Appendix 5 Other Relevant Data/Information

5-1 Meteorological Data

5-2 Field Report on Hydrological Study

5-3 Geophysical survey

5-4 Summary of Test Drilling/Aquifer Test

5-5 Analysis of Step Drawdown Test

5-6 Examination of Aquifer Coefficients

5-7 Examination of Extent of Influence

5-8 Examination of Influence by Existing Tibewells in the Chenab Wellfield

5-9 Structure of WASA's Standard Monitoring Well

5-10 Water Analysis on Site and by WASA Laboratory of Samples from Tubewells

5-11 Comparison of Population Projections

5-12 Amount of Water Production and Water Supply

5-13 Study on Existing Distribution and Water Supply Facilities

5-14 Comparison of pipeline network calculation

5-15 Socio-economic Survey on the Basic Design Study (Phase 1) and Activities after the completion of the survey

5-16 Socio-economic Survey on the Basic Design Study (Phase 2)

5-17 WASA's Water Tariff

Appendix 5-1 Meteorological Data

Table 1 Annual Precipitation of Major Cities in Punjab(1994－1998)

Name of City	1994	1995	1996	1997	1998	Average
Muree	2,220	1,703	2,192	2,307	1,973	2,078
Rawalpindi	1,690	1,615	1,324	1,414	1,412	1.493
Jhelum	1,000	1,158	989	1,336	967	1,090
Sargodha	360	319	447	629	411	433
Faisalabad	191	172	346	807	332	370
Sialkot	1,191	976	1,642	1,388	1,037	1,247
Lahore	542	826	1,189	1,233	403	839
Multan	303	265	211	264	136	236
D.G. Khan	122	87	157	350	-	179
Bahawalpur	246	203	97	304	159	202

Table 2 Monthly Mean Rainfall・Temperature・Humidity in Faisalabad (1961～1990)

Month	Ave. Temperature (℃)		Precipitation (mm)	Relative Humidity (%)
	Max.	Min.		
1	19.4	4.1	11.5	66.0
2	21.9	7.1	20.1	61.2
3	26.7	12.3	25.7	58.2
4	33.5	18.0	16.9	46.5
5	38.4	22.7	16.1	37.5
6	40.5	26.9	27.9	41.7
7	37.1	27.0	115.0	61.5
8	36.1	26.6	89.8	65.9
9	35.7	23.7	28.6	59.9
10	33.0	17.0	3.8	54.7
11	27.2	10.1	3.0	62.7
12	21.4	5.1	8.6	66.5
平均	30.9	16.7	372.3	56.8

Appendix 5-2 Field Report on Hydrological Study

1. Objectives

The proposed well fields, Alternative-1 and Alternative-2, are located in the vicinity of Chenab river bed near Chiniot bridge; therefore, there is concern that the installed facilities will be influenced by the floods. In addition, some amount of sewage water flows into Chenab river bed from the city of Chiniot, and it may influence the quality of the water source. The objectives of hydrological study are as follows:

- to evaluate the influence of the flood on the proposed facilities in the proposed well fields, especially the possibility of water inundation and land erosion by the flood.

2. Period 15 December 2002 - 5 January 2003

3. Methodology

Hydrological study was conducted by the following steps:

- Site observation around Chenab river bed and bank near Chiniot and Chenabnagar
- Interview with farmers around Chenab river bank about the situation of the floods in the past
- Data collection on the water level and discharge of Chenab river (33 year data from 1970 to 2002, at Rivaz bridge, Chiniot bridge and Qadirabad barrage, provided by Irrigation and Power Department, Lahore.)
- Analysis of the water level and discharge data of Chenab river, the results of interview with farmers, and the results of site observation

4. Findings

1) Collection of hydrological data

The hydrological data shown in Table-1 were provided by the Irrigation and Power Department, Government of the Punjab, Lahore. Some of the discharge and water level data at Chiniot bridge which are not available were obtained by regression estimate as is mentioned in Note of Table-1.

Table-1 Hydrological data available

Station / Year	Rivaz Bridge (69km downstream of Chiniot bridge)		Chiniot Bridge		Qadirabad Barrage (117km upstream of Chiniot bridge)	
	Water Level	Discharge	Water Level	Discharge	Water Level	Discharge
1970	O	O	O	N.A.[2]	O	O
1971	O	O	O	N.A.[2]	O	O
1972	O	O	O	N.A.[2]	O	O
1973	O	partly N.A.	O	N.A.[2]	O	O
1974	O	partly N.A.	O	N.A.[2]	O	O
1975	O	O	O	N.A.[2]	O	O
1976	O	O	O	N.A.[2]	O	O
1977	O	O	O	N.A.[2]	O	O
1978	O	O	O	N.A.[2]	O	O
1979	O	O	O	N.A.[2]	O	O
1980	O	O	O	N.A.[2]	O	O
1981	O	O	O	N.A.[2]	O	O
1982	O	O	O	N.A.[2]	O	O
1983	O	O	O	N.A.[2]	O	O
1984	O	O	O	N.A.[2]	O	O
1985	O	O	O	N.A.[2]	O	O
1986	O	O	O	N.A.[2]	O	O
1987	O	O	O	N.A.[2]	O	O
1988	O	O	O	N.A.[2]	O	O
1989	O	O	O	N.A.[2]	O	O
1990	O	O	O	N.A.[2]	O	O
1991	O	O	O	N.A.[2]	O	O
1992	O	O	O	partly N.A.[2]	O	O
1993	O	O	O	partly N.A.[2]	O	O
1994	O	O	partly N.A.[3]	partly N.A.[2]	O	O
1995	O	O	partly N.A.[3]	partly N.A.[2]	O	O
1996	O	O	O	partly N.A.[2]	O	O
1997	O	O	partly N.A.[3]	partly N.A.[2]	O	O
1998	O	O	partly N.A.[3]	N.A.[2]	O	O
1999	O	O	partly N.A.[3]	partly N.A.[2]	O	O
2000	O	O	partly N.A.[3]	partly N.A.[2]	O	O
2001	partly N.A.	partly N.A.	partly N.A.[3]	partly N.A.[2]	N.A.	N.A.
2002 (Jan-Sep)	partly N.A.	partly N.A.	O	N.A.[2]	N.A.	N.A.

Note: 1) The items marked "O" indicate the data provided as raw data by the Irrigation and Power Department, Lahore.

2) The discharge data at Chiniot bridge were estimated by regression curves obtained by the relationship between the raw data of water level and discharge in the years 1992 - 1997 and 1999 - 2000.

3) The water level data at Chiniot bridge from 1994 to 2001 were estimated by regression curves obtained by the relationship between the raw data of Rivaz bridge and Chiniot bridge in the years 1990 - 1993.

2) Outline of flood data in the past

Table-2 and Figure-1 show the maximum water level and discharge data at each station in each year. According to the table and figure, the years of high water flow are 1973, 1976, 1988, 1992, 1995, 1996 and 1997, while the years of drought are 1987 and 1998. The flood which occurred in 1973 is the severest one in the past 30 years. Maximum flood in each year occurs mostly in July or August, sometimes in September. Comparing the flood data of Rivaz bridge, Chiniot bridge and Qadirabad barrage, the time lag of floods from Qadirabad to Chiniot and from Chiniot to Rivaz is approximately one day (=24 hours) respectively.

Table-2 Flood data of Chenab river in the past 30 years

Year	Rivaz Bridge			Chiniot Bridge			Qadirabad Barrage		
	Maximum Discharge (cusec)	Maximum Water Level (ft)	Date	Maximum Discharge (cusec)	Maximum Water Level (ft)	Date	Maximum Discharge (cusec)	Maximum Water Level (ft)	Date
1970	123,221	518.45	03-Sep-1970	151,593	592.08	02-Sep-1970	237,572	693.82	01-Sep-1970
1971	201,878	518.80	12-Aug-1971	165,731	592.38	04-Aug-1971	305,968	694.80	03-Aug-1971
1972	87,082	517.25	14-Jul-1972	117,783	591.30	08-Aug-1972	178,203	693.70	10-Jul-1972
1973		523.00	12-Aug-1973	1,203,343	597.75	11-Aug-1973	847,249	699.45	10-Aug-1973
1974		517.30	07-Aug-1974	142,517	591.88	18-Jul-1974	198,228	693.70	25-Jul-1974
1975	148,200	517.80	13-Sep-1975	126,046	591.50	12-Sep-1975	198,210	691.20	12-Sep-1975
1976	651,000	521.50	09-Aug-1976	504,961	595.20	08-Aug-1976	577,015	696.00	07-Aug-1976
1977	225,900	518.00	07-Aug-1977	207,591	593.20	17-Jul-1977	452,532	695.60	17-Jul-1977
1978	139,575	518.90	12-Aug-1978	141,180	591.85	23-Jul-1978	293,418	695.50	10-Aug-1978
1979	142,326	518.00	06-Aug-1979	89,291	590.55	19-Jul-1979	240,785	694.10	03-Aug-1979
1980	167,117	518.00	17-Jul-1980	117,783	591.30	17-Jul-1980	97,697	694.10	10-Aug-1980
1981	275,000	520.00	29-Jul-1981	154,835	592.15	31-Jul-1981	505,638	696.90	26-Jul-1981
1982	182,000	518.30	04-Aug-1982	128,156	591.55	03-Aug-1982	225,517	694.50	02-Aug-1982
1983	182,420	518.30	05-Sep-1983	147,929	592.00	04-Sep-1983	283,229	695.95	03-Sep-1983
1984	156,800	517.80	30-Aug-1984	86,698	590.45	15-Aug-1984	90,023	694.30	15-Aug-1984
1985	226,000	519.00	10-Aug-1985	152,516	592.10	09-Aug-1985	213,460	696.40	19-Jul-1985
1986	177,000	518.20	07-Aug-1986	161,899	592.30	06-Aug-1986	244,022	695.40	06-Aug-1986
1987	115,000	516.70	29-Jul-1987	78,254	590.00	28-Jul-1987	96,996	693.10	09-May-1987
1988	550,000	521.20	29-Sep-1988	630,340	595.75	28-Sep-1988	529,664	698.70	27-Sep-1988
1989	245,000	519.30	03-Aug-1989	218,515	593.40	01-Aug-1989	295,085	697.10	01-Aug-1989
1990	250,000	519.40	24-Mar-1990	141,180	591.85	15-Jul-1990	339,191	696.00	23-Mar-1990
1991	226,000	518.80	16-Apr-1991	147,929	592.00	15-Jul-1991	249,663	694.50	15-Apr-1991
1992	475,000	520.50	13-Sep-1992	529,400	595.70	12-Sep-1992	948,530	700.30	11-Sep-1992
1993	282,000	519.80	14-Jul-1993	282,500	594.00	13-Jul-1993	434,754	697.30	12-Jul-1993
1994	274,900	519.80	23-Jul-1994	166,696	592.40	06-Aug-1994	425,567	697.00	21-Jul-1994
1995	620,000	521.60	01-Aug-1995	667,000	596.00	30-Jul-1995	640,577	698.40	29-Jul-1995
1996	785,000	522.60	27-Aug-1996	700,000	596.20	26-Aug-1996	728,432	699.90	25-Aug-1996
1997	587,000	521.80	31-Aug-1997	546,600	595.30	30-Aug-1997	600,246	699.70	29-Aug-1997
1998	126,000	517.00	07-Jul-1998	76,255	589.89	07-Jul-1998	68,983	698.80	01-Aug-1998
1999	97,000	516.30	10-Aug-1999	90,200	590.60	09-Aug-1999	111,102	691.50	08-Aug-1999
2000	186,420	518.50	25-Jul-2000	147,200	592.20	25-Jul-2000	190,640	693.50	24-Jul-2000
2001	115,000	516.70	26-Jul-2001	80,000	590.00	25-Jul-2001			
2002				147,200	592.20	16-Aug-2002			

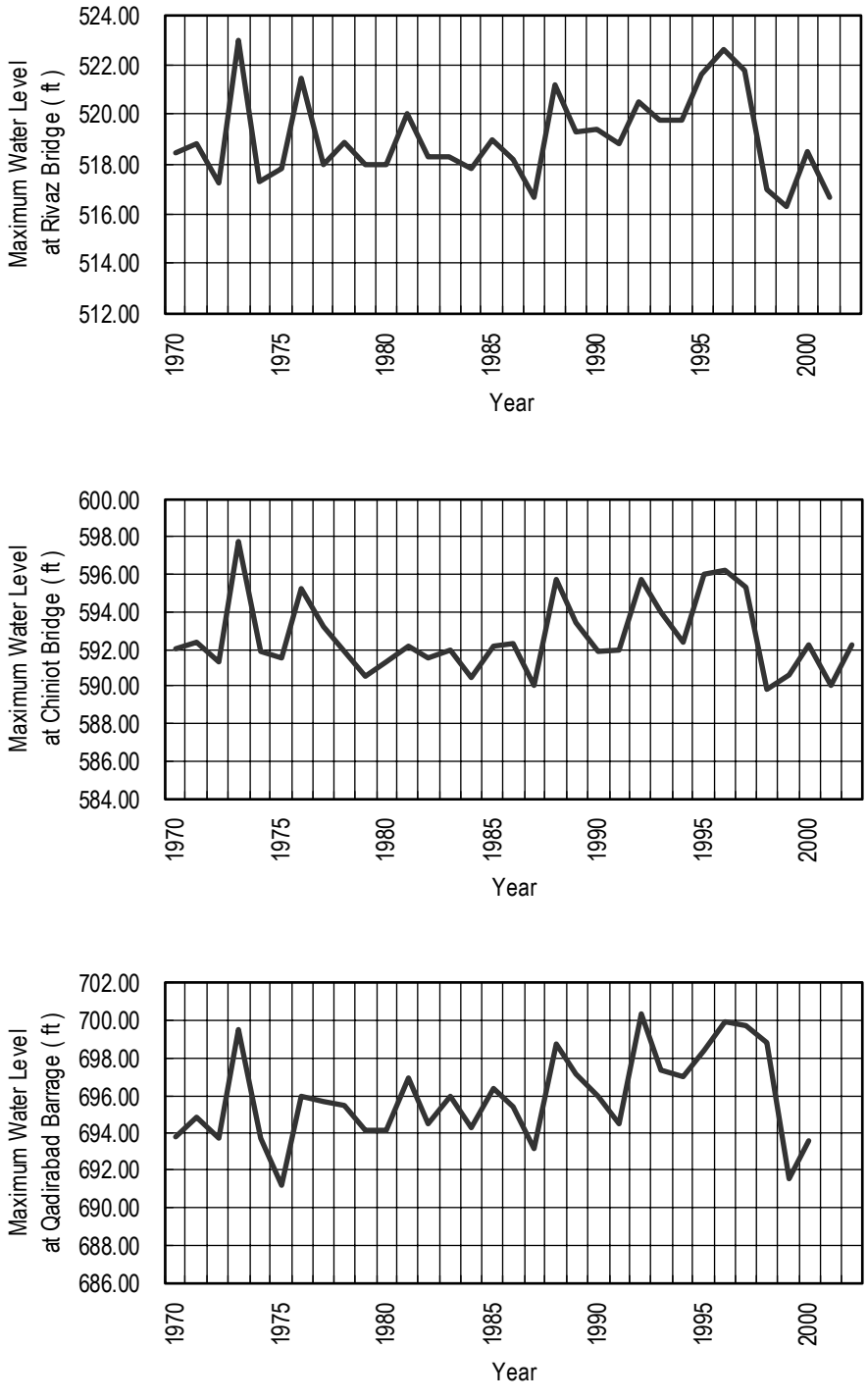


Figure-1 Flood data of Chenab river in the past 30 years

3) Characteristics of the distribution of water level and discharge

Figure-2 shows the annual change of water level and discharge at Chiniot bridge in several typical years of high water flow and drought. In the years of drought, water level usually does not go up to the level of more than 590.0 or 591.0 feet, and discharge does not go up to more than 80,000 or 90,000 cusec. Water level ranges from 583.0 to 591.0 feet in wet season from March to September, from 581.5 to 583.0 feet in other months. On the other hand, in the years of high water flow, several days from July to September show the water level of more than 590.0 feet and the discharge of more than 200,000 cusec.

Figure-3 indicates the distribution of the discharge at Chiniot bridge in several typical years of high water flow and drought. The characteristics of the typical years are shown in Table-3.

Table-3 Characteristics of the years of high water flow and drought

	Typical years of high water flow	Typical years of drought
Maximum water level in a year	> 595.0 feet	< 591.0 feet
Maximum discharge in a year	> 500,000 cusec	< 90,000 cusec
Total discharge in a year	19.0 - 37.0 billion m^3	15.0 - 20.0 billion m^3
Number of days more than 50,000 cusec	35 - 100 days	25 - 70 days
Number of days more than 100,000 cusec	10 - 40 days	0 days
Number of days more than 200,000 cusec	1 - 10 days	0 days

Figure-4 shows the logarithmic normal distribution of annual maximum discharge in the past 33 years. Based on this distribution, the return period for annual maximum discharge in each year is obtained as indicated in Table-4.

Table-4 Return period for annual maximum discharge

Year	Maximum discharge (cusec)	Return period
1973	1,203,343	approximately 50 years
1996	700,000	15 to 20 years
1995	667,000	10 to 15 years
1988	630,343	10 to 15 years
1997	546,600	5 to 10 years
1992	529,400	5 to 10 years
1976	504,961	5 to 10 years

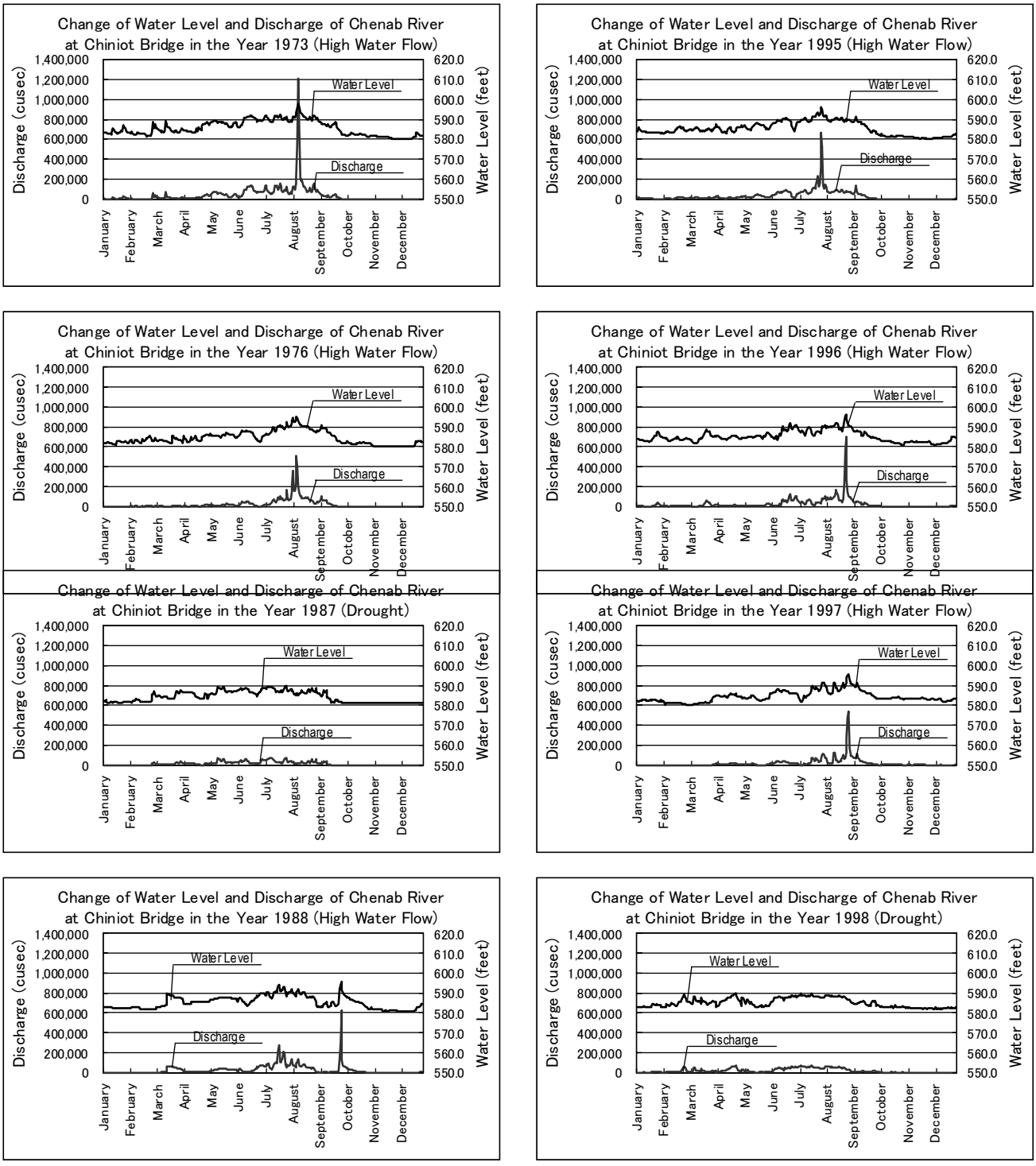
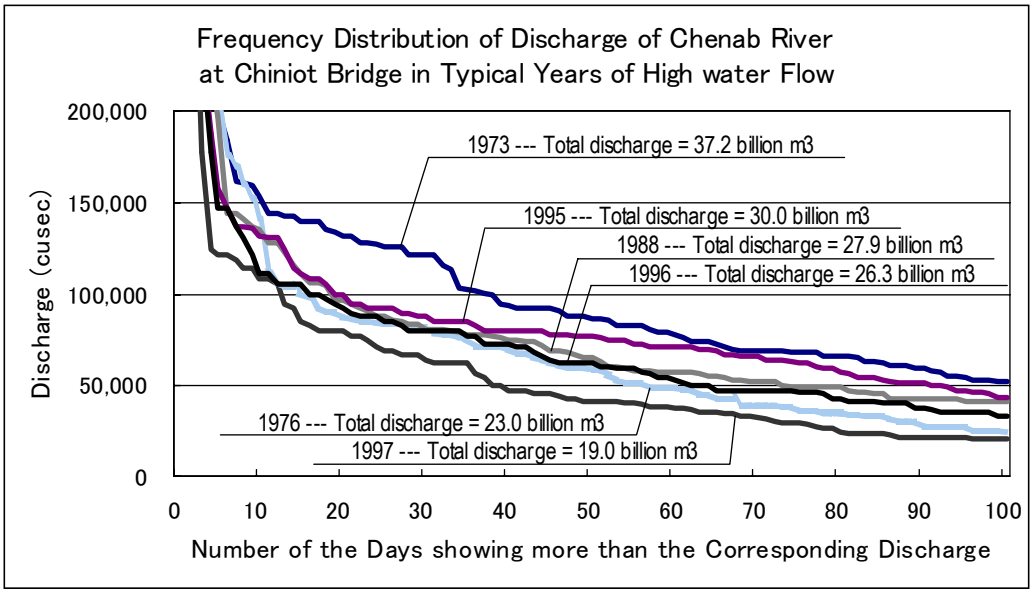


Figure-2 Annual change of water level and discharge at Chiniot bridge

Typical year of high water flow: 1973, 1976, 1988, 1995, 1996, 1997.

Typical year of drought: 1987, 1998.



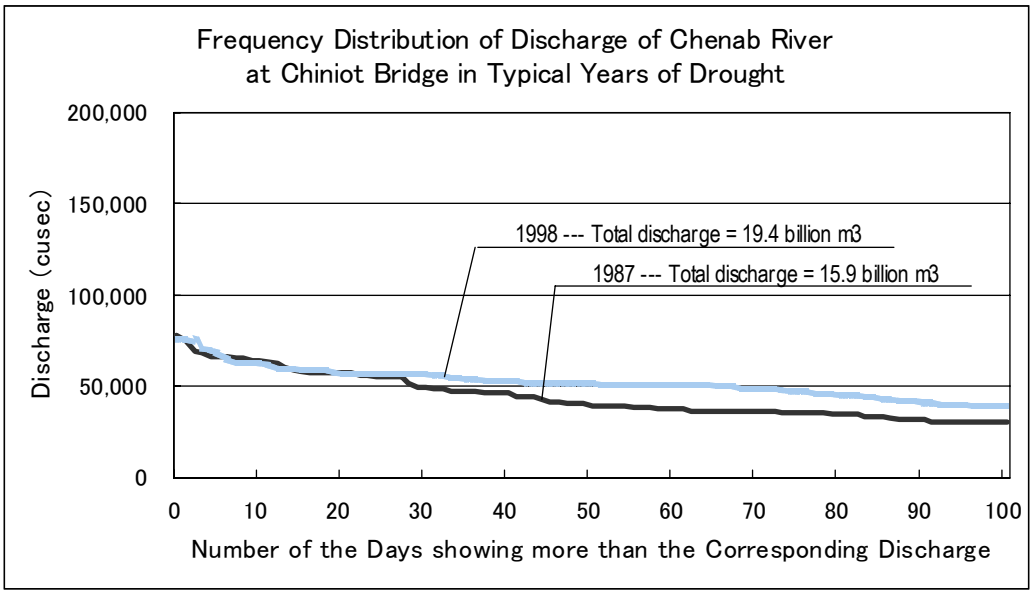
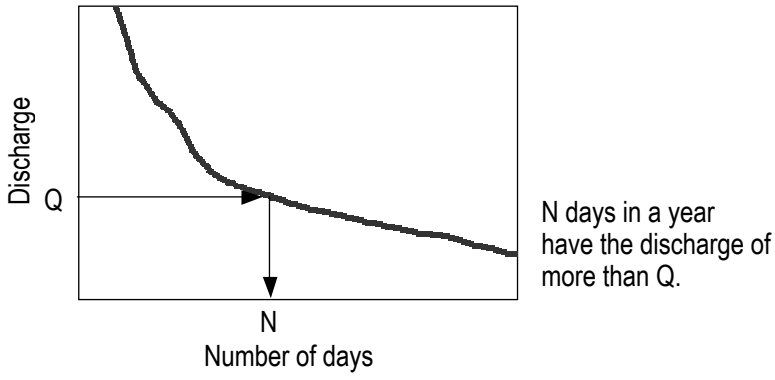


Figure-3 Distribution of discharge at Chiniot bridge

Note: The meaning of the above charts is as follows:



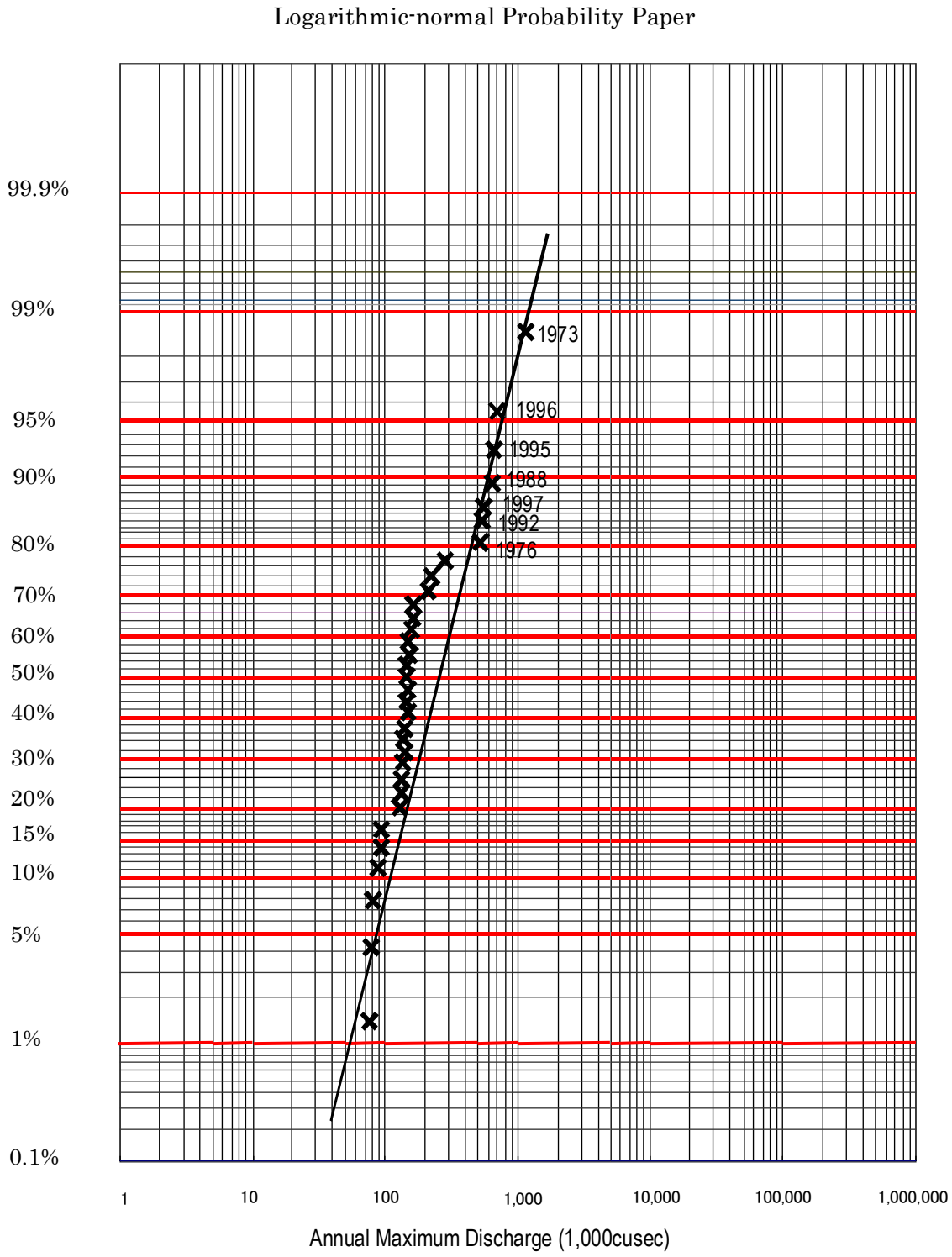


Figure-4 Logarithmic normal distribution of annual maximum discharge

4) Characteristics of the flood flow in the Chenab river basin

Figure-5 shows the situation of floods in the past, that is, the range of flooded area in several years when severe flood occurs, with water depth at several points indicated according to the interview results. As is clarified by the numerical data analysis, the interview results also show that severe flood occurred in the years 1973, 1992, 1995 and 1997. In 1973 when the severest flood in the past 30 years occurred, the flood overflowed the Chiniot-Jhang road, while such severe flood has not occurred in other years.

The left bank of the river is composed of several terraces which are 2 to 4 meter high, and the ups and downs are rather big. Therefore, the left bank is of higher ground level than the right bank side.

The bed and the bank of the river are made of sandy loose soils which compose terraces of 2 to 4 meter height. According to the fact that the main stream of the river is running close to the right bank, and that the right bank is of lower ground level than the left bank, the right bank side has been more easily and more frequently attacked and broken by floods.

The location of the well construction site and the protection measures against the influence of floods should be determined taking into consideration the topographical features of the river bed and the bank. According to the above-mentioned facts, the left bank side, if it is on a higher terrace and far from the river bed, has little fear of being attacked by floods.

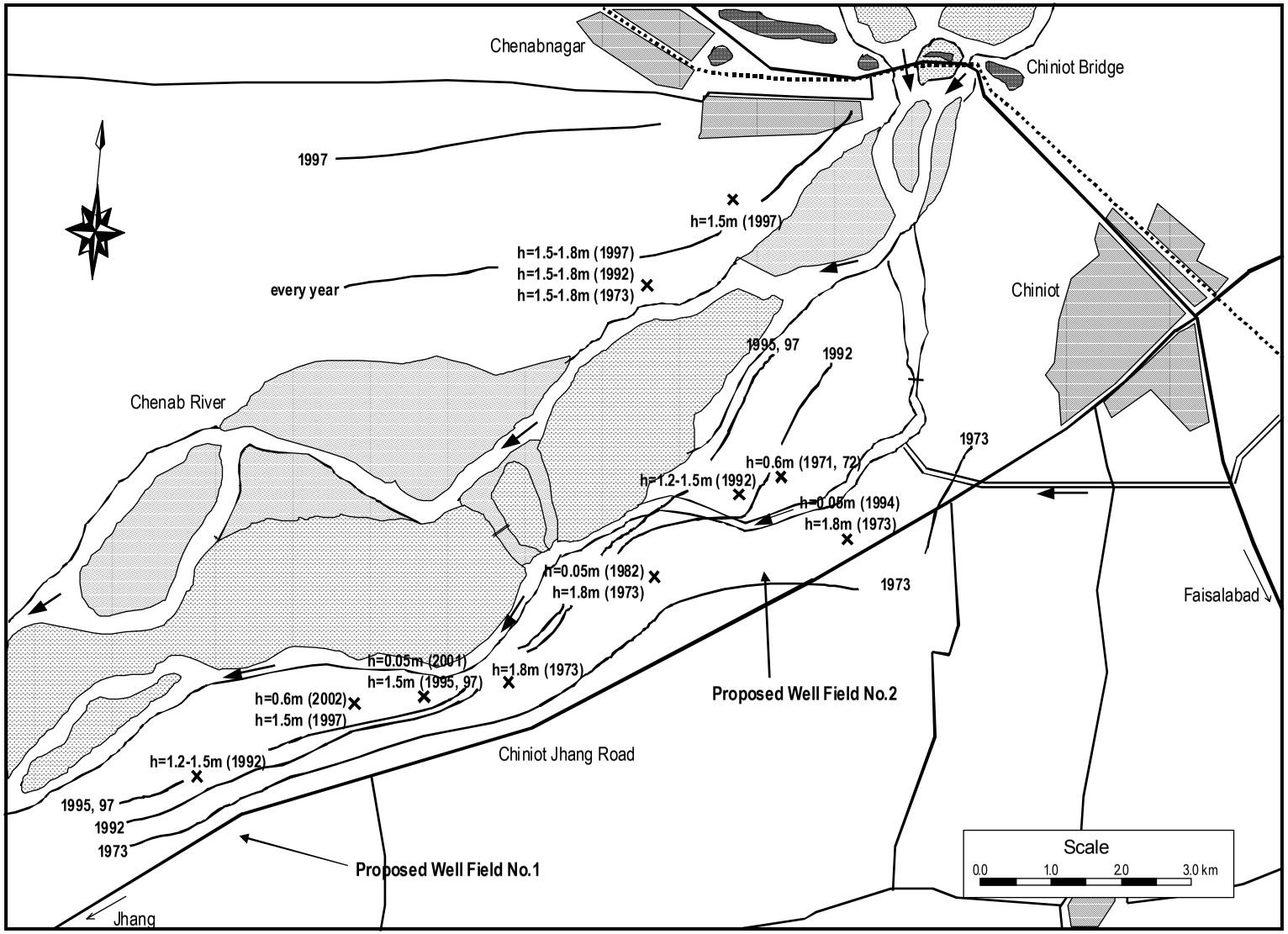


Figure-5 Situation of the flooded area in the past

5. Conclusion

The proposed well fields, Alternative-1 and Alternative-2, are located in the vicinity of Chenab river bed. The left bank side where the well fields are planned are composed of several terraces, and far from the main stream of the river. Consequently, if the proposed facilities are constructed on a higher terrace, far from the river bed, there is not a worry about the influence of flood on the facilities. It should be noted that the construction site be determined in consideration of the topographic features of the river bed and the river bank.

Appendix 5-3 Geophysical Survey

1) Outline of the Survey

The geophysical survey of the proposed wellfield and its vicinity was carried out in an area about 12km long and 3 km wide along the Jhang Branch Canal to examine the vertical and horizontal continuity of prospective aquifers that can provide information on design for screen length, basic drilling depth in the wellfield, etc..

The outline of the survey was as shown in the following table.

Table 1 Outline of Geophysical Survey

	Item	Description
1	Period of field survey	Aug. 15 to Aug. 21, 2003
2.	Type of the survey	Surface electrical resistivity survey
3.	No. of resistivity stations	24 stations
4.	Method of the survey	Wenner 4-electrode configuration
5	Depth of measurement	200m
6	Layout of stations	a No. 1 track just beside the embankment of left bank (11 stations) b. No. 2 track one km south of No. 1 (9 stations) 3. No. 3 track about one km south of No. 2 (4 stations) (Refer to Fig. 2-2-1-8 for locations.)

(Refer to Fig. 1 for the locations of survey stations.)

2) Survey Results

After the field survey, the data analysis was made, based upon geological information from the records of drilling carried out in and around the survey area. For this study, the following data is available:

a. Lithology of the test well installed by Binnie & Partners at RD259
b. Lithology of the test well installed by REC at RD245
c. Lithology of the test well under this study at RD 245

The results of analysis are summarized as follows:

a. Unconsolidated deposits continue from surface down to 200m and seem to compose a single continued aquifer as a whole. According to the analysis, this aquifer is divided into 3 sections, each one separated with an interbed of clayey formations

with relatively low permeability, as follows:

* First section	up to 30 m in depth
*Second section	up to 76 to 140 m in depth
*Third section	up to 170 m in depth

b. The main aquifer is the second section. Although it varies slightly in depth along the track from upstream to downstream, it is uniformly distributed through the area, showing the highest values of resistivity.

c. The occurrence of the third section seems to depend upon the location. Some stations lack this section. For the construction of production wells, it is planned to confirm it with the geophysical survey at the very points where they are to be drilled.

d. The horizontal relation of the second and the sections are confirmed through the analysis. Therefore, drilling depth is recommended to be the average of 150 and 170m, namely 160m.

e. The first section is composed of Recent deposits of mainly sand where unconfined groundwater flows through. Irrigation tubewells tap this section, with a part of them further reaching the upper horizon of the second section.

f. The second and the third sections are interpreted to consist of Pleistocene alluvium of fine to medium sand. Each of the aquifers can further be subdivided into 3 to 4 layers from clayey materials to sand. Those showing high resistivity is sand, while those with low one is clayey materials.

The plotted curves of 24 stations are attached herewith, together with a sectional correlation of layers at the 11 stations along the first measurement line. All of the plots show similar trends in the pattern of their curves, indicating similar hydrogeological characteristics of the subsurface conditions along the measurement line. The typical trends of the plotted curves are shown in Fig. 2.

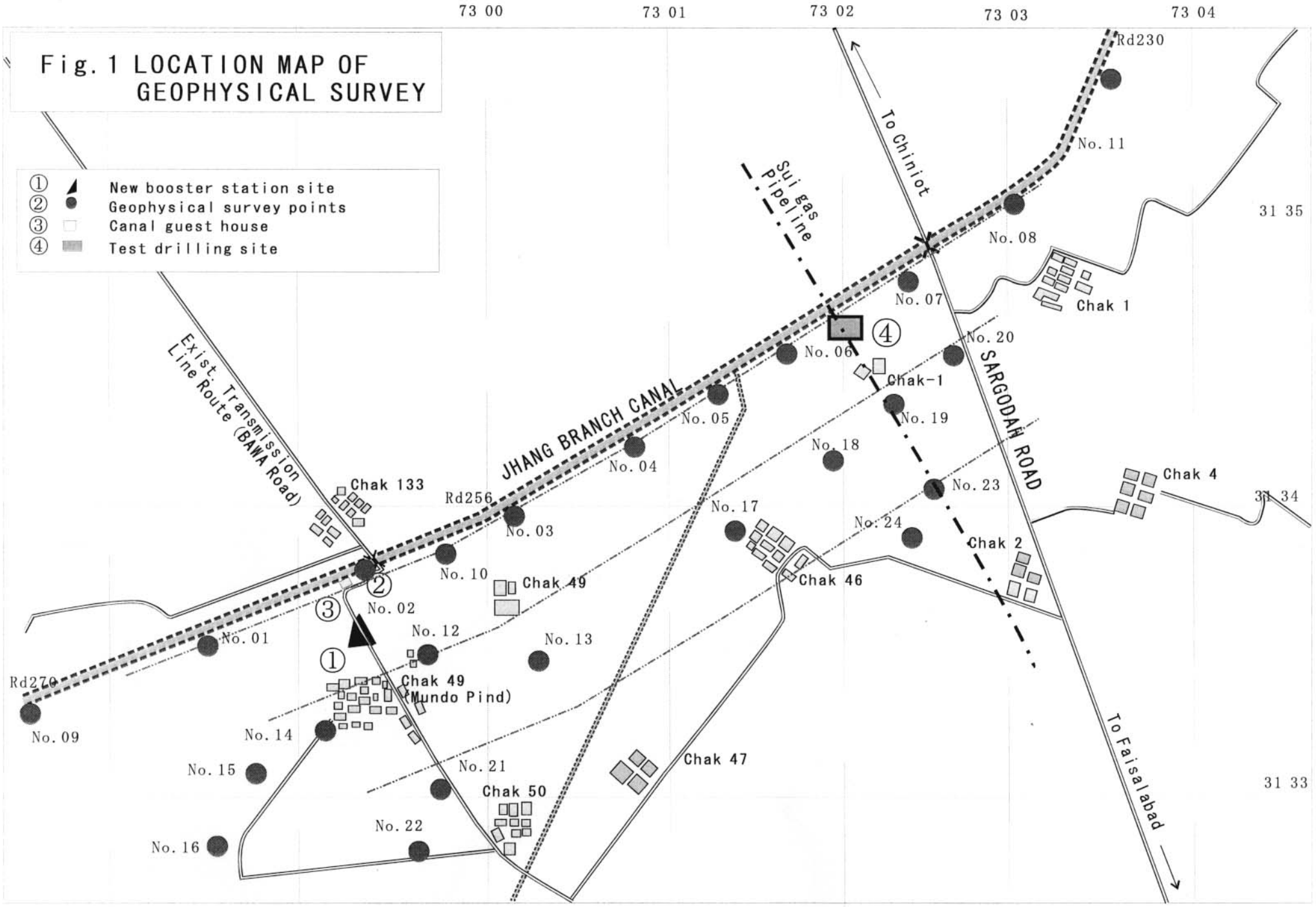


Fig. 1 LOCATION MAP OF GEOPHYSICAL SURVEY
① New booster station site
② Geophysical survey points
③ Canal guest house
④ Test drilling site
73 00
73 01
73 02
73 03
73 04
31 35
31 34
31 33
Rd230
To Chiniot
Sui gas Pipeline
No. 11
No. 08
No. 07
Chak 1
④
No. 06
No. 20
Chak-1
No. 19
No. 05
No. 18
No. 04
JHANG BRANCH CANAL
SARGODAH ROAD
Exist. Transmission Line Route (BAWA Road)
Chak 133
Rd256
No. 03
No. 17
No. 23
Chak 4
No. 24
Chak 2
No. 10
Chak 49
Chak 46
②
③
No. 02
No. 01
No. 12
No. 13
①
Rd270
Chak 49 (Mundo Pind)
No. 09
No. 14
No. 15
No. 21
Chak 50
Chak 47
No. 22
No. 16
To Faisalabad

Fig. 2 Typical plot pattern

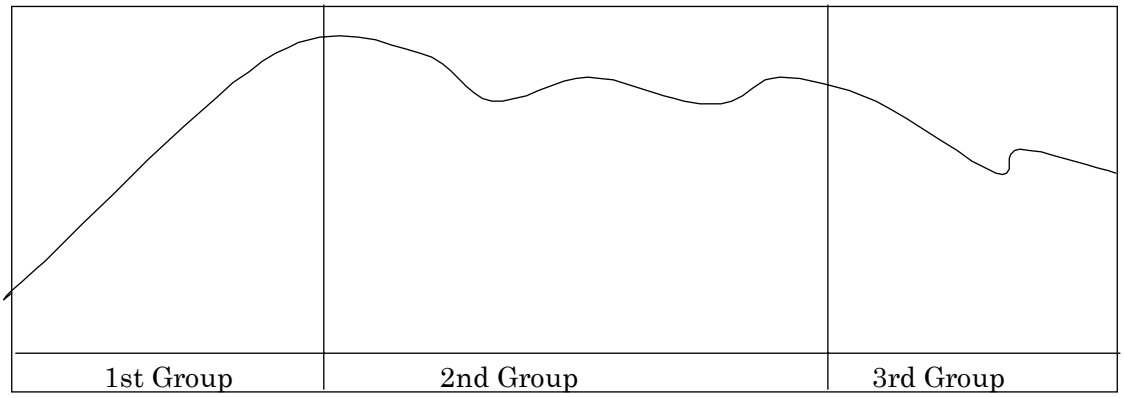
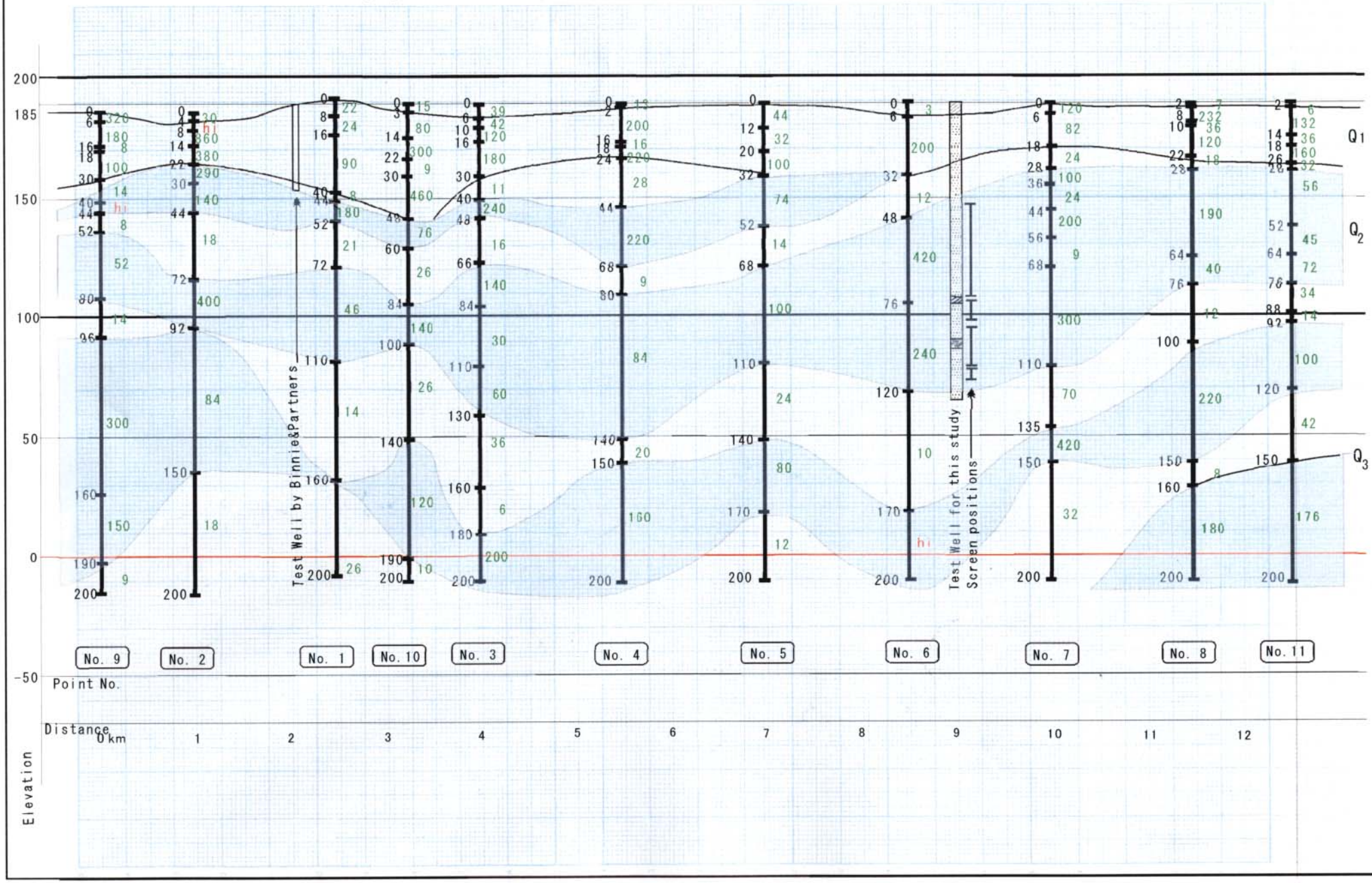
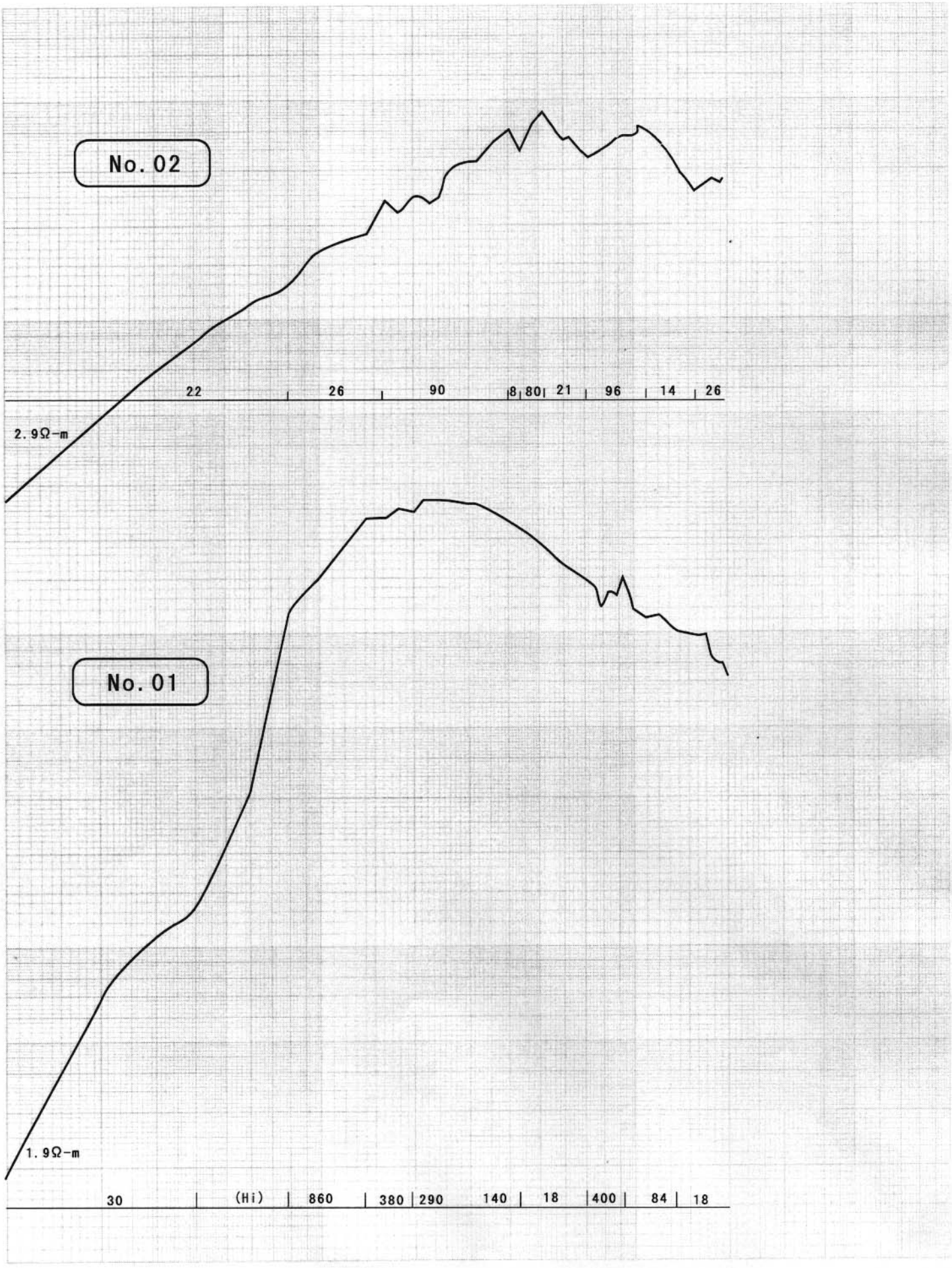
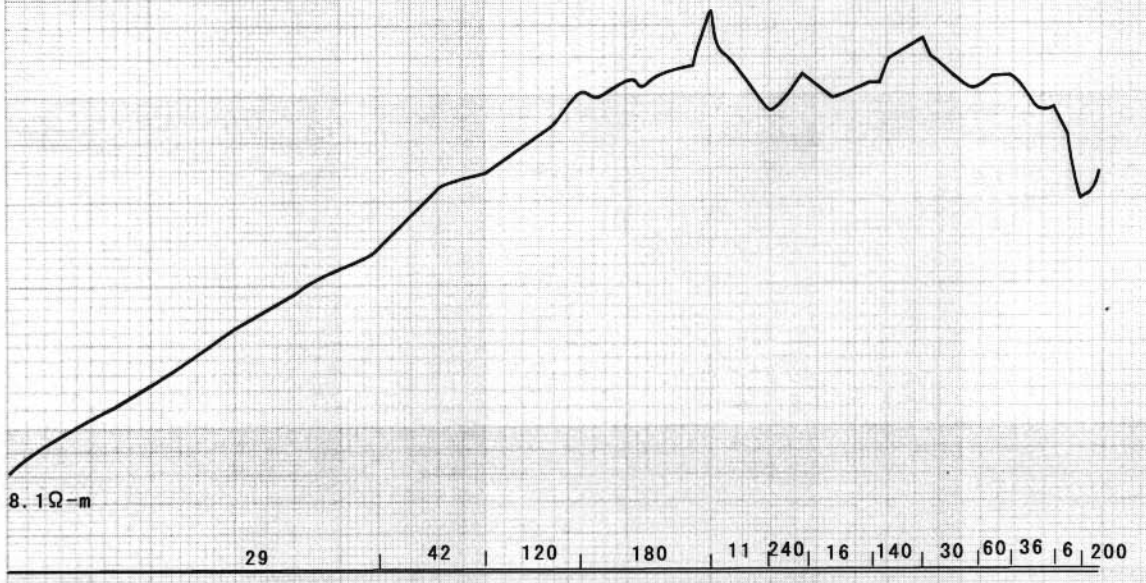


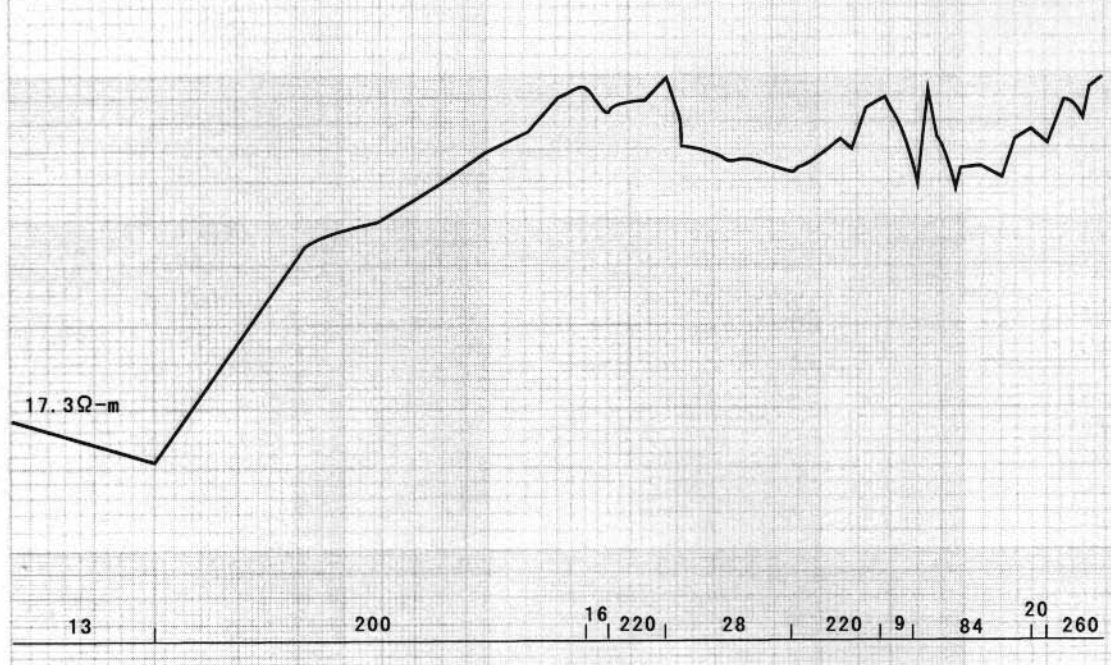
Fig. 3 Correlated Aquifer Section Based on the Geophysical Survey

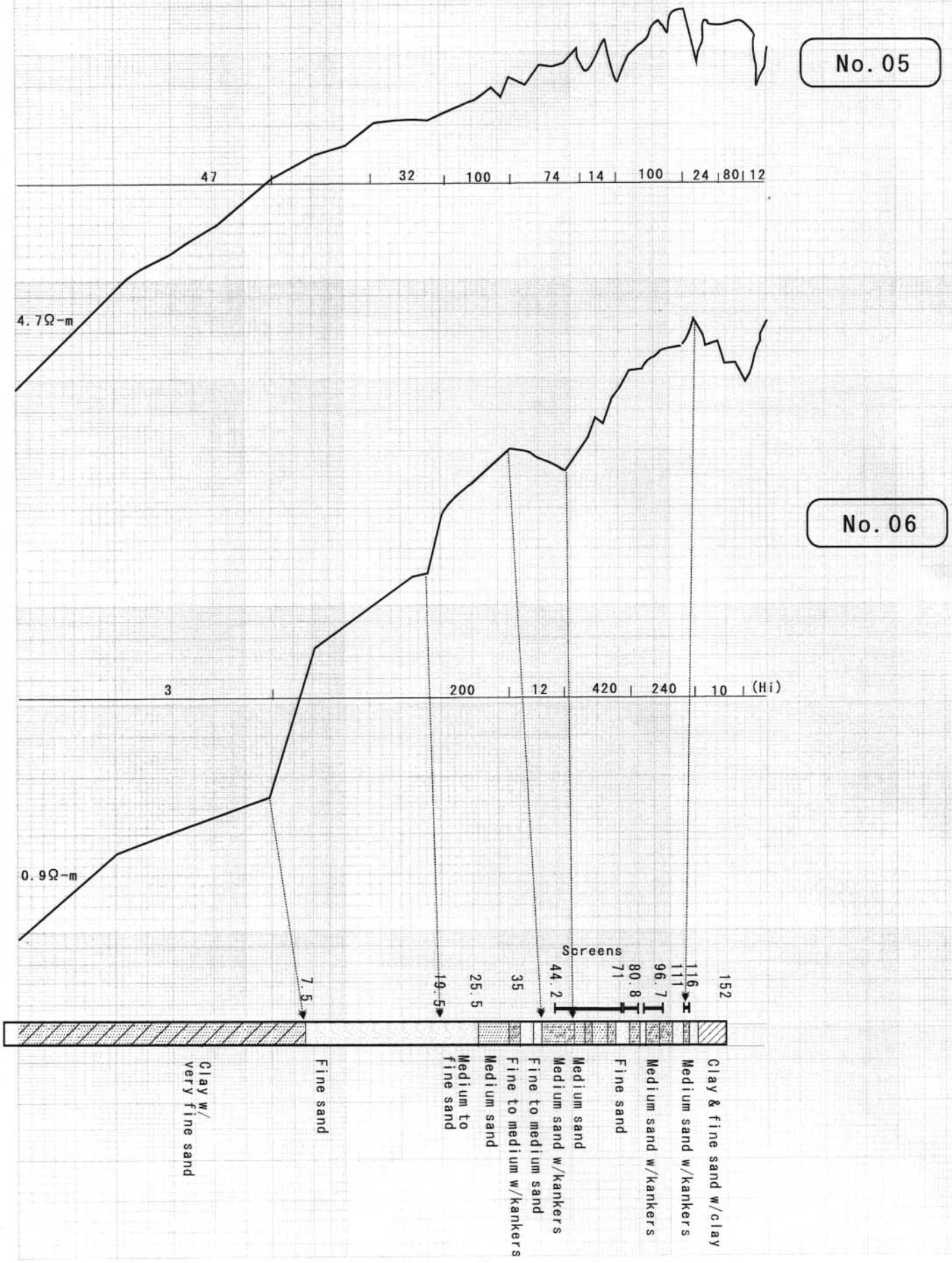
Figures indicate: Black ones, analyzed depth
Green ones: analyzed resistivity




No. 02
22
26
90
8
80
21
96
14
26
2.9Ω-m
No. 01
1.9Ω-m
30
(Hi)
860
380
290
140
18
400
84
18


No. 03
8.1Ω-m
29
42
120
180
11
240
16
140
30
60
36
6
200


No. 04
17.3Ω-m
13
200
16
220
28
220
9
84
20
260


No. 05
47
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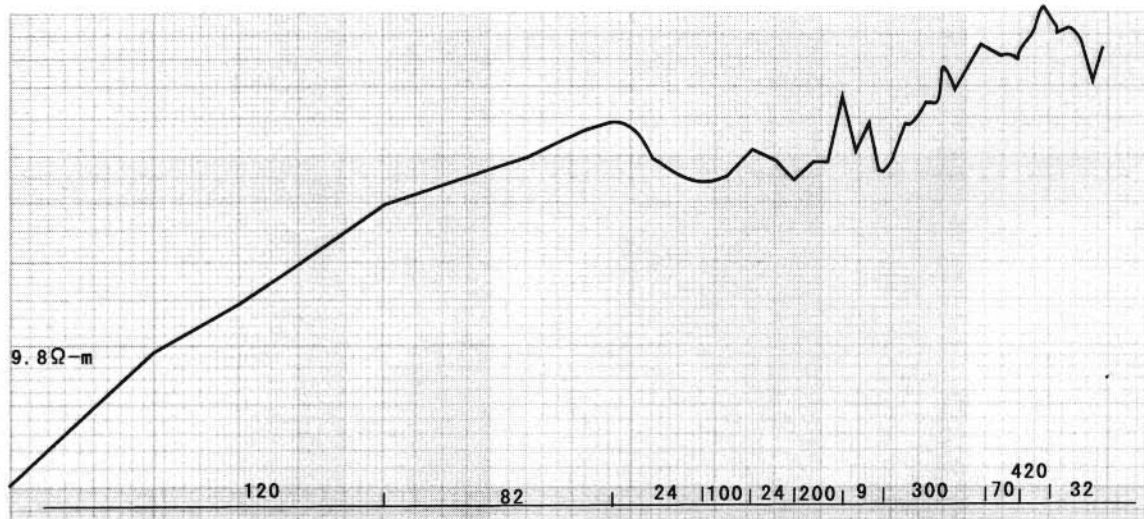
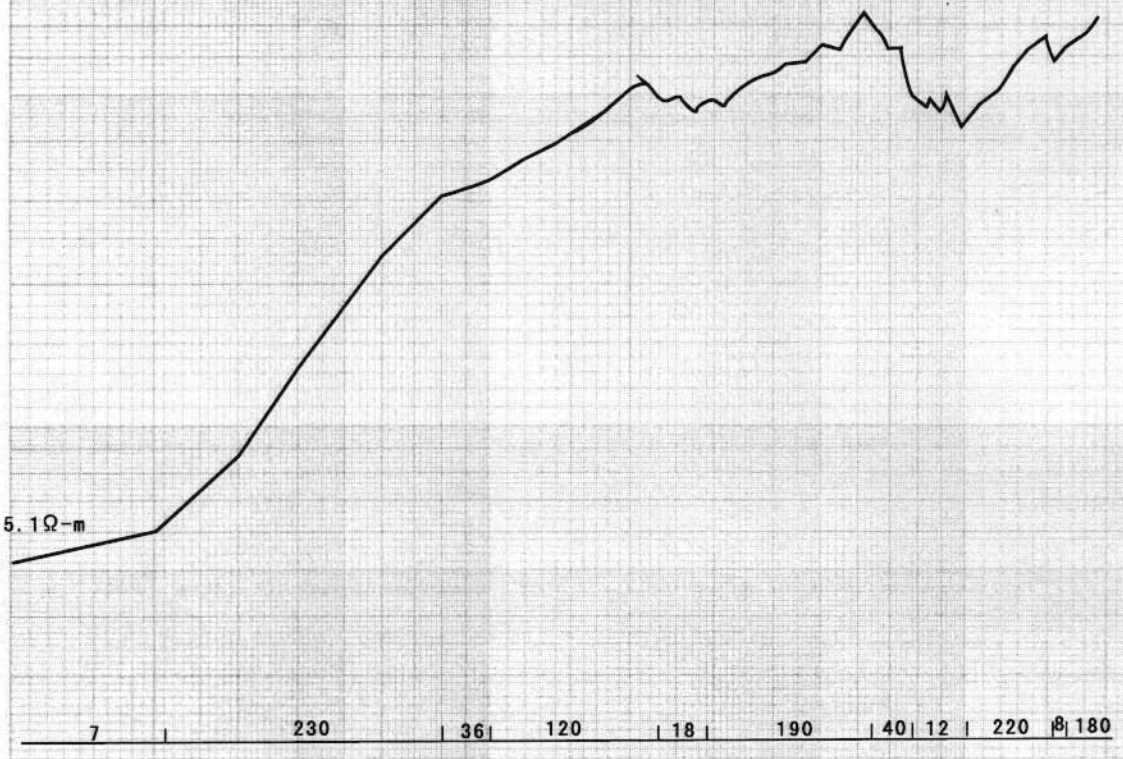
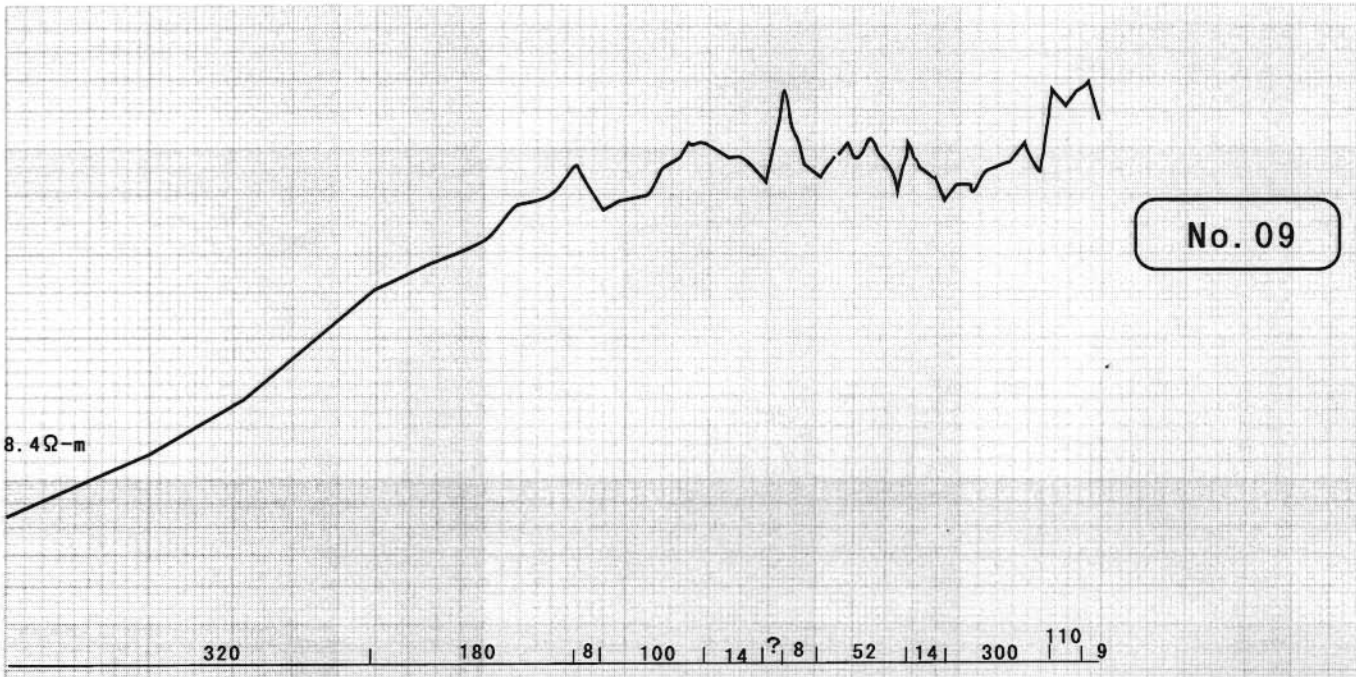
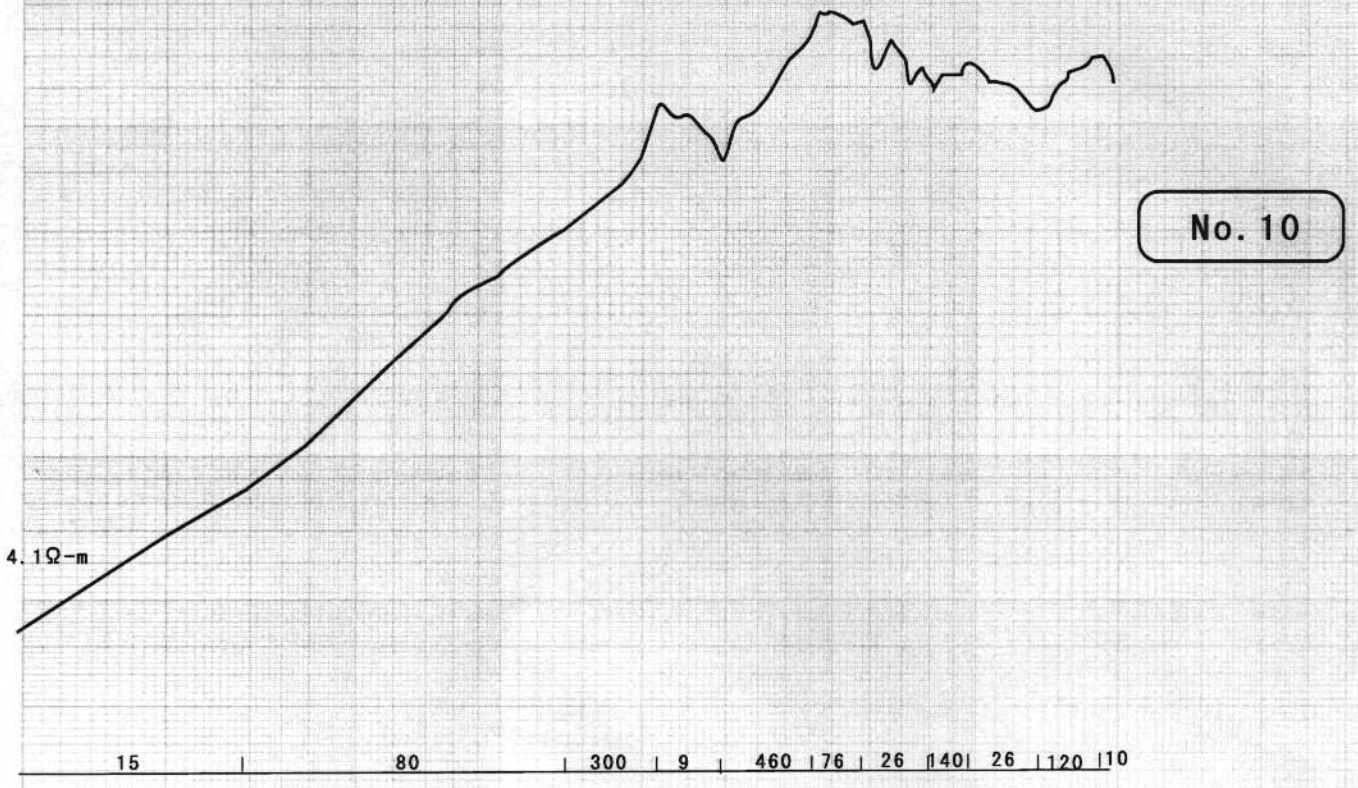
74
14
100
24
80
12
4.7Ω-m
No. 06
3
200
12
420
240
10
(Hi)
0.9Ω-m
Screens
7.5
19.5
25.5
35
44.2
71
80.8
96.7
111
116
152
Clay w/ very fine sand
Fine sand
Medium to fine sand
Medium sand
Fine to medium w/kankers
Fine to medium sand
Medium sand w/kankers
Medium sand
Fine sand
Medium sand w/kankers
Medium sand w/kankers
Clay & fine sand w/clay

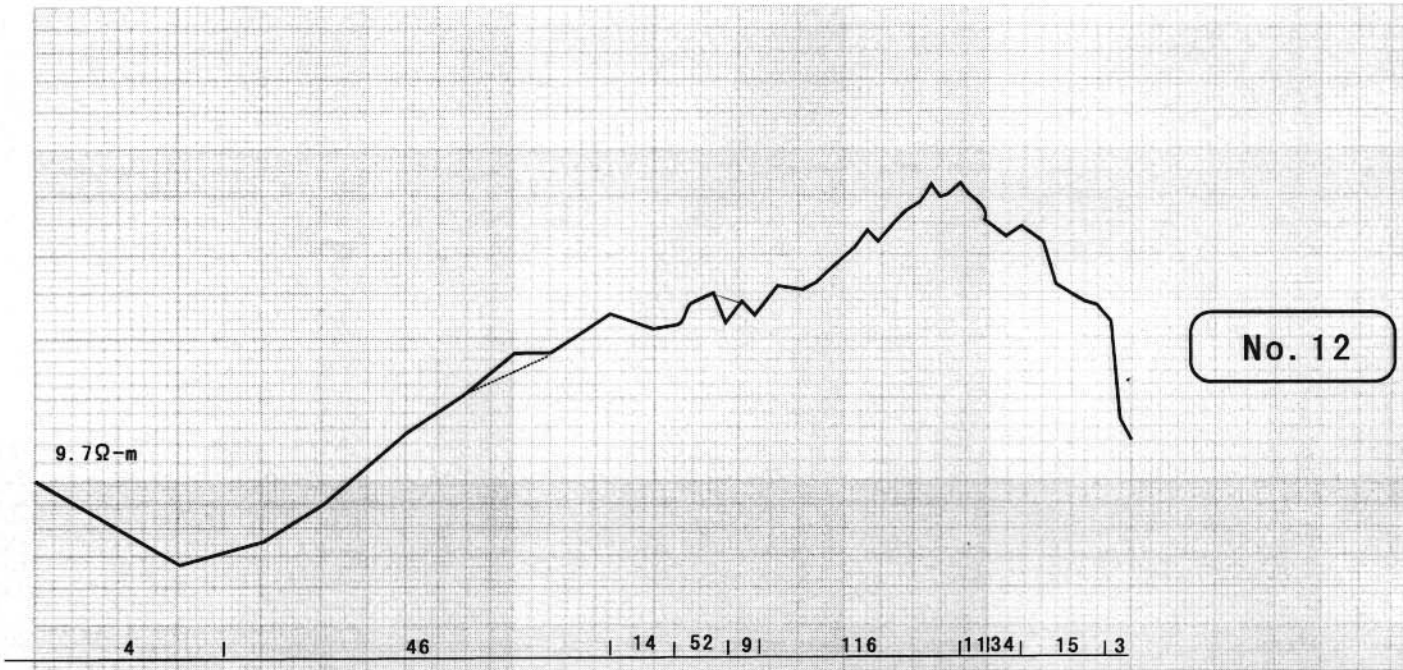

No. 07
9.8Ω-m
120
82
24
100
24
200
9
300
70
420
32

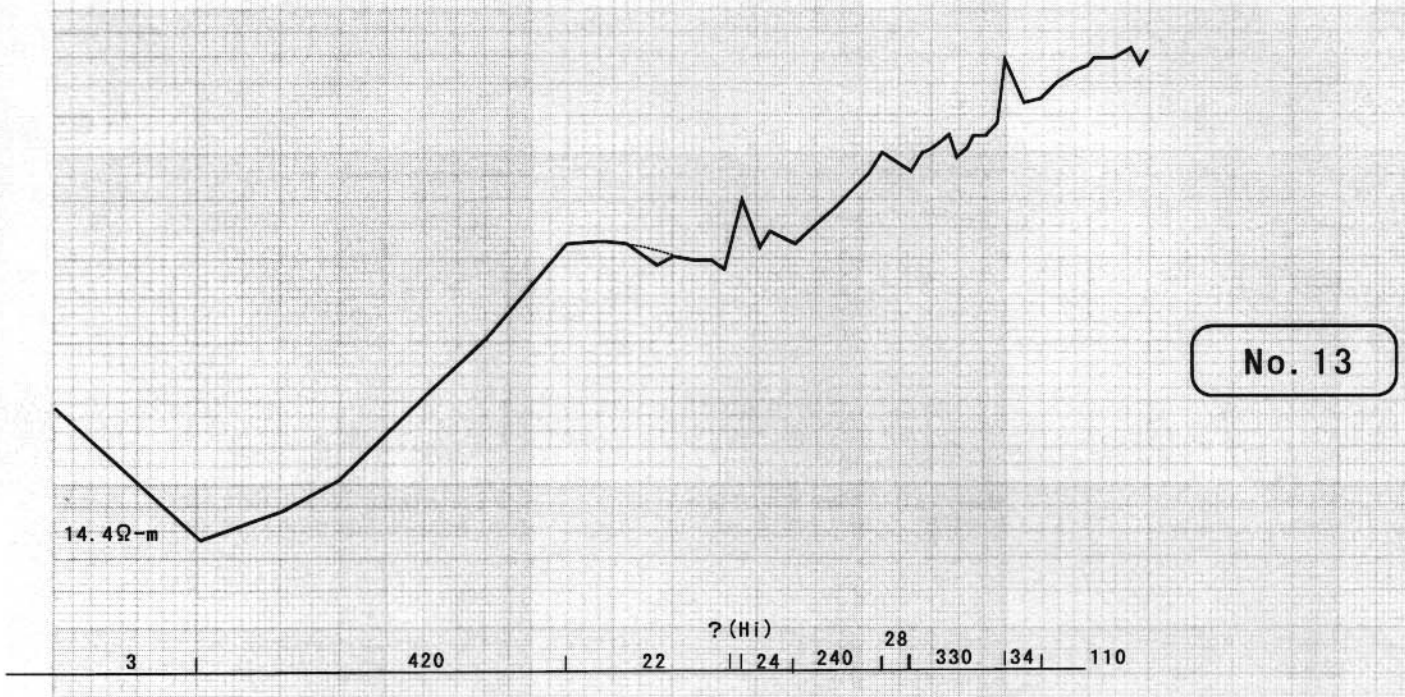

No. 08
5.1Ω-m
7
230
36
120
18
190
40
12
220
8
180

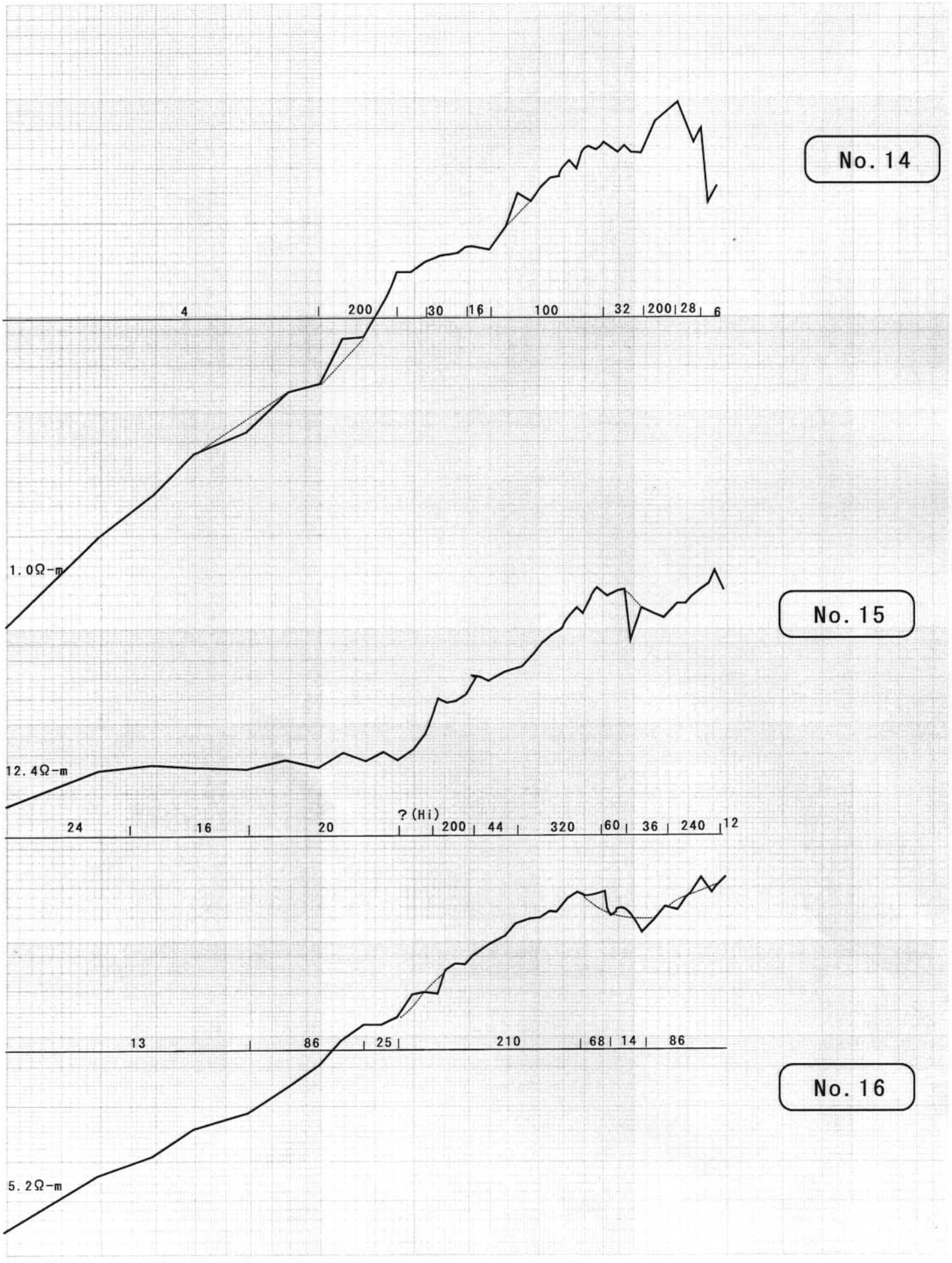

No. 09
8.4Ω-m
320
180
8
100
14
?
8
52
14
300
110
9

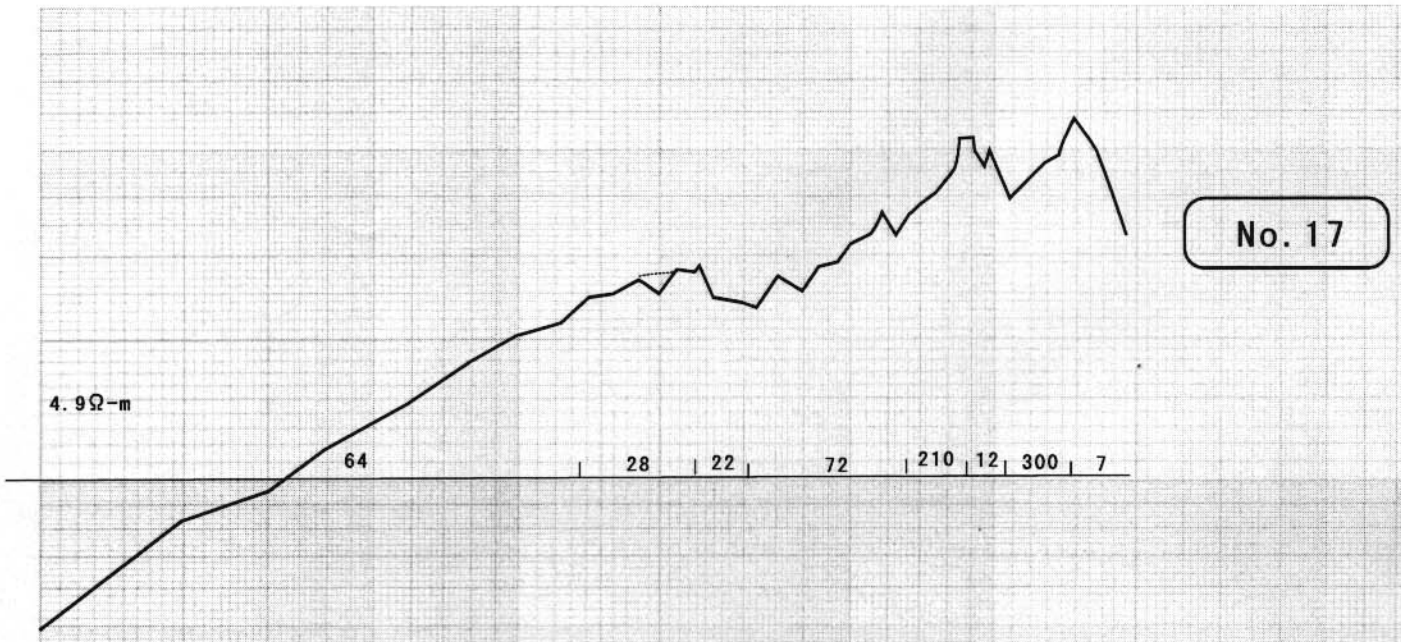

No. 10
4.1Ω-m
15
80
300
9
460
76
26
140
26
120
10

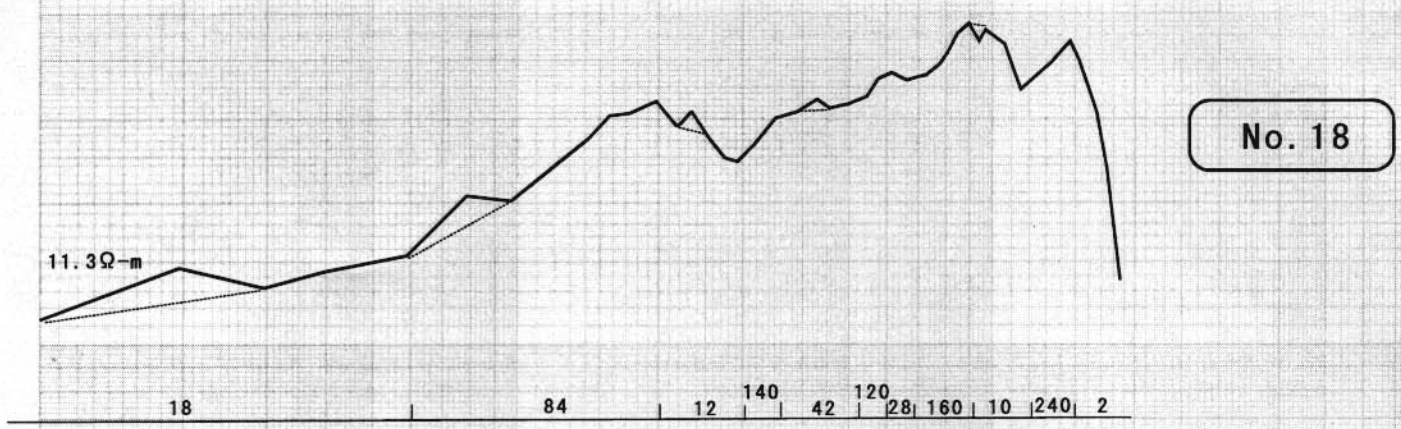
No. 11

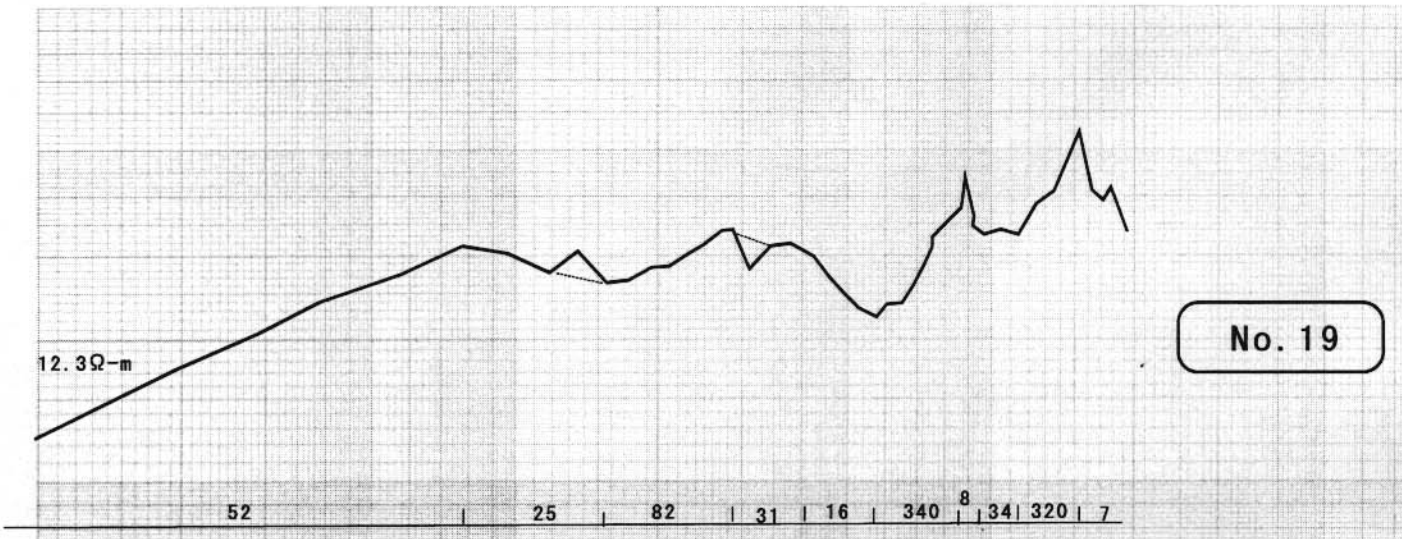

No. 12
9.7Ω-m
4
46
14
52
9
116
11
34
15
3

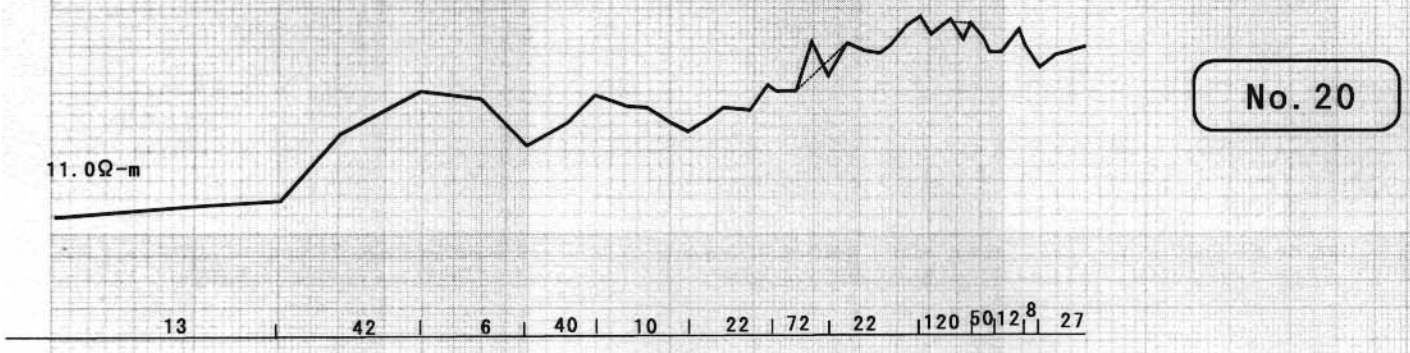

No. 13
14.4Ω-m
3
420
22
?(Hi)
24
240
28
330
34
110

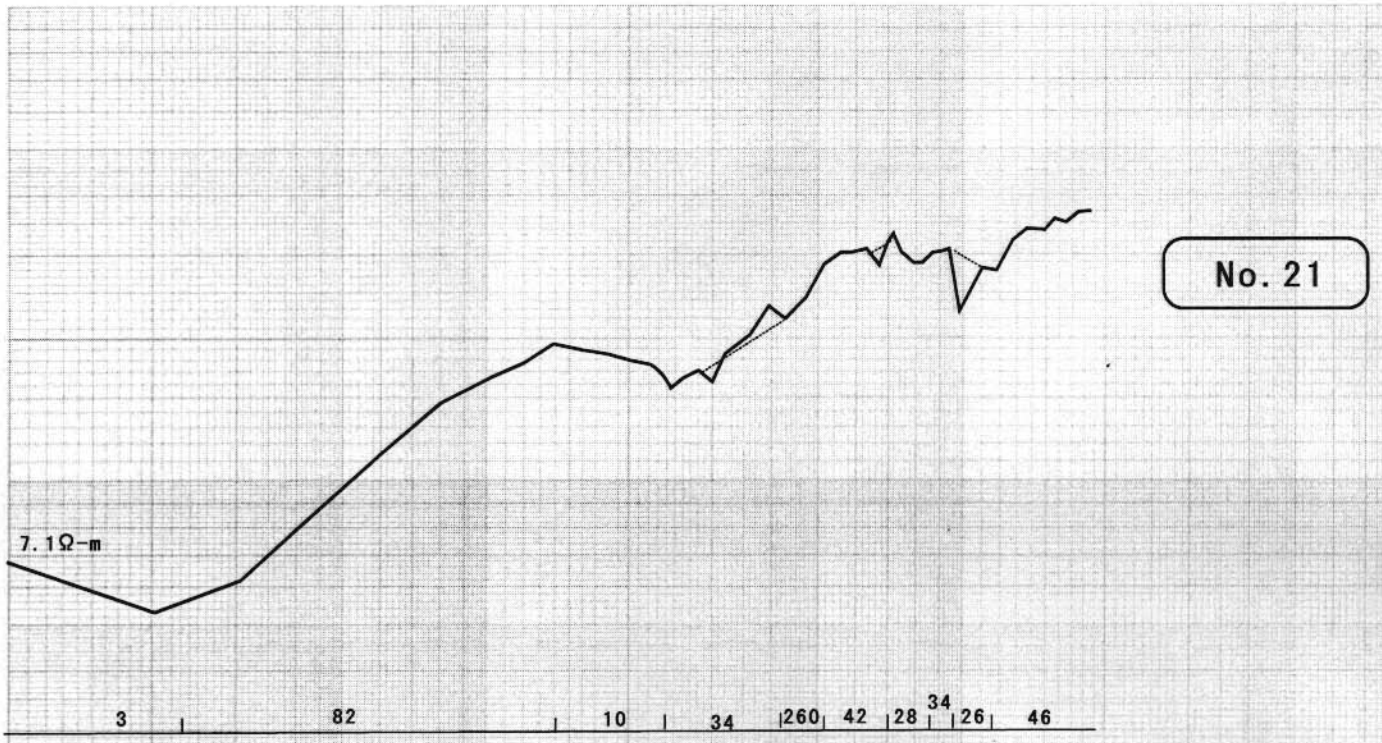

No. 14
4
200
30
16
100
32
200
28
6
1.0Ω-m
No. 15
12.4Ω-m
24
16
20
? (Hi)
200
44
320
60
36
240
12
No. 16
13
86
25
210
68
14
86
5.2Ω-m

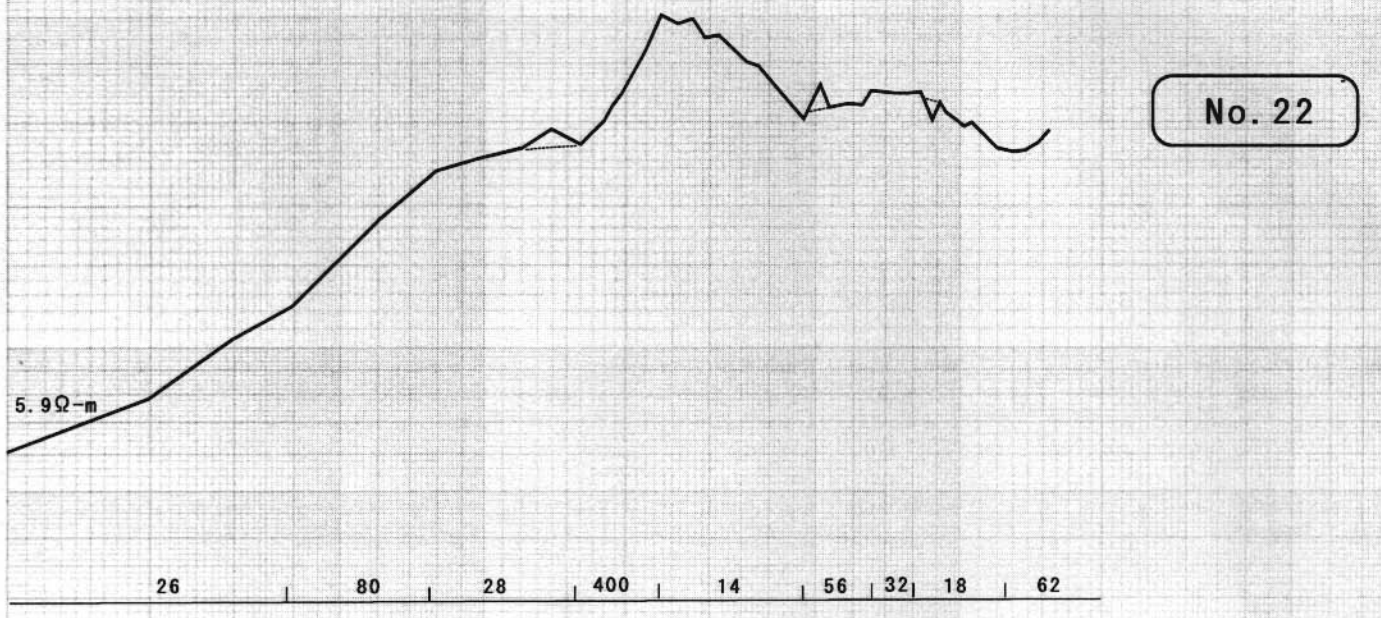

No. 17
4.9Ω-m
64
28
22
72
210
12
300
7

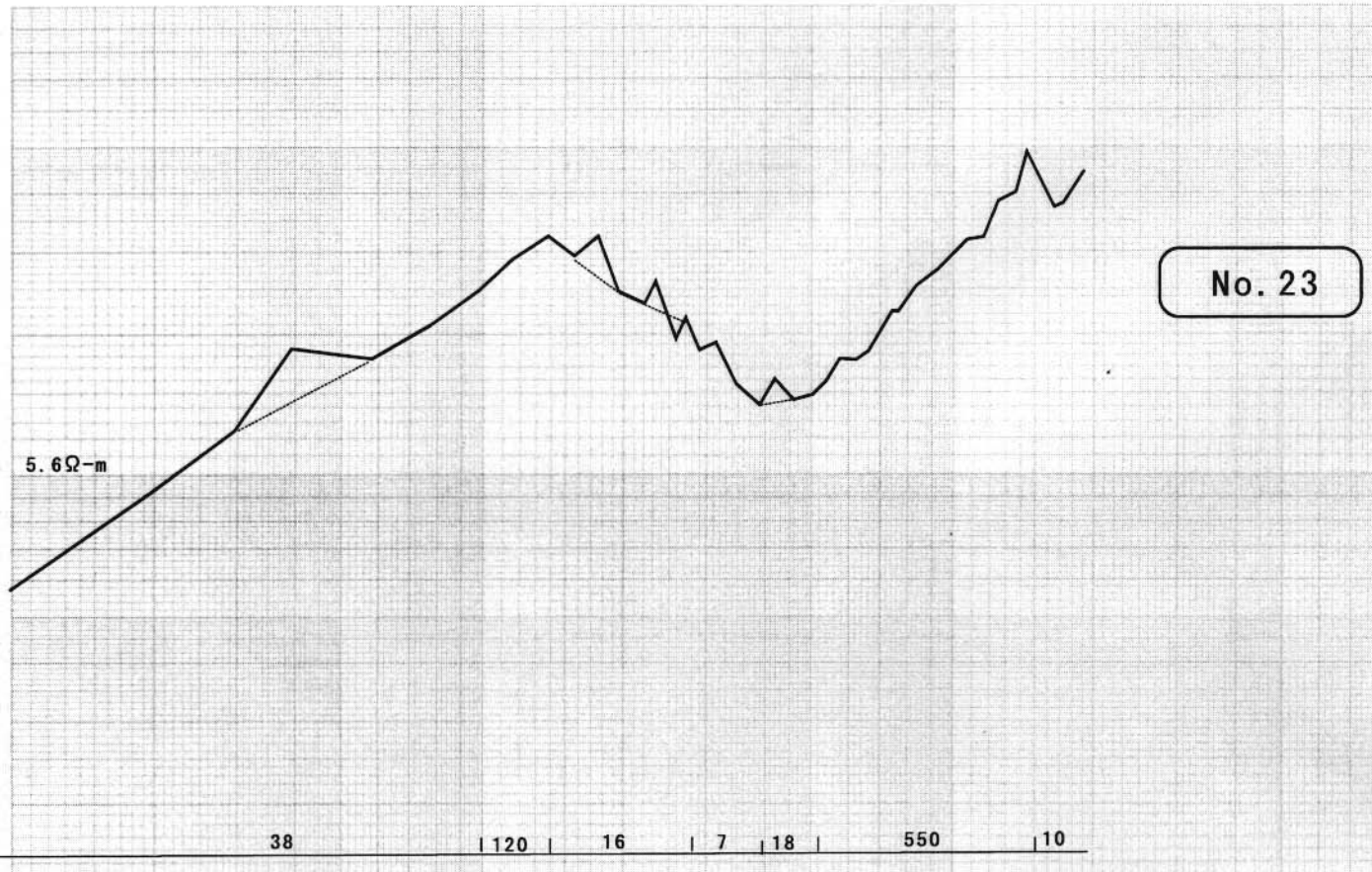

No. 18
11.3Ω-m
18
84
12
140
42
120
28
160
10
240
2

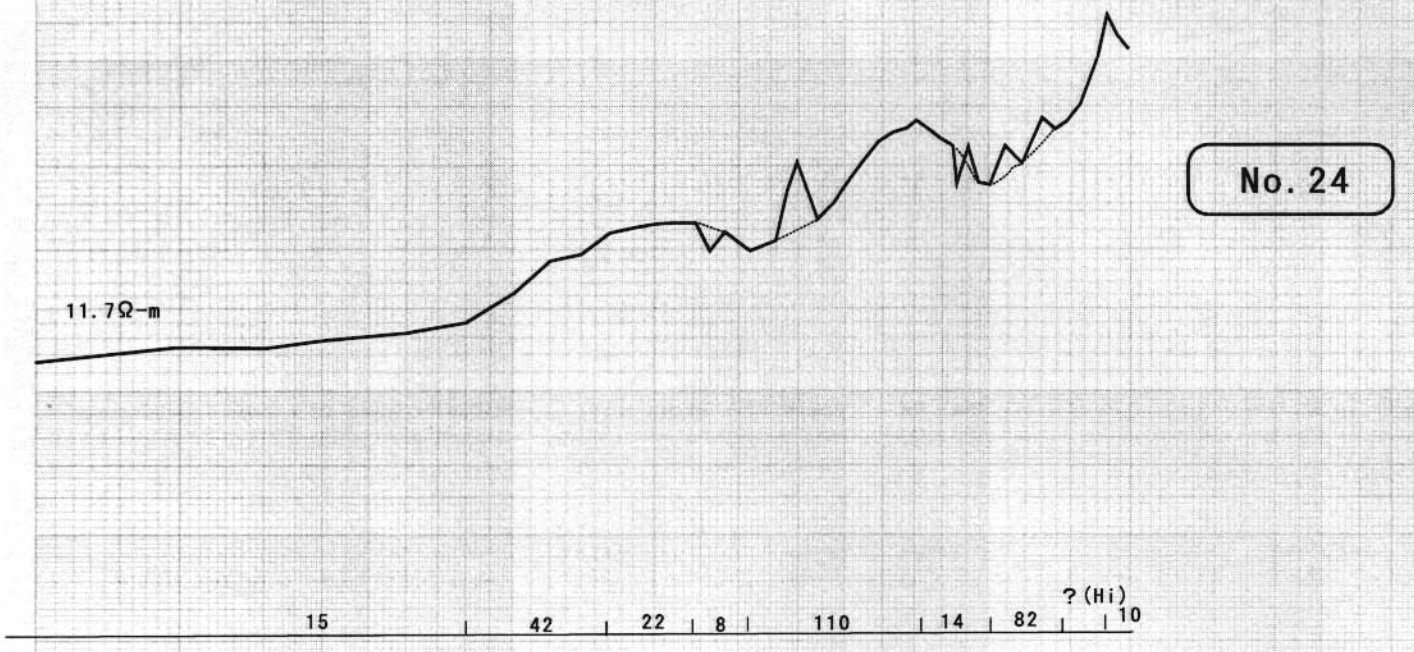

No. 19
12.3Ω-m
52
25
82
31
16
340
8
34
320
7


No. 20
11.0Ω-m
13
42
6
40
10
22
72
22
120
50
12
8
27


No. 21
7.1Ω-m
3
82
10
34
260
42
28
34
26
46


No. 22
5.9Ω-m
26
80
28
400
14
56
32
18
62


No. 23
5.6Ω-m
38
120
16
7
18
550
10


No. 24
11.7Ω-m
15
42
22
8
110
14
82
?(Hi)
10