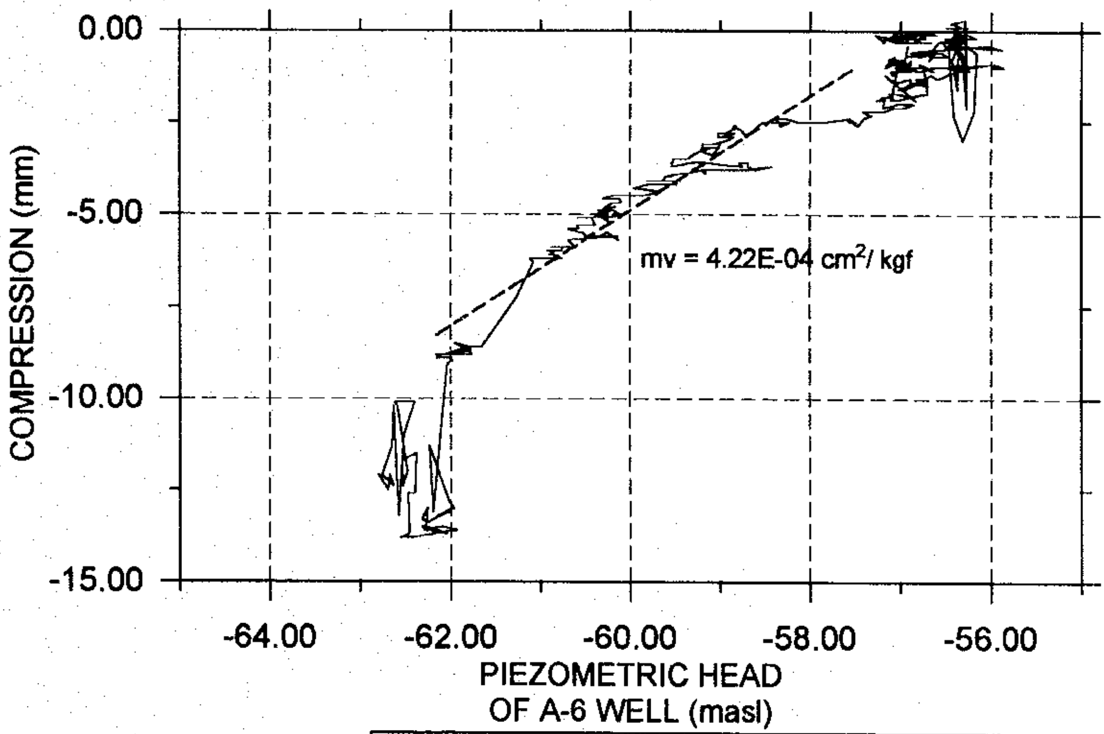
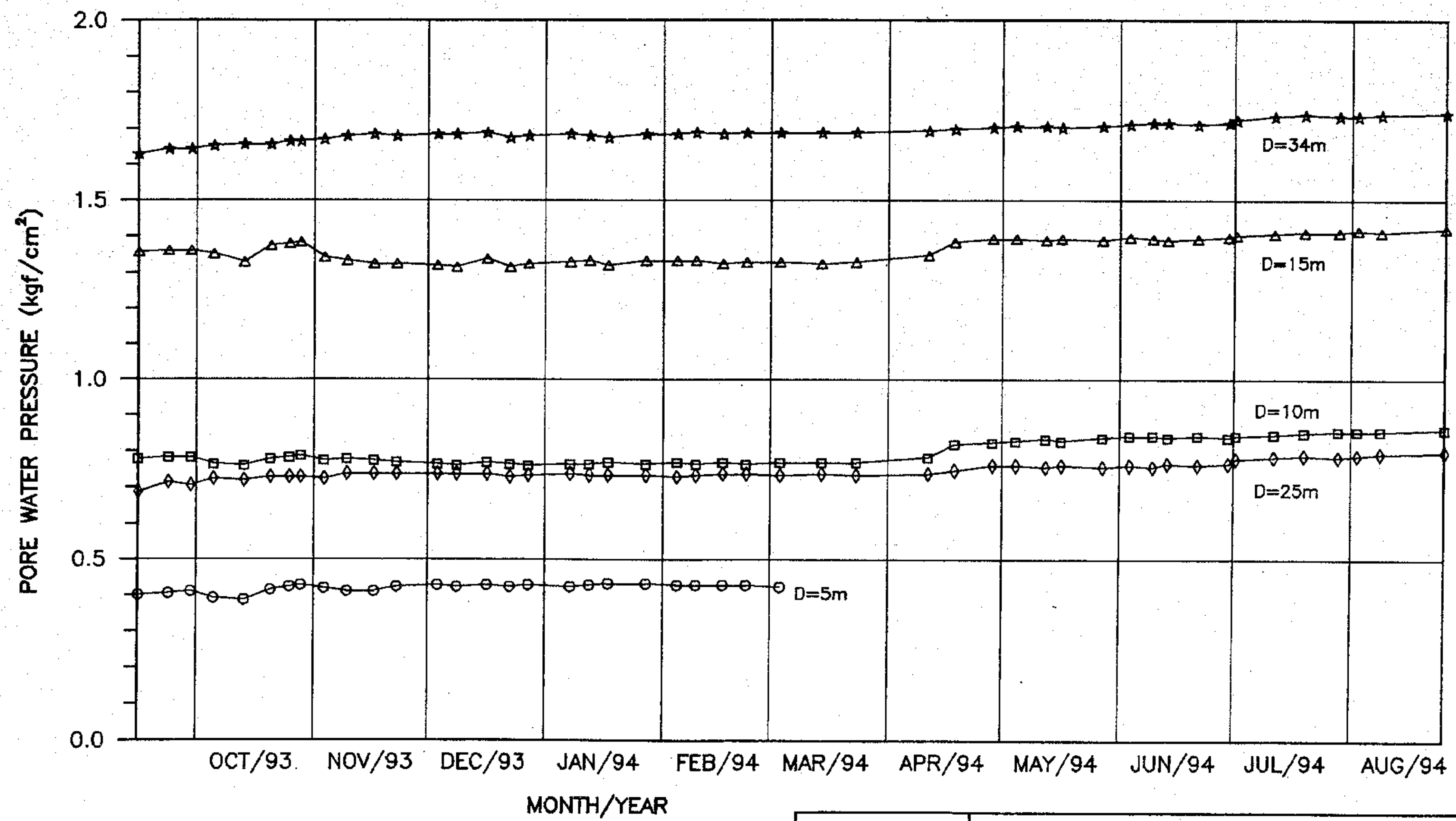


Figure 6.1.12	ANALYSIS OF MONITORING RECORDS AT JICA A-8 WELL AND JICA A-6 WELL
THE STUDY ON MANAGEMENT OF GROUNDWATER AND LAND SUBSIDENCE IN THE BANGKOK METROPOLITAN AREA AND ITS VICINITY	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	KOKUSAI KOGYO CO., LTD.



LOCATION : Site–A, Lat Krabang
UTM Grid : 879215

Figure 6.1.13 CHANGES IN PORE WATER PRESSURE AT SITE–A

THE STUDY ON MANAGEMENT OF GROUNDWATER AND LAND SUBSIDENCE IN THE BANGKOK METROPOLITAN AREA AND ITS VICINITY

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA) | KOKUSAI KOGYO CO., LTD.

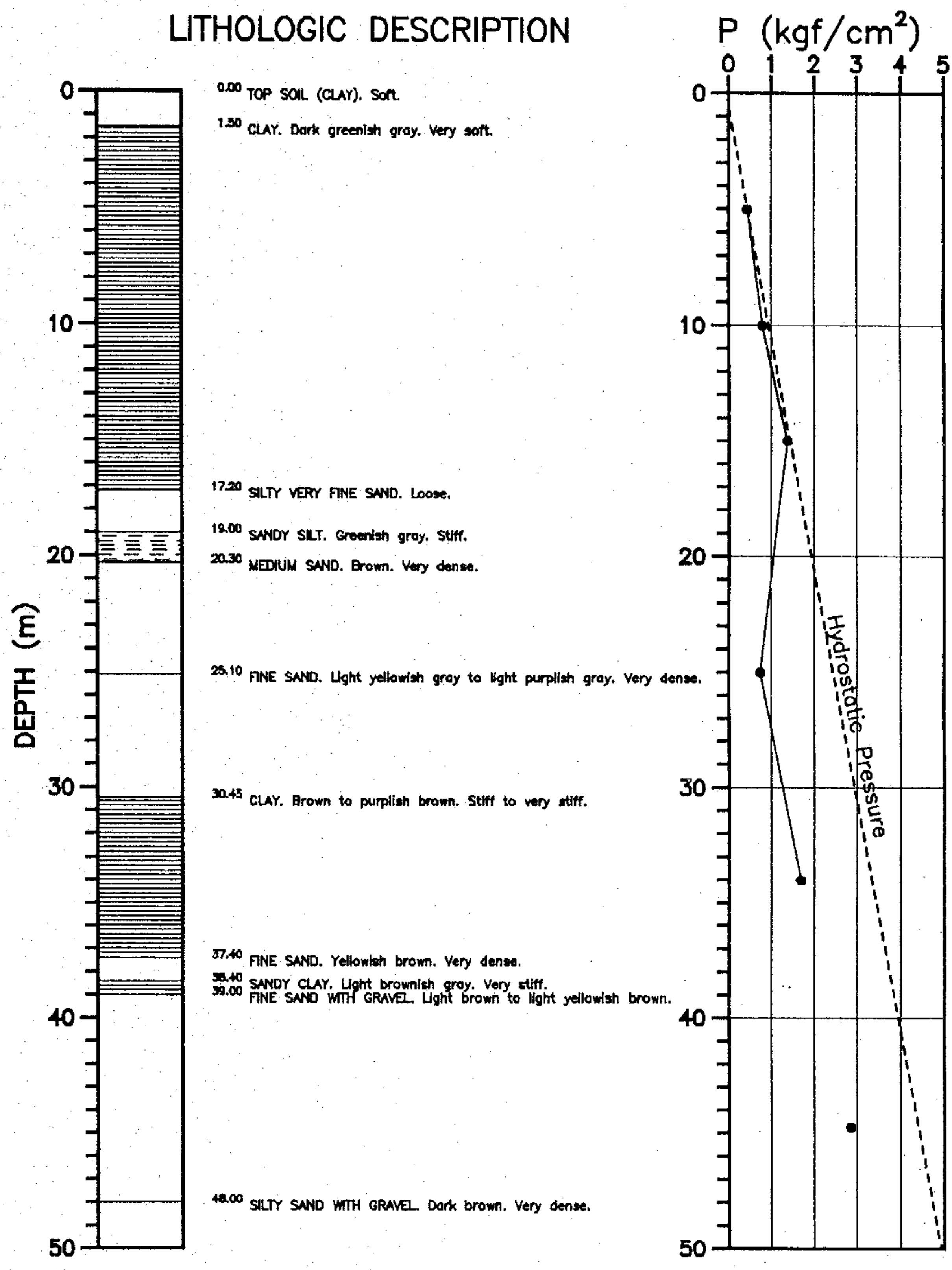
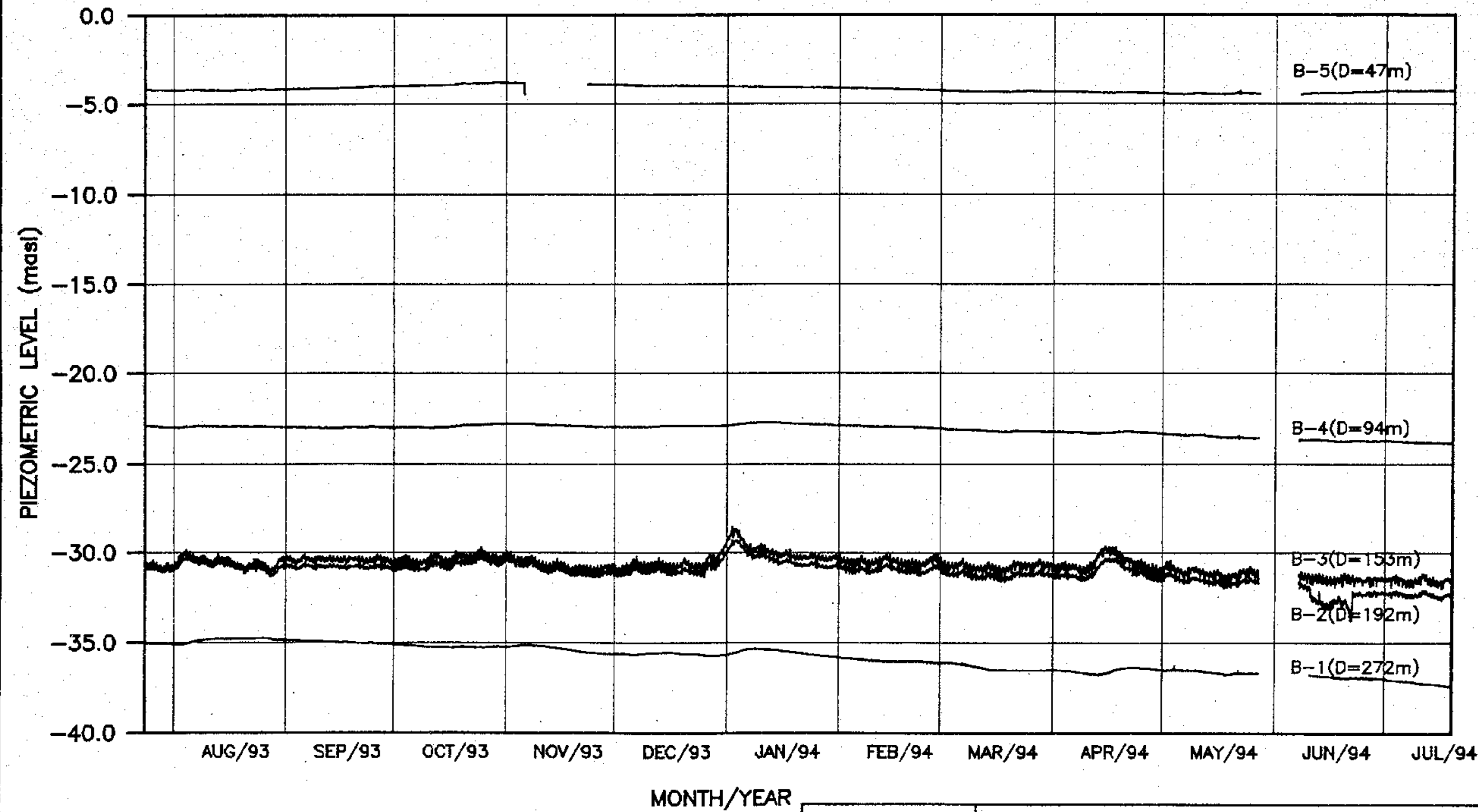
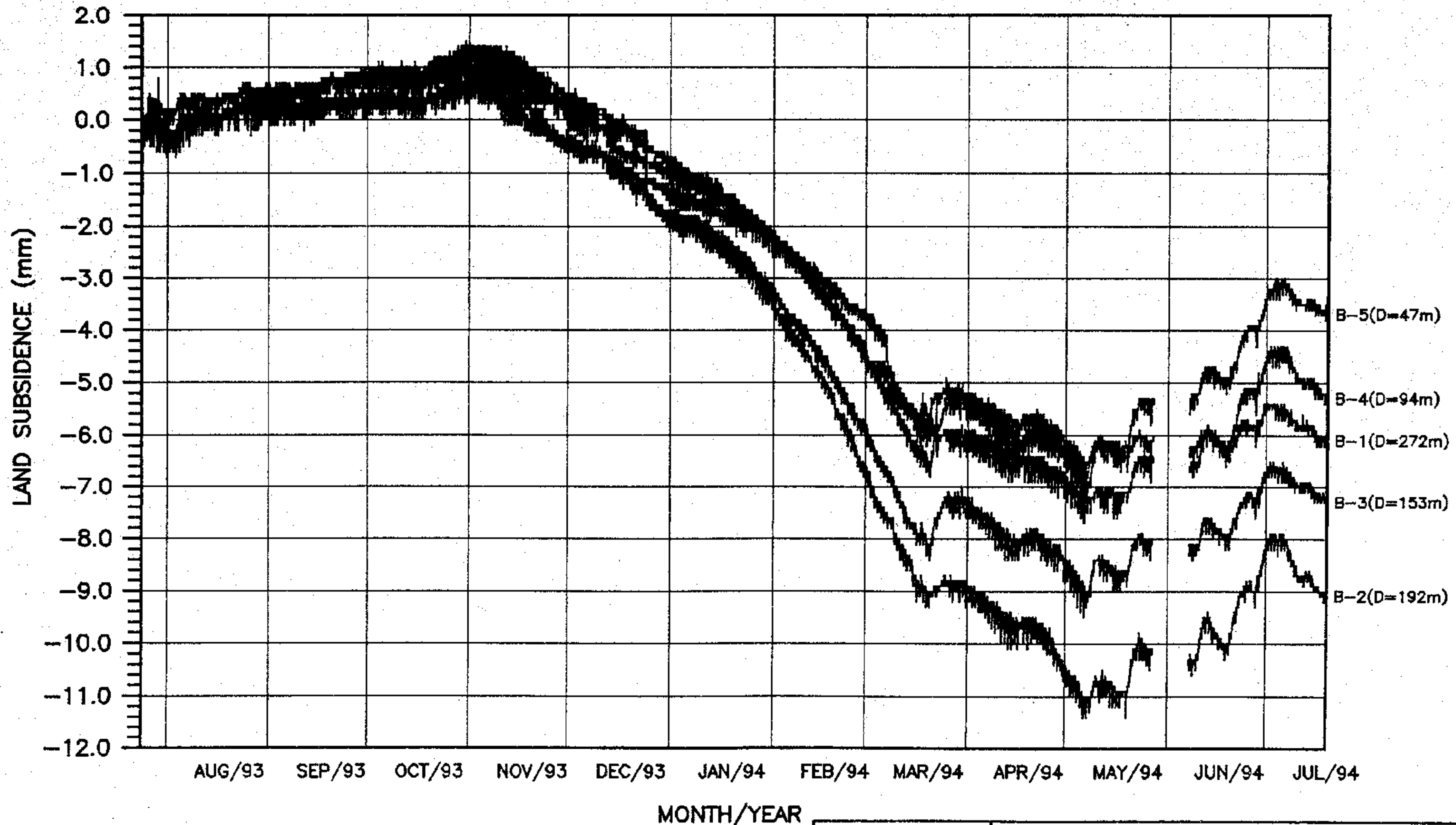


Figure 6.1.14	DISTRIBUTION OF PORE WATER PRESSURE AT SITE–A
THE STUDY ON MANAGEMENT OF GROUNDWATER AND LAND SUBSIDENCE IN THE BANGKOK METROPOLITAN AREA AND ITS VICINITY	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	KOKUSAI KOGYO CO., LTD.



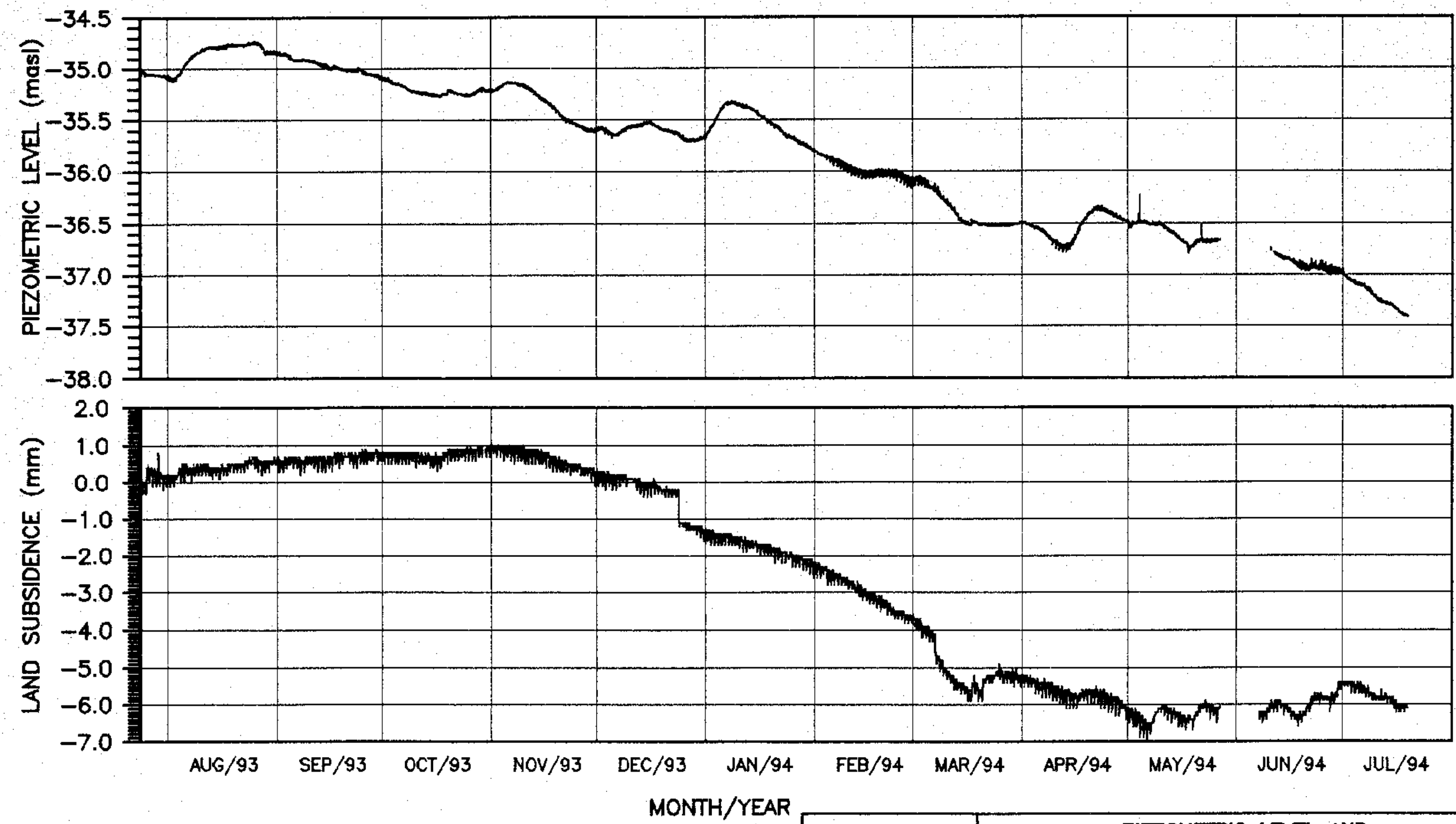
WELL NO.: JICA B−1 to B−5
LOCATION: AIT
UTM GRID: 746568

Figure 6.1.15	PIEZOMETRIC LEVELS AT SITE−B
THE STUDY ON MANAGEMENT OF GROUNDWATER AND LAND SUBSIDENCE IN THE BANGKOK METROPOLITAN AREA AND ITS VICINITY	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	KOKUSAI KOGYO CO., LTD.



WELL NO.: JICA B−1 to B−5
LOCATION: AIT
UTM GRID: 746568

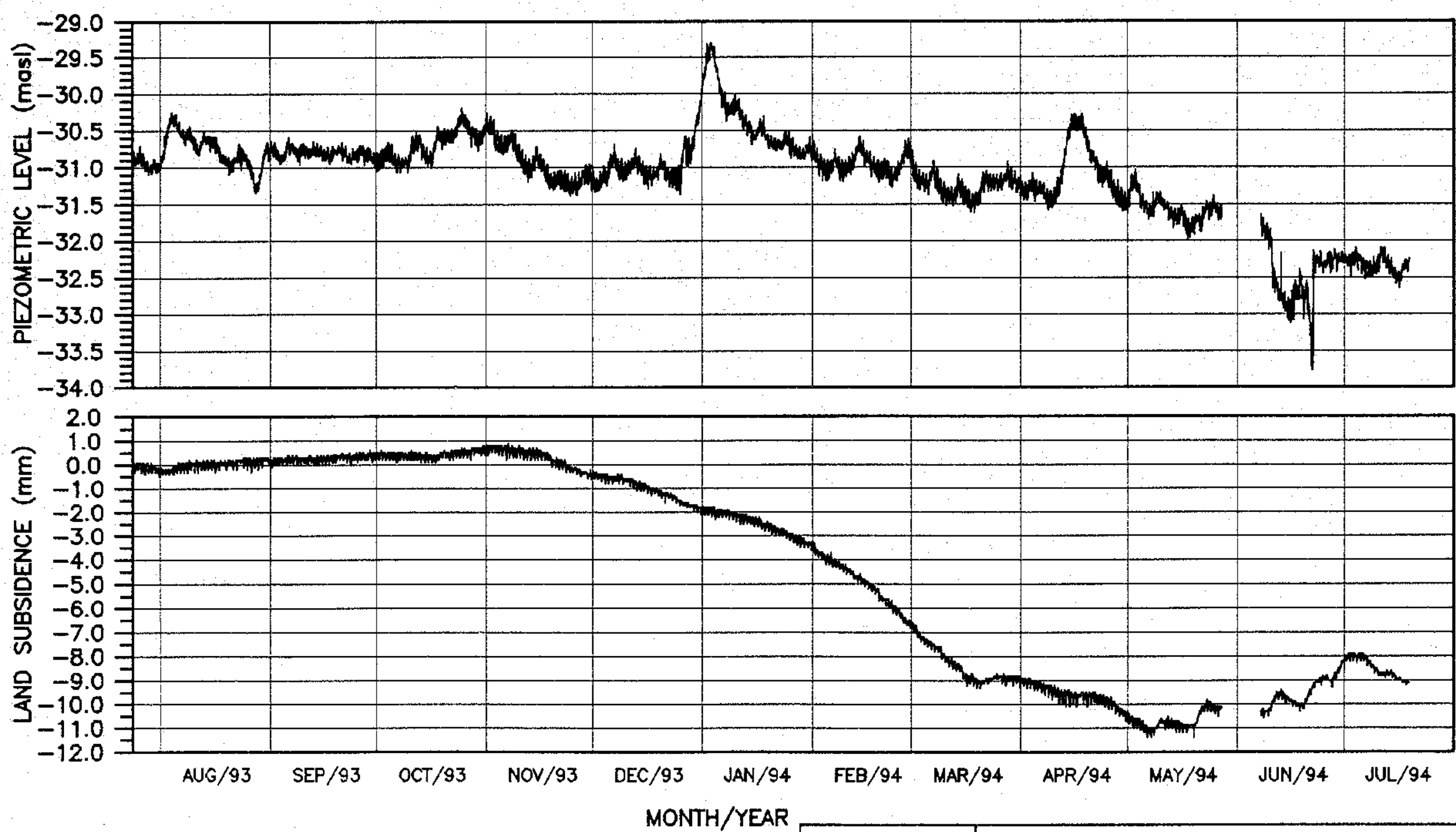
Figure 6.1.16	LAND SUBSIDENCE AT SITE−B
THE STUDY ON MANAGEMENT OF GROUNDWATER AND LAND SUBSIDENCE IN THE BANGKOK METROPOLITAN AREA AND ITS VICINITY	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	KOKUSAI KOGYO CO., LTD.



WELL NO.: JICA B–1
LOCATION: AIT, PATHUM THANI
UTM GRID: 746568

WELL DEPTH: 272m
SCREEN DEPTH: 263.180–271.495m
SCREEN LENGTH: 7.25m
AQUIFER TAPPED: NONTHABURI AQUIFER

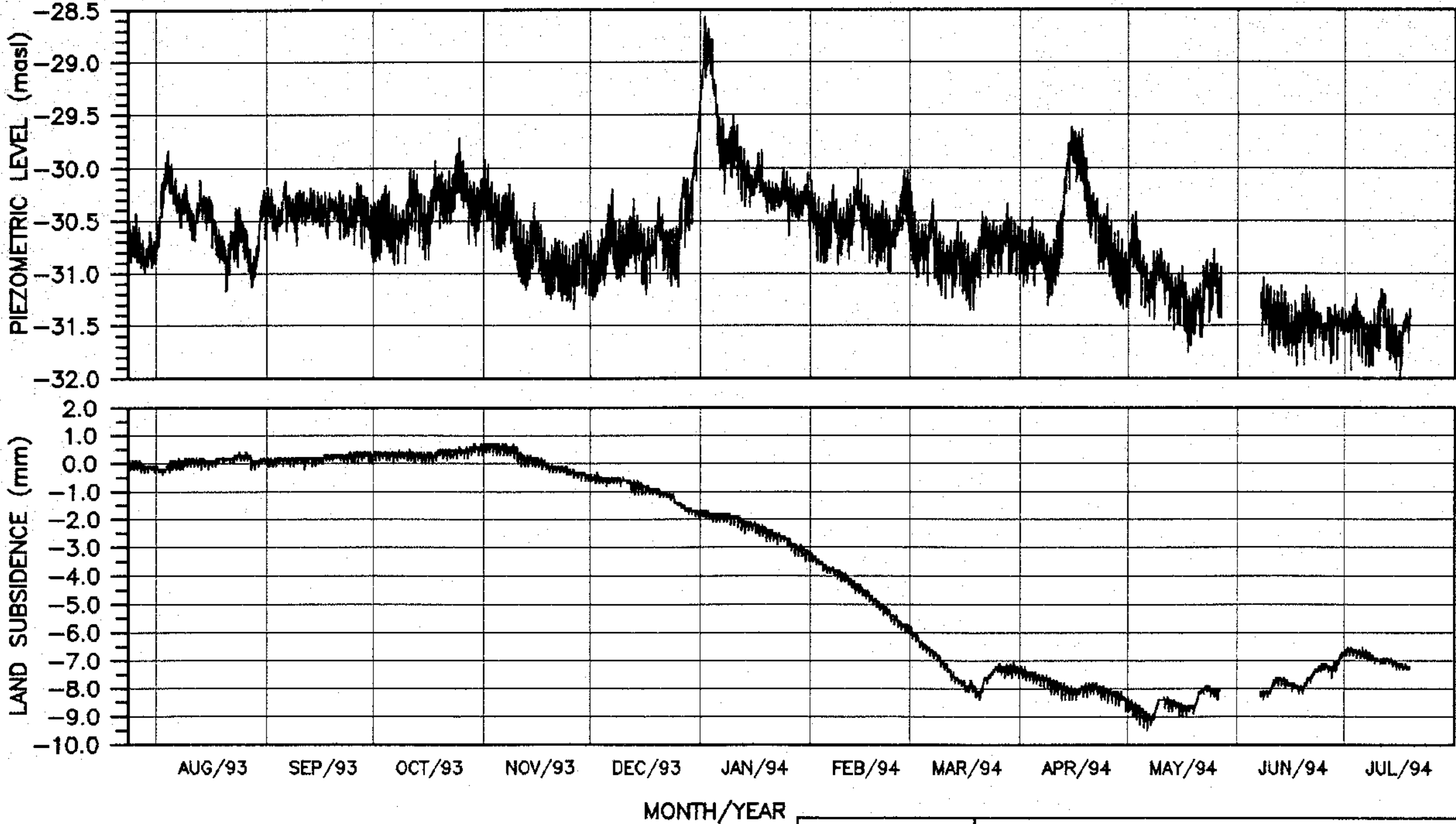
Figure 6.1.17	PIEZOMETRIC LEVEL AND LAND SUBSIDENCE AT JICA B–1 WELL
THE STUDY ON MANAGEMENT OF GROUNDWATER AND LAND SUBSIDENCE IN THE BANGKOK METROPOLITAN AREA AND ITS VICINITY	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	KOKUSAI KOGYO CO., LTD.



WELL NO.: JICA B−2
LOCATION: AIT, PATHUM THANI
UTM GRID: 746568

WELL DEPTH: 192m
SCREEN DEPTH: 185.970−191.495m
SCREEN LENGTH: 5.00m
AQUIFER TAPPED: NAKHON LUANG AQUIFER

Figure 6.1.18	PIEZOMETRIC LEVEL AND LAND SUBSIDENCE AT JICA B−2 WELL
THE STUDY ON MANAGEMENT OF GROUNDWATER AND LAND SUBSIDENCE IN THE BANGKOK METROPOLITAN AREA AND ITS VICINITY	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	KOKUSAI KOGYO CO., LTD.



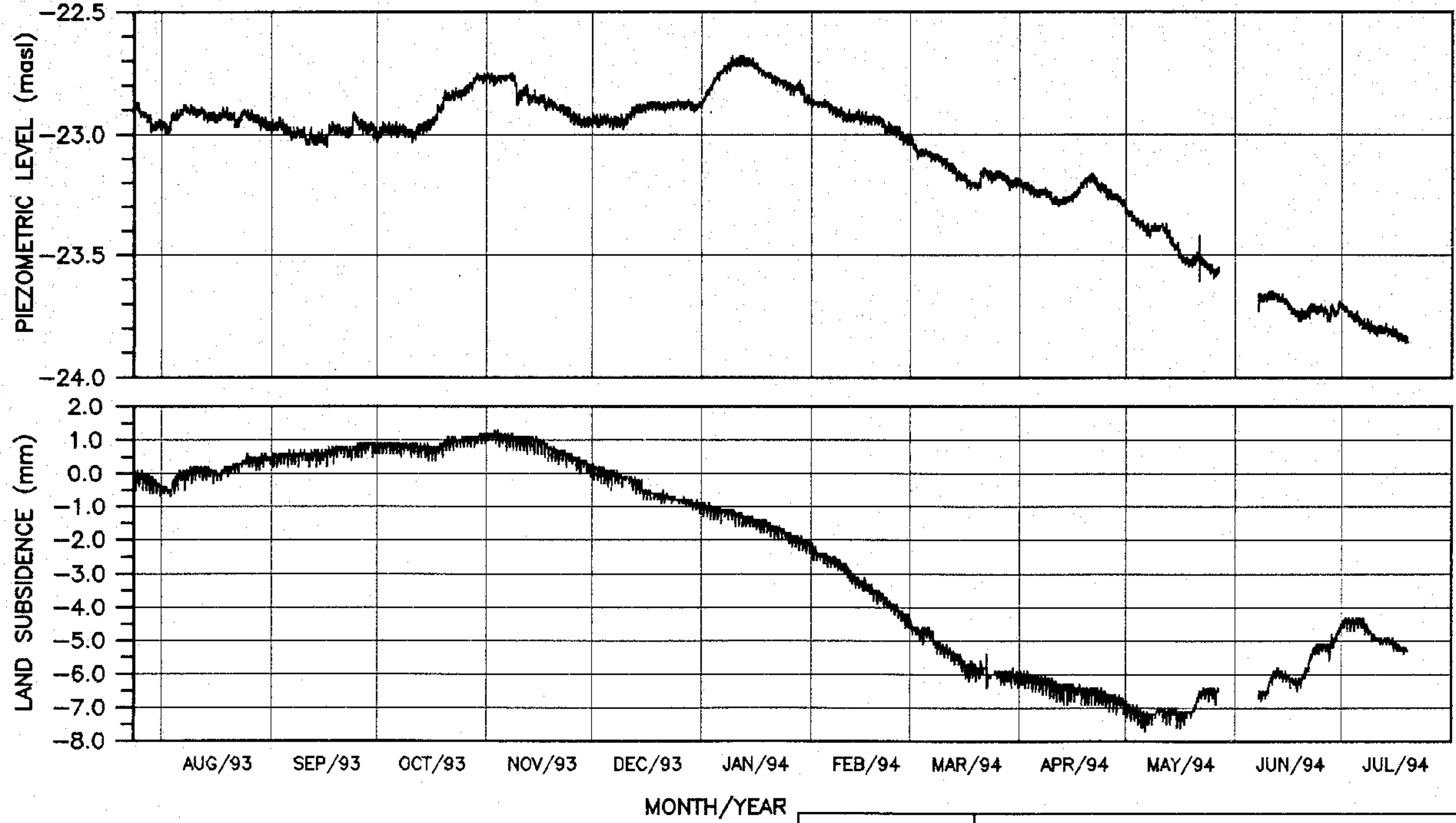
WELL NO.: JICA B-3
LOCATION: AIT, PATHUM THANI
UTM GRID: 746568

WELL DEPTH: 153m
SCREEN DEPTH: 146.970~152.495m
SCREEN LENGTH: 5.00m
AQUIFER TAPPED: NAKHON LUANG AQUIFER

Figure 6.1.19 PIEZOMETRIC LEVEL AND LAND SUBSIDENCE AT JICA B-3 WELL

THE STUDY ON MANAGEMENT OF GROUNDWATER AND LAND SUBSIDENCE IN THE BANGKOK METROPOLITAN AREA AND ITS VICINITY

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA) | KOKUSAI KOGYO CO., LTD.



WELL NO.: JICA B-4
LOCATION: AIT, PATHUM THANI
UTM GRID: 746568

WELL DEPTH: 94m
SCREEN DEPTH: 87.960-93.495m
SCREEN LENGTH: 5.00m
AQUIFER TAPPED: PHRA PRADAENG AQUIFER

Figure 6.1.20	PIEZOMETRIC LEVEL AND LAND SUBSIDENCE AT JICA B-4 WELL
THE STUDY ON MANAGEMENT OF GROUNDWATER AND LAND SUBSIDENCE IN THE BANGKOK METROPOLITAN AREA AND ITS VICINITY	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	KOKUSAI KOGYO CO., LTD.

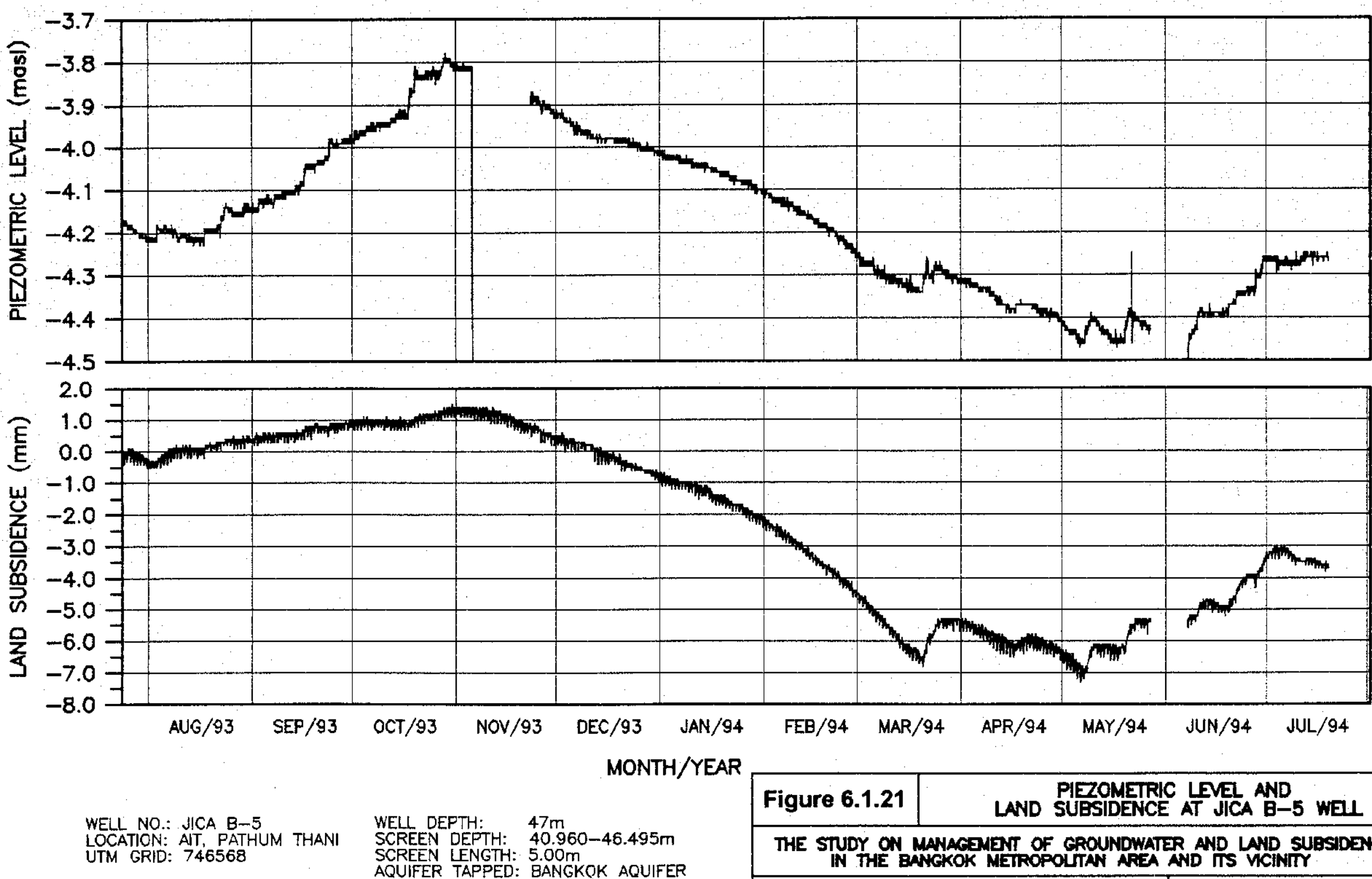
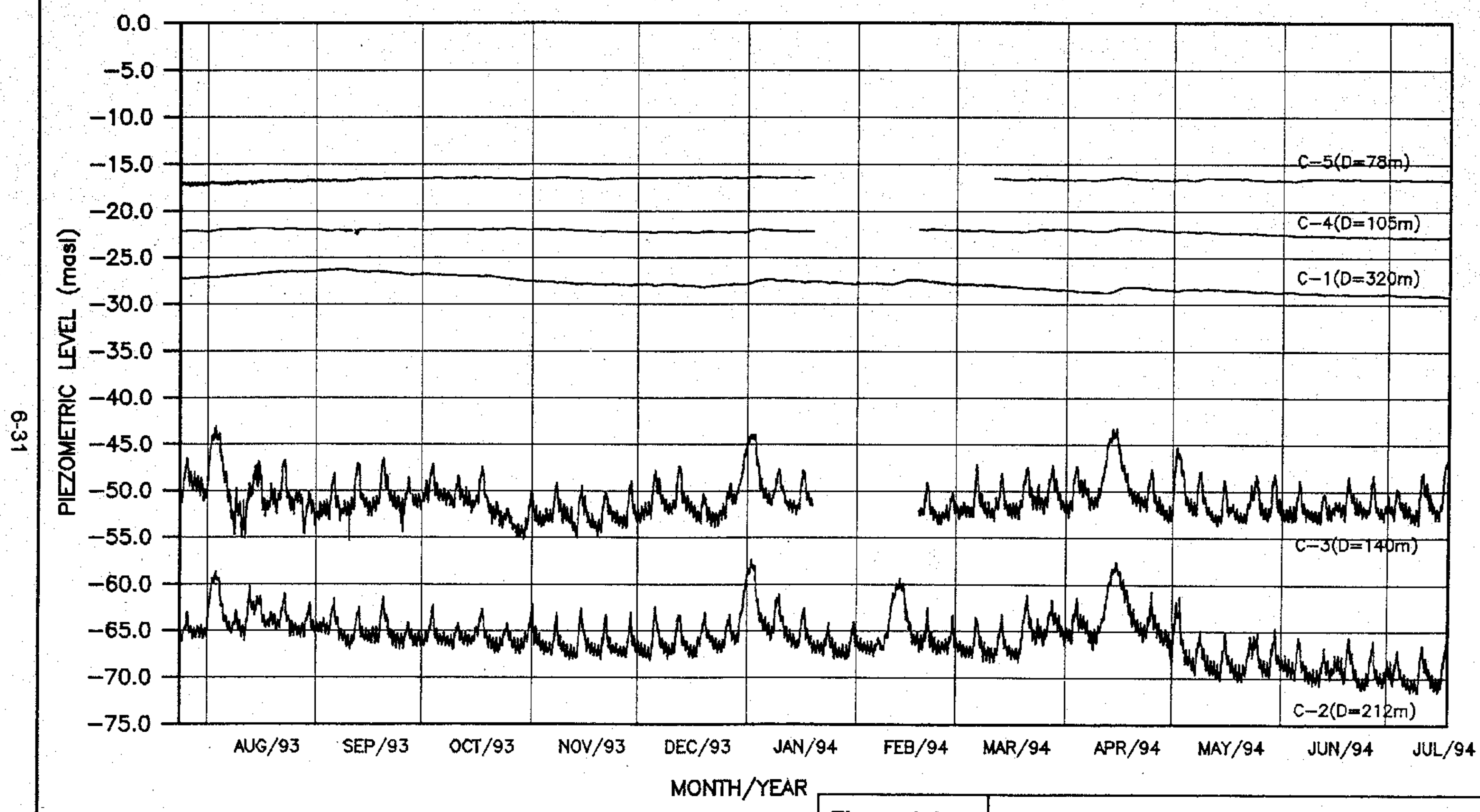


Figure 6.1.21 PIEZOMETRIC LEVEL AND LAND SUBSIDENCE AT JICA B-5 WELL

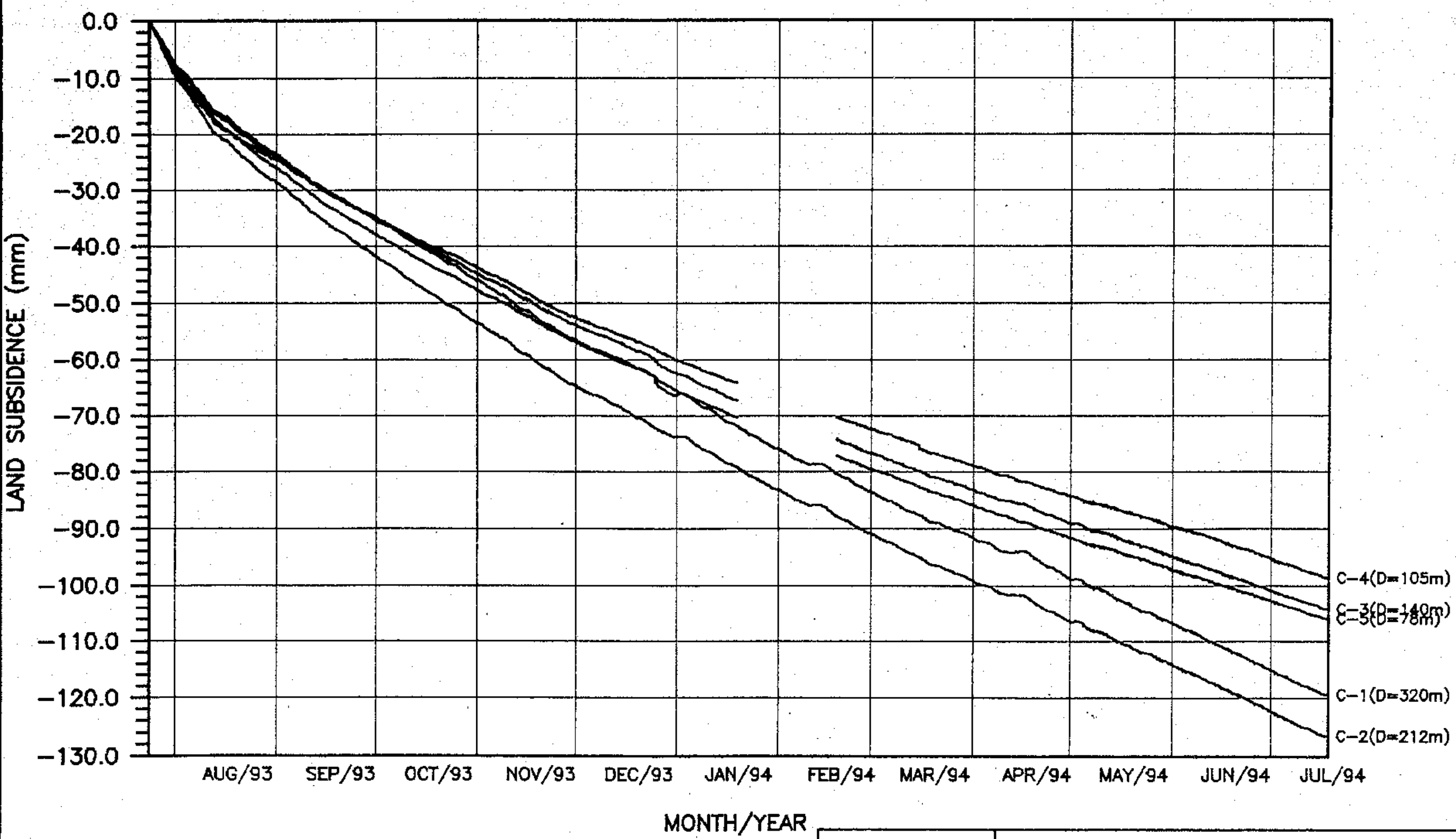
THE STUDY ON MANAGEMENT OF GROUNDWATER AND LAND SUBSIDENCE IN THE BANGKOK METROPOLITAN AREA AND ITS VICINITY

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA) | KOKUSAI KOGYO CO., LTD.



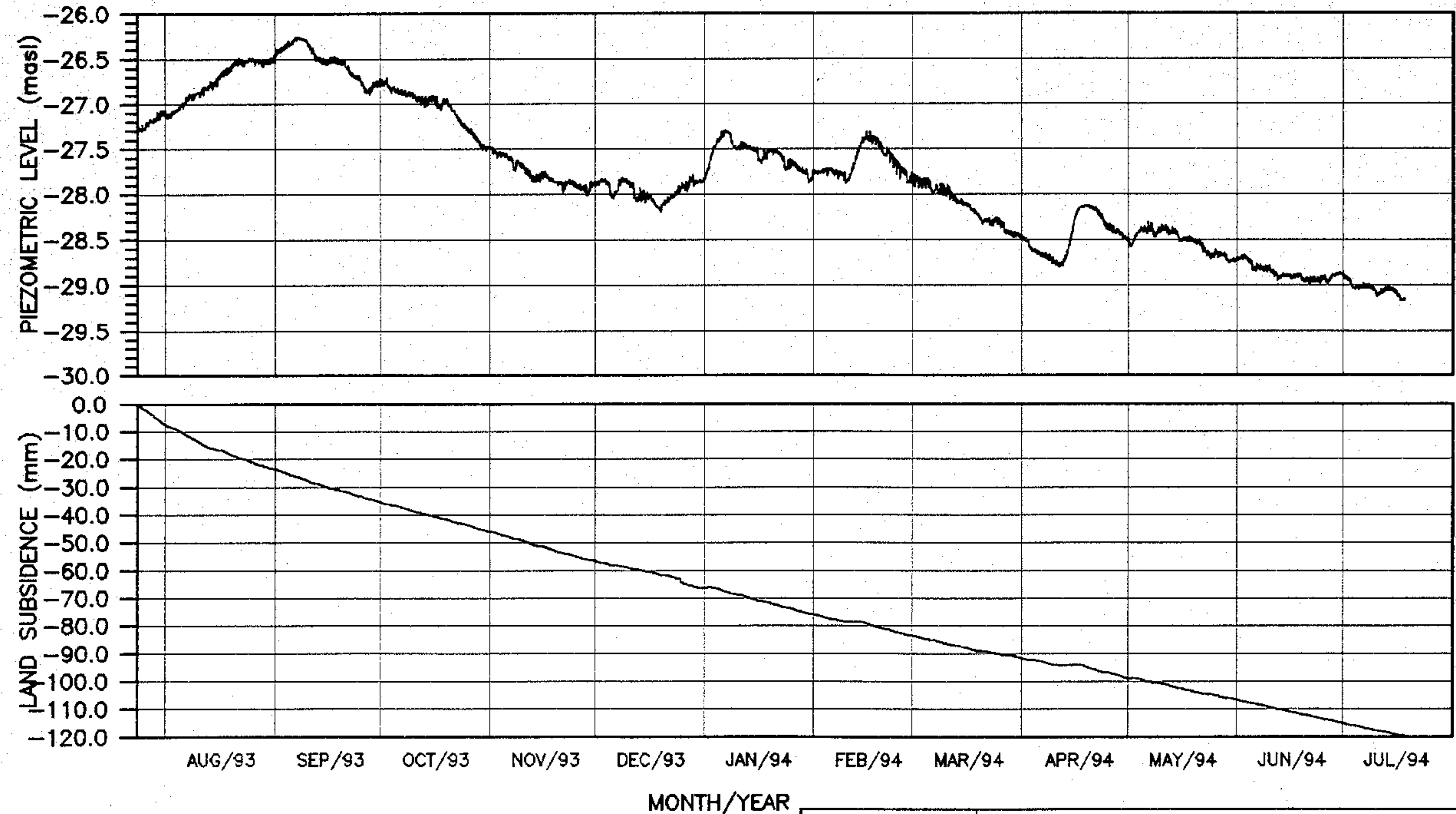
WELL NO.: JICA C-1 to C-5
LOCATION: SAMUT SAKHON
UTM GRID: 381007

Figure 6.1.22	PIEZOMETRIC LEVELS AT SITE-C
THE STUDY ON MANAGEMENT OF GROUNDWATER AND LAND SUBSIDENCE IN THE BANGKOK METROPOLITAN AREA AND ITS VICINITY	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	KOKUSAI KOGYO CO., LTD.



WELL NO.: JICA C−1 to C−5
LOCATION: SAMUT SAKHON
UTM GRID: 381007

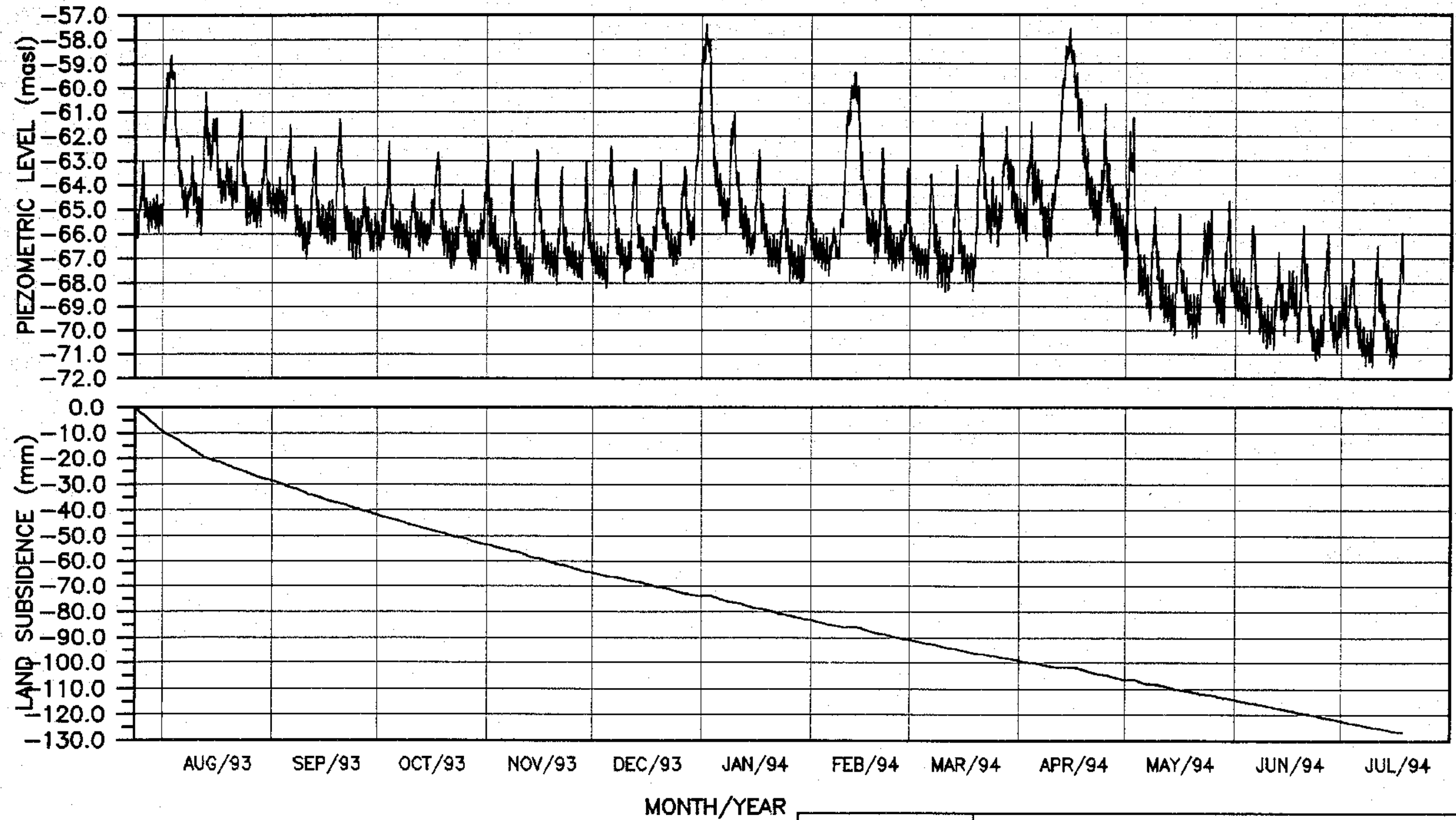
Figure 6.1.23	LAND SUBSIDENCE AT SITE−C
THE STUDY ON MANAGEMENT OF GROUNDWATER AND LAND SUBSIDENCE IN THE BANGKOK METROPOLITAN AREA AND ITS VICINITY	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	KOKUSAI KOGYO CO., LTD.



WELL NO.: JICA C-1
LOCATION: SAMUT SAKHON
UTM GRID: 381007

WELL DEPTH: 320m
SCREEN DEPTH: 311.190-319.495m
SCREEN LENGTH: 7.25m
AQUIFER TAPPED: SAM KHOK AQUIFER

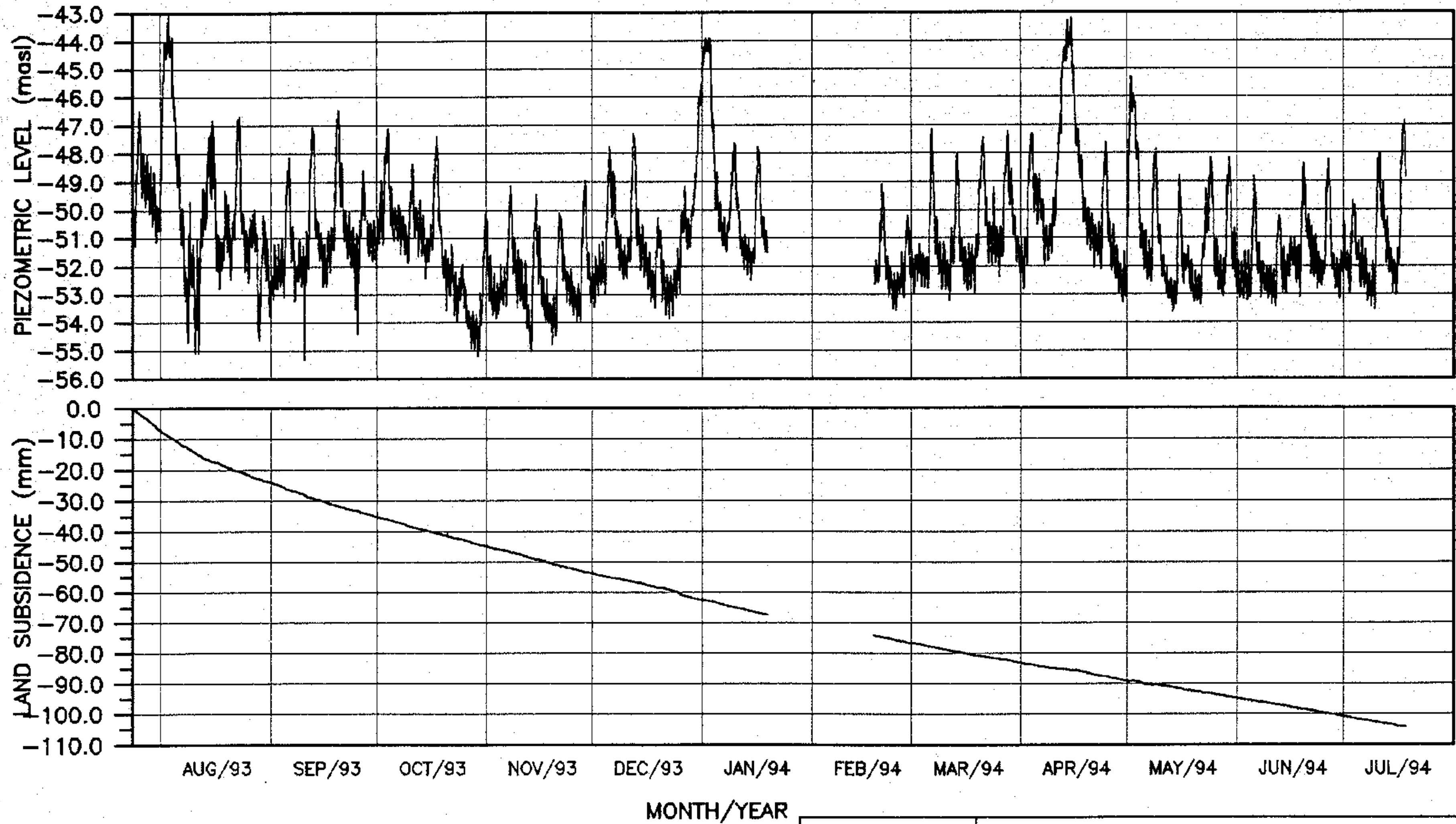
Figure 6.1.24	PIEZOMETRIC LEVEL AND LAND SUBSIDENCE AT JICA C-1 WELL
THE STUDY ON MANAGEMENT OF GROUNDWATER AND LAND SUBSIDENCE IN THE BANGKOK METROPOLITAN AREA AND ITS VICINITY	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	KOKUSAI KOGYO CO., LTD.



WELL NO.: JICA C-2
LOCATION: SAMUT SAKHON
UTM GRID: 381007

WELL DEPTH: 212m
SCREEN DEPTH: 205.970-211.500m
SCREEN LENGTH: 5.00m
AQUIFER TAPPED: NONTHABURI AQUIFER

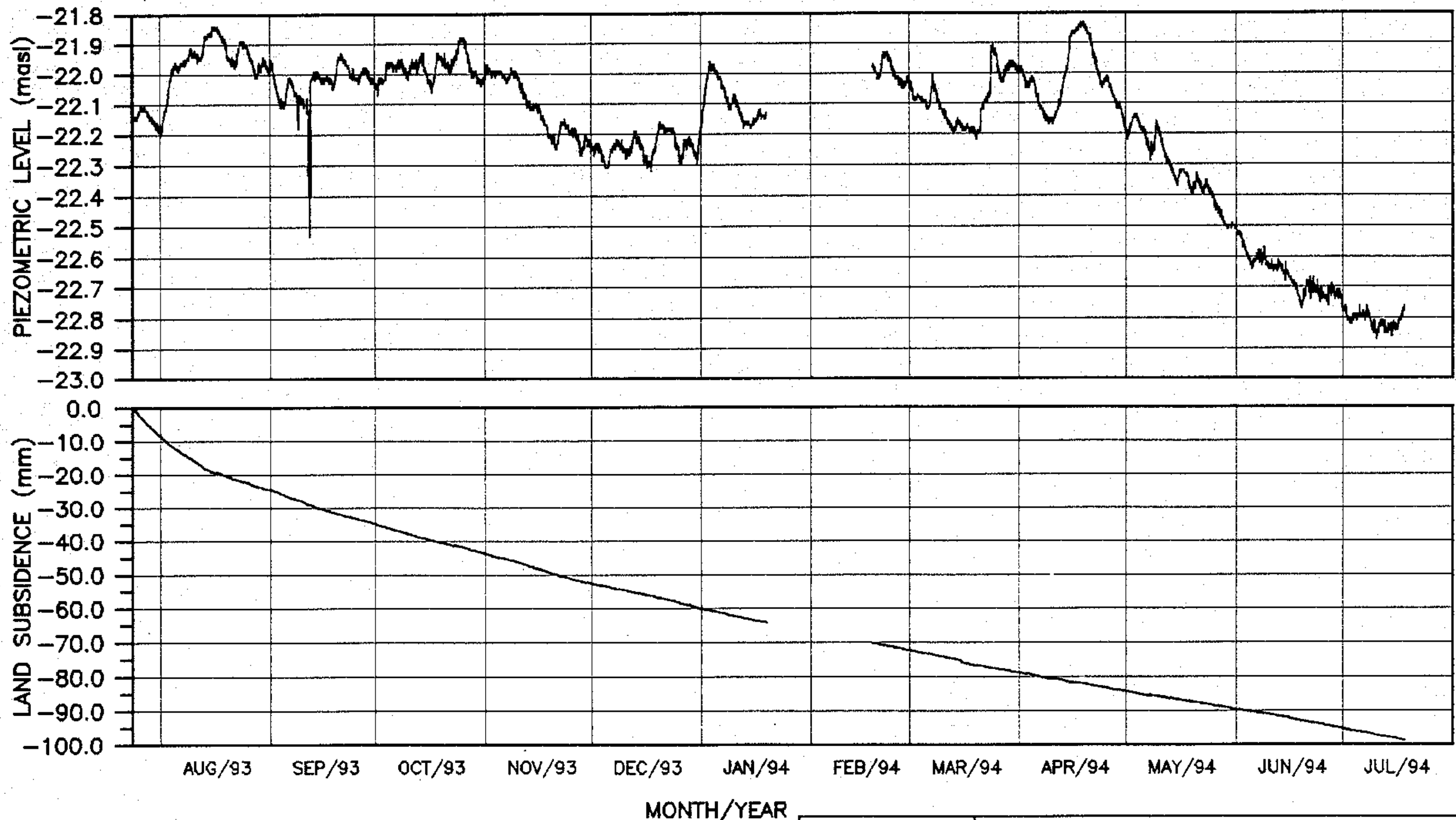
Figure 6.1.25	PIEZOMETRIC LEVEL AND LAND SUBSIDENCE AT JICA C-2 WELL
THE STUDY ON MANAGEMENT OF GROUNDWATER AND LAND SUBSIDENCE IN THE BANGKOK METROPOLITAN AREA AND ITS VICINITY	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	KOKUSAI KOGYO CO., LTD.



WELL NO.: JICA C-3
LOCATION: SAMUT SAKHON
UTM GRID: 381007

WELL DEPTH: 140m
SCREEN DEPTH: 133.960-139.495m
SCREEN LENGTH: 5.00m
AQUIFER TAPPED: NAKHON LUANG AQUIFER

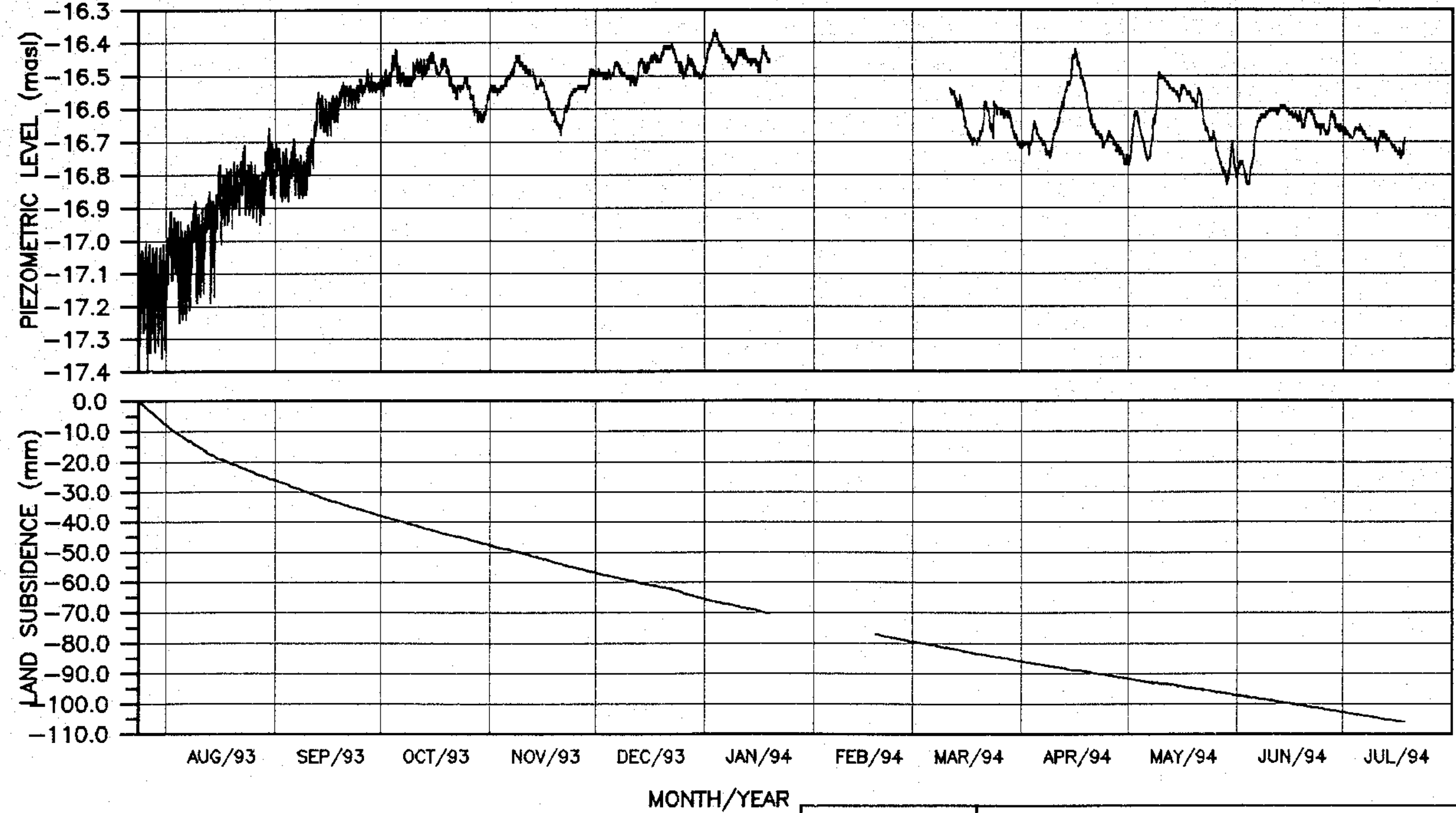
Figure 6.1.26	PIEZOMETRIC LEVEL AND LAND SUBSIDENCE AT JICA C-3 WELL
THE STUDY ON MANAGEMENT OF GROUNDWATER AND LAND SUBSIDENCE IN THE BANGKOK METROPOLITAN AREA AND ITS VICINITY	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	KOKUSAI KOGYO CO., LTD.



WELL NO.: JICA C-4
LOCATION: SAMUT SAKHON
UTM GRID: 381007

WELL DEPTH: 105m
SCREEN DEPTH: 98.960-104.495m
SCREEN LENGTH: 5.00m
AQUIFER TAPPED: PHRA PRADAENG AQUIFER

Figure 6.1.27	PIEZOMETRIC LEVEL AND LAND SUBSIDENCE AT JICA C-4 WELL
THE STUDY ON MANAGEMENT OF GROUNDWATER AND LAND SUBSIDENCE IN THE BANGKOK METROPOLITAN AREA AND ITS VICINITY	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	KOKUSAI KOGYO CO., LTD.



WELL NO.: JICA C−5
LOCATION: SAMUT SAKHON
UTM GRID: 381007

WELL DEPTH: 78m
SCREEN DEPTH: 71.960−77.495m
SCREEN LENGTH: 5.00m
AQUIFER TAPPED: PHRA PRADAENG AQUIFER

Figure 6.1.28	PIEZOMETRIC LEVEL AND LAND SUBSIDENCE AT JICA C−5 WELL
THE STUDY ON MANAGEMENT OF GROUNDWATER AND LAND SUBSIDENCE IN THE BANGKOK METROPOLITAN AREA AND ITS VICINITY	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	KOKUSAI KOGYO CO., LTD.

6.2 Records of DMR Monitoring Stations

The DMR Ground Water Division has a monitoring network having 103 stations in the study area (Figure 6.2.1). The groundwater levels have been monitored since 1978 at least once in a month. The DMR has constructed 86 surface benchmarks in the study area. Most benchmarks are located in the monitoring stations. The leveling survey has been conducted since 1991 by the DMR Survey Division.

6.2.1 Groundwater Levels

Recent data of groundwater levels until May 1994 were added to the database system prepared by the Study Team. Piezometric level maps in May 1994 and piezometric level decline maps were made for Phra Pradaeng aquifer, Nakhon Luang aquifer, and Nonthaburi aquifer.

(1) Phra Pradaeng (PD) aquifer
The piezometric levels of PD aquifer in May 1994 is shown in Figure 6.2.2. Deep piezometric level below 50m from ground surface is found near Lat Krabang, Bangkok. The areas where the piezometric level is below 30m are distributed from eastern Bangkok to Samut Prakan and Pathum Thani. Figure 6.2.3 shows the rate of piezometric level change in PD aquifer from January 1992 to January 1994 with locations of production wells. The declining rate of piezometric level in eastern Bangkok and northeastern Pathum Thani is more than 2.0 m/year. The declining rate of Samut Prakan where many production wells exist ranges 1.0 to 1.5 m/year.

(2) Nakhon Luang (NL) aquifer
The piezometric levels of NL aquifer in May 1994 is shown in Figure 6.2.4. A large depression of piezometric levels where the level is below 40m from ground surface spreads from eastern Samut Prakan to Pathum Thani through eastern Bangkok. The piezometric level at Minburi and Lat Krabang is below 60m. Another depression is found in Samut Sakhon where the deepest piezometric level is below 65m from ground surface. Figure 6.2.5 shows the rate of piezometric level change from January 1992 to January 1994. More than 5.0 m/year of decline is found at Don Muang, Bangkok and Lam Luk Ka, Pathum Thani. The declining rate at Bang Phli, Samut Sakhon exceeds 3.0 m/year.

(3) Nonthaburi (NB) aquifer
The piezometric levels of NB aquifer in May 1994 is shown in Figure 6.2.6. Depressions of piezometric levels below 40m from ground surface are found in the areas from Pathum Thani to eastern Bangkok, eastern Samut Prakan, and Samut Sakhon. Some monitoring wells in the areas show the piezometric levels below 50m. Figure 6.2.7 shows the rate of piezometric level change from January 1992 to January 1994. The areas where the rate more than 3.0 m/year are found in Pathum Thani, northern and eastern parts of Bangkok, and a part of Nakhon Pathom.