SALINITY MEASUREMENTS IN HOT WATER WELLS USING TEMPERATURE AND CONDUCTIVITY LOGGING, LAUGARNES GEOTHERMAL AREA, REYKJAVIK, ICELAND

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ABSTRACT

The Laugarnes area has been exploited by the Municipal District Heating Service of Reykjavik (Hitaveita Reykjavíkur) since 1928. Until today more than 50 deep water wells have been drilled in the area producing hot water up to 130°C. The wells are not all connected to the water supply system due to reasons such as; they are too shallow, the water temperature is too low or the water yield of the wells is too small. Besides some of the production wells have been taken off-line as increasing amount of dissolved salts (sea water) in the geothermal water has caused depositions in down-hole pumps. The project work have reported is a study of the salinity distribution in several wells in the Laugarnes area. Ten unused (off-line) wells have been selected for measuring their temperature and conductivity values. The temperature and conductivity logging tools are the most convenient and effective equipment which can give us a very precise temperature and conductivity profile in a short period of time. Salinity profiles of these ten investigation wells have also been computed from the above measurements using relationships between conductivity, salinity and temperature. The calculated values have also been compared with laboratory salinity values on water samples from the wells. By means of the salinity profiles we can estimate the depths at which sea water may intrude these wells and also the direction of the sea water invasion into the system.

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1. INTRODUCTION

This report is written from the writer's experience in specialized training programme in borehole geophysics by The United Nations University with the close cooperation of Borehole Geophysics Department, National Energy Authority of Iceland.

The Laugarnes area is one of the three major hydrothermal areas within a radius of 6 kilometers from the centre of Reykjavik. A large number of hot water wells have been drilled in this area since 1928. In the early day's the wells were free flowing but since 1958, when most of the production wells were equipped with high efficiency pumps, the water-level was drawn down to 100-150 m depth in the wells. As the Laugarnes area is located nearby the seashore it is not surprising that the decreasing geohydrostatic pressure might lead to invasion of sea water into the reservoir.

So a preliminary study has been carried out in order to find some traces of invading sea water into the geothermal system. A direct method for this would be to measure the salinity profiles for each wells. But as no reliable salinity logging tool exits in present logging systems indirect methods must be applied. In our case three methods were used:

1 Conductivity logging: It is well known that fluid conductivity increases as the concentration of dissolved salts increases. Conductivity is therefore often used as a measuring parameter for salt concentration in water. If further the temperature of the fluid is known it is also possible to calculate from the conductivity value the true salinity of the fluid. The conductivity logging tool used has been designed and developed recently by the staff of Borehole Geophysics Department.

2 Temperature logs: Invasion of cold sea water into the system will inevitably lead to cooling of the reservoir in due time. Temperature log was therefore run in each well and the log compared with earlier temperature logs. The temperature values

were also used in calculations of the salinity of the fluid from the conductivity log.

3 Down-hole sampling: A few water samples were taken from different depths in each well. The samples were analyzed for true values of salinity and conductivity by Einar Gunnlaugsson at Hitaveita Reykjavíkur. These values were compared with the measured and calculated values in the wells.

2. THEORY AND APPLICATION

2.1. Temperature log

Geothermal gradient is the rate of change of temperature with depth. The variation of this geothermal gradient is according to the geographical location and the thermal conductivity of the formation.

Iceland is situated in the a very active zone and the utilization of geothermal energy in this country has been a great success and is in advanced stages. A large number of drill holes have been drilled and this number is being increased each year. Some geothermal gradients of these wells are different from place to place depending on their distances from the active zone.

So one might say that the fundamental parameter in geothermal investigation and utilization is the temperature. Temperature log tool is one the most useful and effective instrument which can be used for determination of geothermal gradient, formation temperature, water and steam temperature and geothermal reservoir temperature.

For geothermal water wells in which their temperatures do not exceed 150°C, the electronic temperature log tools usually consisted of resistive temperature-sensors are the most frequently used in well logging technique for to-day.

Temperature-sensor usually has small size and its signal is transmitted from the measuring point to a surface recorder via an electric cable. Its measuring value is obtained either directly by a simple resistivity measurement or indirectly by coupling the sensor into a resistance to frequency converter. The data information is then fed through the cable as a pulsed signal where the temperature is given by the frequency of the pulses. Pulsed logging is far less sensitive to electrical leaks in cable and cablehead than dc logging. Neither is it

affected by the changing resistivity of the cable due to temperature variation.

The most commonly used sensors in temperature logging are platinum sensor and nickel-iron alloy sensing element, which both have a fairly good linear response to change in temperature.

The sensor that we used in our temperature probe is the Ni-Fe type produced by Weed Company. The temperature probes and theirs electronic accessory used in our temperature logging system are products of Gearhart-Owen Company.

The accuracy of the resistivity thermometers can be adjusted to be better than ± 0.1°C depending on calibration, but due to the time dependent drift of their electrical properties they need regular recalibration. A very precise and high efficiency calibration bath is often used for this recalibration and checking quality of these temperature probes. When the measuring temperature changes by 1°F the temperature probe gives out electrical pulses with the frequency of 20 Hz per second per 1°F.

Inside the logging truck cabin, three modules are used in temperature logging. These modules are composed of Line Power Module (LPM), Rate Meter Module (RMM) and Differential Temperature Module (DTM). The detailed function of these modules are explained as followed.

LPM : With this module the current needed for the temperature probe can be adjusted according to the specifications and types of each probe which is in our case 50 mA. This module also can simultaneously pick-up the Casing Collar Locator (CCL) signal and give it to a pen on the recorder.

RMM : This module converts the frequency to a DC voltage which is given to a pen on the recorder. This voltage is 50-100 mV max. and is adjustable as well as the time constant suitable for the log. The module also has a pulse-former

which produces one well-shaped pulse for each pulse coming from the temperature probe. These well-shaped pulses are used for the DTM afterward. There is also a 100 Hz built-in oscillator for the purpose of calibration.

DTM : This module receives the pulses from the RMM and converts the frequency to temperature reading on a digital display. Some temperature modules are built for temperature reading in °F and then the module simply divides the frequency with 20. That is frequency divided by 20 is equal to the temperature reading in °F. The DTM used in this investigation displays the temperature in °C and the conversion is frequency divided by 36 plus 17.7 will be equal to the temperature reading in °C. Besides this the DTM gives a DC voltage to a pen on the recorder which is proportional to the changes in the frequency with times. This is a very useful feature because very slight changes (< 0.1°C) in temperature can be clearly seen on the log.

2.2. Conductivity log

The electrical conductivity (C) is the measure of the material's ability to conduct electricity. It is the inverse of the resistivity, and is usually expressed in units of millimhos/m (mmho/m) or mS/m (milli Siemens per meter).

There are two types of conductivity:
(a) Electronic conductivity is a property of solids such as graphite, metals (copper, silver, etc.), haematite, metal sulphides (pyrite, galena) etc.
(b) Electrolytic conductivity is a property of, for instance, water containing dissolved salts or it is a measure of chemical concentration.

The conductivity of a solution depends on the type and number of ions produced by dissociation of the dissolved salt. If the nature of the salt is known, their concentration can be found by conductivity measurements and it may be possible to detect the presence of certain salts.

Electrolytic conductivity is usually expressed in terms of specific conductivity, that is, the conductivity in mhos of a cubic centimetre of liquid as measured between two electrodes each 1 centimetre square and located 1 centimetre apart. In actual practice, electrodes of different spacings and areas are used and the system calibration is adjusted accordingly. Since measurements may be made on liquids having very low conductivity, a smaller unit, the μmhos per centimetre or the micro Siemens per centimetre, is often used.

The conductivity of water depends on both the concentration of dissolved salts and the changing of temperature. The conductivity increases as the concentration increases, up to a certain maximum beyond which undissolved, and therefore non-conducting, salts impede the passage of current carrying ions.

The salinity is a measure of the concentration of dissolved salts. It can be expressed in several ways: (a) parts per million (ppm or μg/g of solution) ; (b) g/litre of solvent ; and (c) g/l of solution. Sodium chloride (NaCl) is the most common salt contained in formation waters and drilling mud. It is customary to express the concentration of other dissolved salts in terms of equivalent NaCl for evaluation of the conductivity of a solution.

As the temperature of water increases, the conductivity of a solution increases and the relationship between conductivity and temperature can be expressed approximately by the Arp's formula:

$$C_{T2} = C_{T1} * [\{T_2 + 21.5\} \div \{T_1 + 21.5\}] \qquad T_1 \text{ and } T^2 \text{ in } ^\circ C$$

where C_{T1} is the solution conductivity at temperature T_1 and C_{T2} is the solution conductivity at temperature T_2.

Our conductivity logging tool has been designed in order to measure the electrolytic conductivity of water containing dissolved salts. The conductivity probe composed of a conductivity cell which consists of two concentric circular perforated

electrodes spaced 1 centimetre apart and mounted firmly within an insulated enclosure which is located near the tip of the probe. This conductivity cell is protected around by four strong stainless steel arms welded tightly together at the tip.

Inside the logging truck cabin, the Gearhart-Owen electric log module is adopted for the conductivity measurement. By using the Point Resistivity position and the Resistivity Scales switched to the range of 100 the exact regulated current value of 1 mA is sent down through the logging cable to the probe. Resistivity Scales switched at the "0" position provides "0" current, and it is used to calibrate the Zero reference on the chart paper. According to this constantly applied current, the voltage drop across this two electrodes of the cell immersed in a solution having very low conductivity such as distilled water, must be very high in order to maintain the same current value. On the contrary, this voltage drop must be very low for a solution having very high conductivity.

However, the measurement of conductivity between this two electrodes presents some difficulties. There are some polarization occurs at the electrodes because of electrolysis. In order to prevent and to minimise this polarization, the alternating current of 100 Hz controlled by an electronic converter is used for the measurement.

3. WHAT WAS DONE AND FIELD PROCEDURE

Ten old wells which are not mounted with pumping equipment and are located near the seashore have been selected to be the investigation wells for this logging methods. They are named as RG-1, RG-2, RG-8, RG-12, RG-14, RG-16, RG-18, H-19, H-27 and H-34. The location of these wells are shown in Fig 1 and 2. In the figures, the names of wells begun with RG have the same meaning as RV.

All of these wells have been measured with the temperature logs, conductivity logs and some water samples were taken. No samples could be taken from RG-18 because the sampler tool could not go down into that well. The depths of investigation were quite closed to the real depth of each wells. There were only a few wells which were shallower than they should be due to some collapsing.

The temperature probes used in this investigation have been precisely calibrated with the temperature calibration bath and all the electronic circuit components have been readjusted or changed by a keen electronic engineer of The Borehole Geophysics Department so that the probes are as accurate as possible.

Before running the temperature probe down into these wells, all three temperature modules have been calibrated in such a way that for the temperature value of 0°F (or -17.7°C), that is, the output frequency is 0 Hz the deflection of the recording pen is adjusted to the 0 cm position on the chart paper and for 302°F (or 150°C) which is equivalent to 6,040 Hz the pen deflection is up against the 24 cm position of the chart and this calibration is done by the aids of 100 Hz built-in oscillator inside the RMM. The logging speed was controlled constantly at about 25 m/min and the temperature value were noted on the recording paper every 10 meters.

The conductivity tool is calibrated in such a way that while there is no voltage drop or no current flow between the two

electrodes of the conductivity cell, the pen deflection is adjusted to the 0 cm position on the chart paper. When the tool is immersed in a very low conductive media as pure cold water, which has its conductivity value less than 100 µS/cm, the pen deflection is adjusted to the position close to 24 cm. In addition to this, the frequency of the electronic converter is adjusted and controlled at 100 Hz because a slight change in frequency causes some changes in the output.

Seven calibration pits containing solution of pure cold water, 164.85, 329.69, 494.54, 659.38, 824.23 and 1648.46 ppm dissolved NaCl in water have been used for the calibration of the conductivity probe in order to find the relationship between the deflection in centimeters of output recorder with the variation of conductivity. The calibrations have been done before running the log and after finishing the logging procedures each day at temperatures close to 20°C at Smiðjuvegur. Also the conductivity of these calibration solutions were measured and the relation between the deflection and conductivity are found as shown in Fig 16. Some attempts have been tried to calibrate this conductivity probe with various different temperature ranges by heating up these solutions from 20 to 60°C and the calibration were performed at 20, 25, 30, 35, 40, 45, 50, 55 and 58°C respectively. These results are shown in Fig 17.

The YSI Model 33 and 33M S-C-T Meters which are portable, battery powered, transistorized instruments designed to accurately measure salinity, conductivity, and temperature, have also been used in our calibrations. These three properties of the fluid samples containing in the calibration pits are measured by the YSI Meters in order to find some relationship between the deflection of the recording pen (in cm) and the true values of salinity and conductivity at the same room temperature which is about 20°C and at the same increment increasing of temperature up to 60°C.

The sampler tool was also used for collecting some water samples at certain different depths of these observation wells. Inside it there is an electric motor controlled by the LPM (Line Power Module) which can open and close the valve at a certain depth and its capacity of collecting water sample is two liters. This valve is closed while taking the tool down into the wells and opened for collecting at desired depths. These samples have been taken later to The Hitaveita Reykjavikur to be analyzed by the chemical method for the true value of salinity and conductivity.

The temperature data obtained from this observation have been converted to the temperature profiles as function of temperature in °C versus depths with the aid of computer facilities at The National Energy Authority. This enabled a more effective and understandable comparison of the temperature profiles between wells.

The conductivity profiles were obtained by the same way as above and they were plotted as function of deflection in centimeters versus depth in meters.

For a qualitative interpretation of the temperature and conductivity, profiles were plotted with reference to the same depth of 1500 meters.

Some computer program have been tried and created in order to obtain the salinity profiles which already have been corrected for the effect of temperature changes in these wells. The program needs deflection and temperature logs (deflection and temperature versus depth) and computes NaCl salinity as a function of depth in the wells. In the program deflection is converted to resistivity by the experimentally determined relation :

$$\sigma = ad^2 + bd + c$$

where σ : resistivity in Ohmm

d : deflection in cm

$a = -0.2463582336$

$b = 0.4822916509$

$c = 0.06628615805$

The salinity is then determined from the following relation between conductivity σ (s/m), salinity C (molar concentration) and temperature T (°C) for NaCl solution (Ucok 1979)

$$\sigma(C,T) = \Sigma\ \Sigma\ C_i\ B_{ij}\ T_j\ .$$

In this relation:

$C_1 = C,\ C_2 = C^{3/2},\ C_3 = C^2 \ln C$

and:

$T_1 = 1,\ T_2 = T^{-1},\ T_3 = T,\ T_4 = T^2,\ T_5 = T^3$

The 3*5 matrix B_{ij} is given by:

3.470	-59.21	0.455100	$-9.346*10^{-5}$	$-1.766*10^{-6}$
-6.650	198.10	-0.205800	$7.368*10^{-5}$	$8.768*10^{-7}$
2.633	-64.80	0.005799	$6.741*10^{-5}$	$-2.136*10^{-7}$

This relation predicts the conductivity of NaCl solutions with about 2 percent accuracy for concentration from 0 to 6 molars and over the temperature range 25 to 375°C. For a given temperature T_0 the conductivity is a monotonically increasing function of C and for a given conductivity σ_0 the salinity C is therefore determined by solving the equation

$$\sigma(C,T_0) - \sigma_0 = 0$$

by the Newton Rapson method.

4. RESULTS AND ANALYSIS

From the data comparison between the measured temperature profiles in these ten investigation wells and the old profiles measured mostly in 1977, the results of the new profiles are nearly quite the same as they have been measured for the past ten years. The new profiles show a slightly lower temperature of 1°C to 2°C but their shapes and features are about the same as shown from Fig 3 to Fig 7. This temperature difference may be due to the fact that the temperature probes were only calibrated within ± 2 °C in year 1977. So we can assume that the reservoir behaviour of this Laugarnes geothermal area has still maintained its temperature and has had no significant sign of cooling down, even though a very large amount of hot water has been utilized from the area for nearly a decade.

However, if we compare the temperature profiles among these ten investigation wells with the same reference depth of 1500 meters, we can see that there are some steep decrease in temperature gradient between the depths of 300-500 meters. This may be due to some cold water flowing in this layer or it may be only the true temperature behaviour of the formation itself. According to the geological cross-section in this area there are hydrothermally altered basalts forming an aquifer lying from the depth 200 m to 400 m and dipping in the NW-SE direction. From depths deeper than 700 m down to the depth say about 1500 m the temperature profiles tend to reach the temperature of 140°C they have only a slight increase. These are also the indications that the hydrogeothermal reservoir temperature in this area is not more than 150°C. The compared temperature profiles are shown in Fig 13.

From the results of our conductivity profiles in these wells we can roughly divide them into two groups. The first one is the conductivity profiles of wells RG-1, RG-2, and RG-14 which seem to have higher conductivity values than the second group, that is, wells RG-8, RG-12, RG-14, RG-16, H-19 and H-34. But for the first portion of the conductivity profile of

well RG-16 which is from the depth of 41 m to 100 m it tends to have the same value as the first group and below 300 m its profile tends to have the same feature as the second.

Due to the fact that the conductivity of fluid water can be increased by both increasing of its temperature and salinity. By comparing the temperature profiles with the conductivity profiles we can clearly see that the rapid changes in these conductivity profiles at the depth between 0 to 300 m are due to the effect of rapid temperature changes in these wells. From the depth below 500 m where the temperature gradients are slightly changed the conductivity profiles are quite smooth and maintain their deflection values down to the bottom of the wells. So our first guess is that the difference of the conductivity profiles of these two groups may be due to the difference in their salinity as well. From this point of view we can see that the high conductivity deflection of wells RG-1, RG-2 and RG-14 from the depth between 300 m to about 600 m are due to higher salinity. All the conductivity profiles recently measured in the area are shown from Fig 8 to 12.

The results of chemical analysis of the water samples taken from different depth of these wells seem to support our preliminary hypothesis. The chemical analysis results are shown on Table 2. For a rather qualitative interpretation we can observe that the salinity concentrations of wells RG-1, RG-2 and RG-14 at the depth between 300 m to 600 m are very high, that is, 621.96 ppm for RG-1 at 330 m, 1652.42 ppm for RG-2 at 350 and 476.24 ppm for RG-14 at 540 m. At the depth of 50 m for RG-1, RG-2, RG-14 and RG-16 the salinity values of their water samples are around 329.69 ppm while it is only around 82.42 ppm for RG-8, RG-12, RG-18, H-19 and H-34 at this depth. For the depth below 100 m down to the bottoms, the salinity values of wells RG-8, RG-12, RG-16, RG-18, H-19 and H-34 are very low around 82.42 to 164.84 ppm. But the salinity values are more than 164.84 ppm for the case of wells RG-1, RG-2 and RG-14 at the depth below 600 m. These chemical

analysis results seem to coincide with the results of the conductivity profiles. The increasing or the decreasing and the difference of the conductivity deflection among these wells are due to the different in there salinity values.

From the results of our temperature profiles and conductivity profiles together with the chemical analysis results we can roughly separate the hot water wells which have very low salinity values less than 164.84 ppm, from the wells which their salinity values are more than 494.54 ppm.

Some computer program mentioned in our previous section have been tried to convert our conductivity profiles which show the unit of conductivity changes in term of the deflection in centimetre of recording pen to their calculated salinity profiles which have also been compensated for the effect of temperature changes. The conductivity probe have calibrated by immersing it into the calibration pits containing solutions of pure water, 164.85, 329.69, 494.54, 659.38, 824.23 and 1648.46 ppm of NaCl. The pits temperature have also been varied from 20°C to 60°C. By this methods, we can find the relationship between the pen deflection and the true conductivity values of these solutions with the variable ranges of temperature and the results are shown in Fig 17. We have also tried to extrapolate this calibration results up to 150°C by means of polynomial of second degree. So from our conductivity profiles data and temperature profiles data and the results from our calibrations, we can obviously calculate and obtained our new salinity profiles of these wells. However, after we have compared our computer results with the results from the chemical analysis of the water samples, these two different results cannot be correlated with each other. The salinity in ppm of NaCl content computed by such computer program are larger than the values obtained from the chemical analysis except for well RG-2 that the calculated values are smaller.

The reasons for the above contradiction may be due to many factors. We have some problems of heating up our solution in

the calibration pits and maintaining their temperatures during measurements and when their temperatures are increased there is some evaporation which might change the salinity and conductivity as well. We have tried to extrapolate our calibration results to higher degree but the result is unsatisfactory. Besides these we also have had some difficulties in finding a reliable data for the relationship between conductivity and temperature at different salinities. Therefore our calculated results obtained from the computer program which seemed to have some disagreements with the result from chemical analysis of the samples should be left for a further discussion. Other problems are involved in the electronic functions of the conductivity tool, methods of calibration, methods of calculations, few collection of water samples etc. For example, the number of our water samples with different depth of these wells are only a few and their intervals of collection are sometimes too large, so it is not quite correct to use them as fixed reference salinity value at a certain depth without any reconfirmation with other adjacent values. For the conductivity tools, if there are only some slight changes of the function of some electric components, such as the frequency converter not being properly adjusted, it may cause some changes in the recorder output and this may distort our shape of the conductivity profiles as well.

However, from the calculated salinity values, we have tried to draw some contour lines which have same salinity values of 200 ppm(NaCl) at 100 m, 200 m, 300 m and 400 m below sea level in order to find some traces of sea water that might invasion to the area. These results are shown from Fig 19 to 22 which the shaded area show salinity above 200 ppm(NaCl).

5. DISCUSSION

As the conductivity of fluid depends on both its salinity and temperature. When the conductivity and the temperature of the fluid are known, it is possible to calculate for its salinity. But in actual practice there exists some difficulties such as the precision of the instruments, carefully adjusting of some electronic functions and accuracy of some calibrations of the standard solutions with different concentrations and temperatures. The results of this investigation cannot be correlated to each other because there are some disagreements between the measuring results, the theoretical calculations obtained from some computer program and the results from the chemical analysis. However, this is not quite an discouraging situation, it is merely an unfinished task. Some of the above difficulties probably be overcome by making some recalibrations, repeating procedures of conductivity logging in all these wells or in other wells in this area and this will probably reveal some of these problems.

6. CONCLUSION

From the theoretical point of view, when the conductivity and the temperature of a certain kind of fluid are known it is always possible to calculate for its salinity. So by means of our temperature logging tool we can obtain a very reliable temperature profile of each well. The conductivity of hot water is also measured by our conductivity logging tool. With these temperature and conductivity profiles together with some results from salinity calibration with some standard solutions, we can also compute for the salinity profiles of these wells.

As it has been mentioned before, our measured results are not fitted with the computer results and the results of chemical analysis. However, from the results of our conductivity profiles we can qualitatively separate the hot water wells which have a very low salinity less than 100 ppm from those which have higher salinity than 300 ppm. But it is still very hard to separate them exactly from each other. Also the salinity profiles calculated and plotted by some of our computer program are unreliable. Due to the unreliable results of our salinity profiles, it is very hard to ensure that there is invasion of sea water into these wells.

7. ACKNOWLEDGEMENTS

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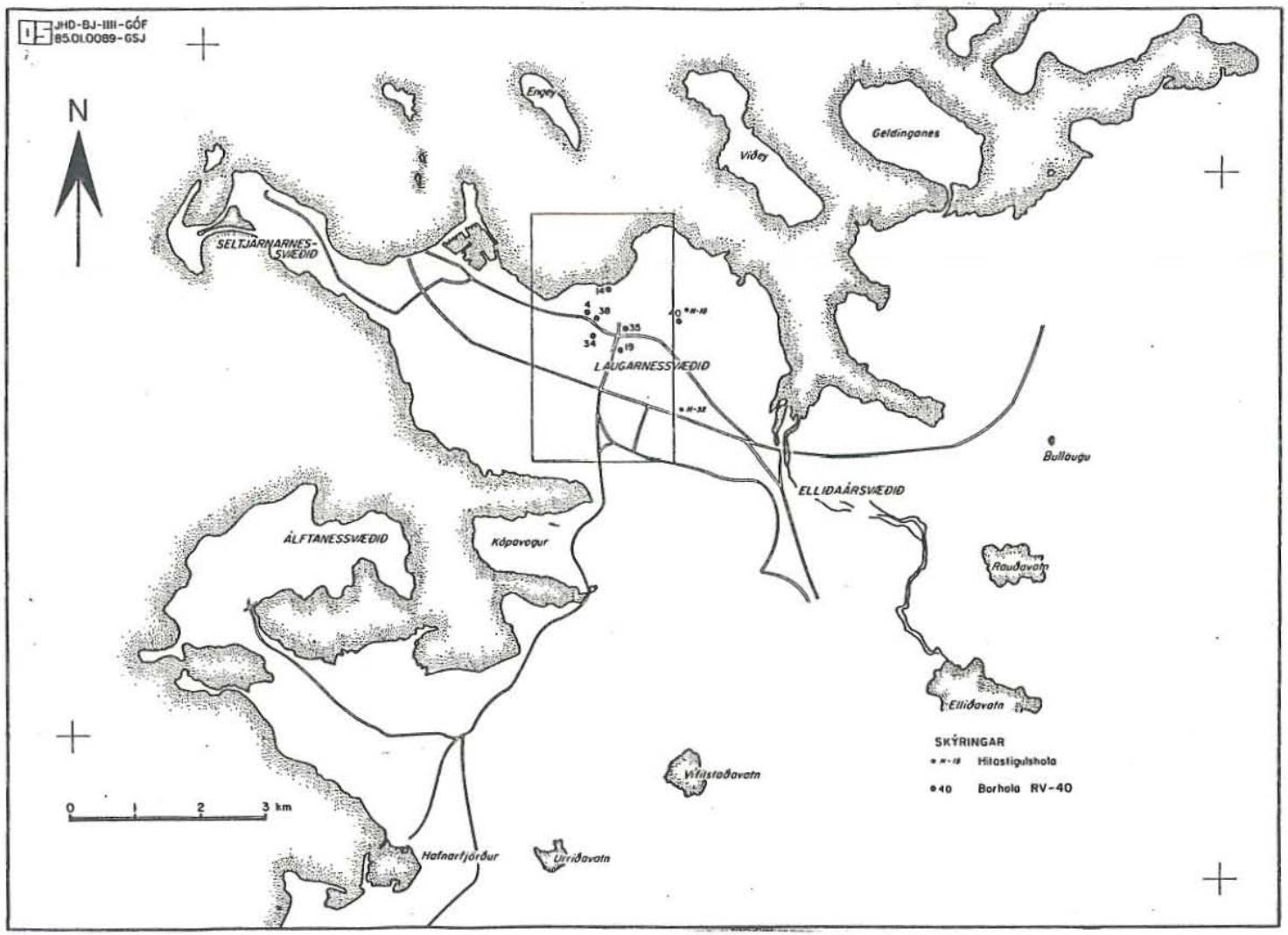


Fig 1. Laugarnes area. Investigation area 1986.

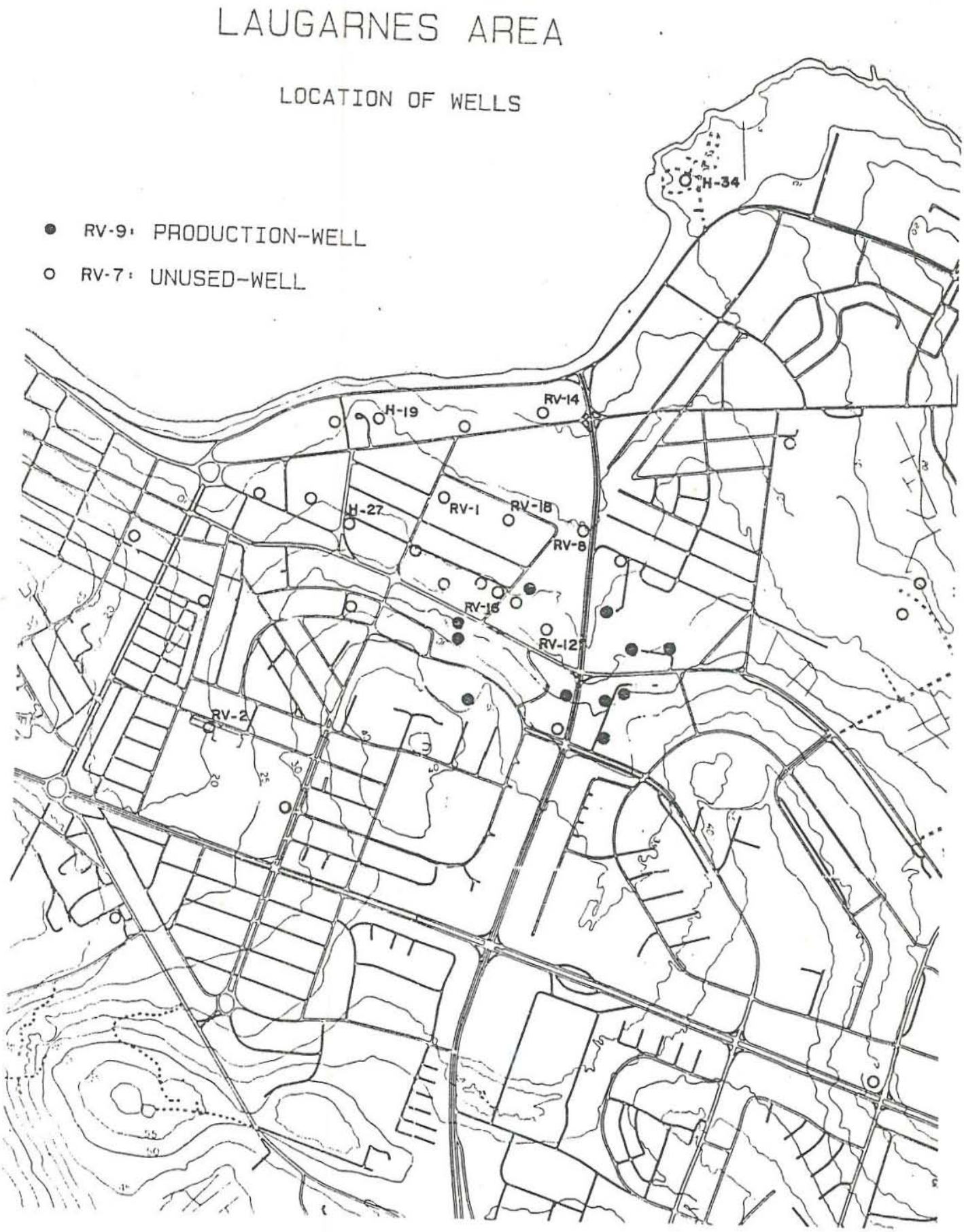


Fig 2. Laugarnes area. Location of wells and Investigated well no.

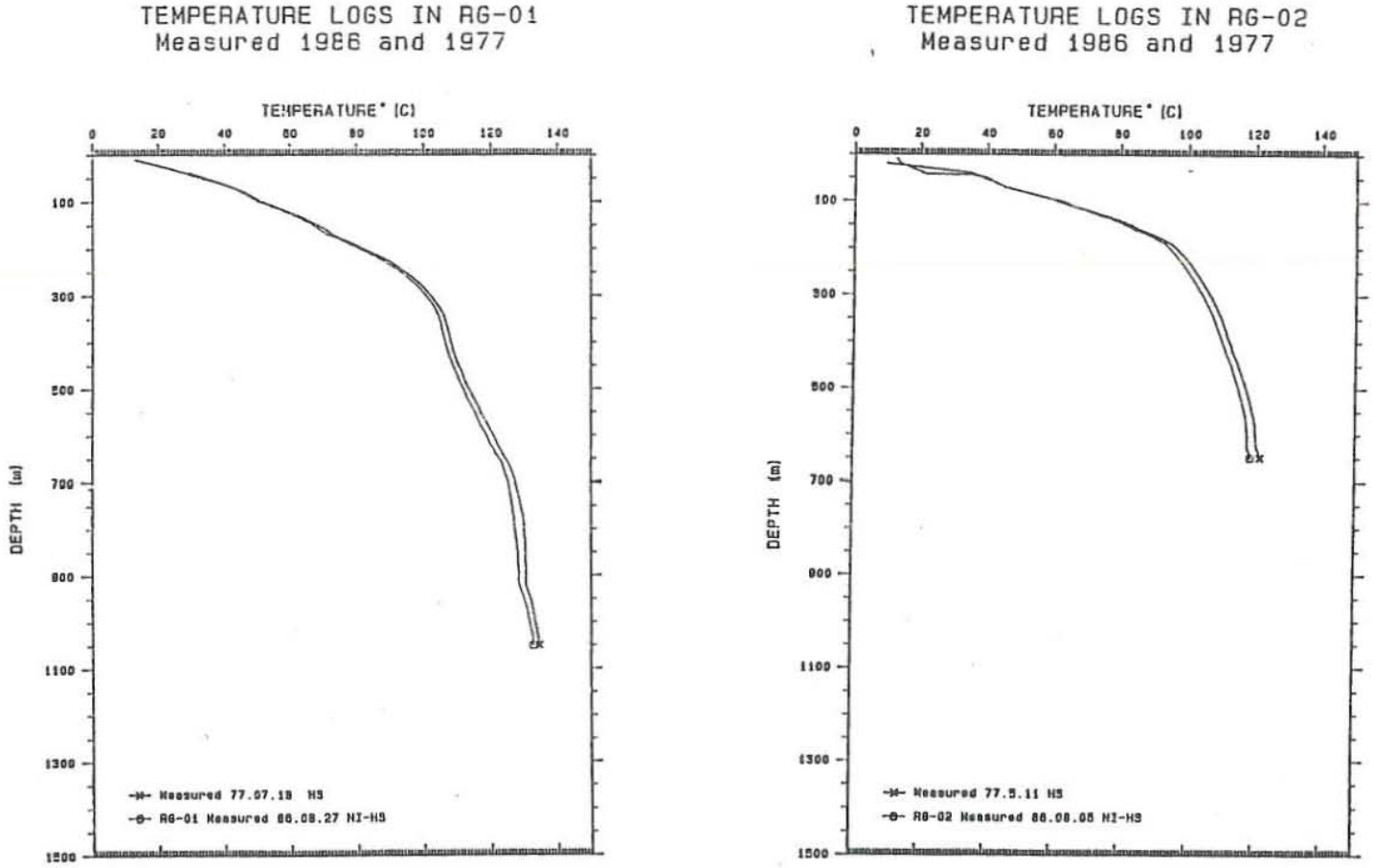


Fig 3. Temperature logs in RG-01 and RG-02 measured 1986 and 1977.

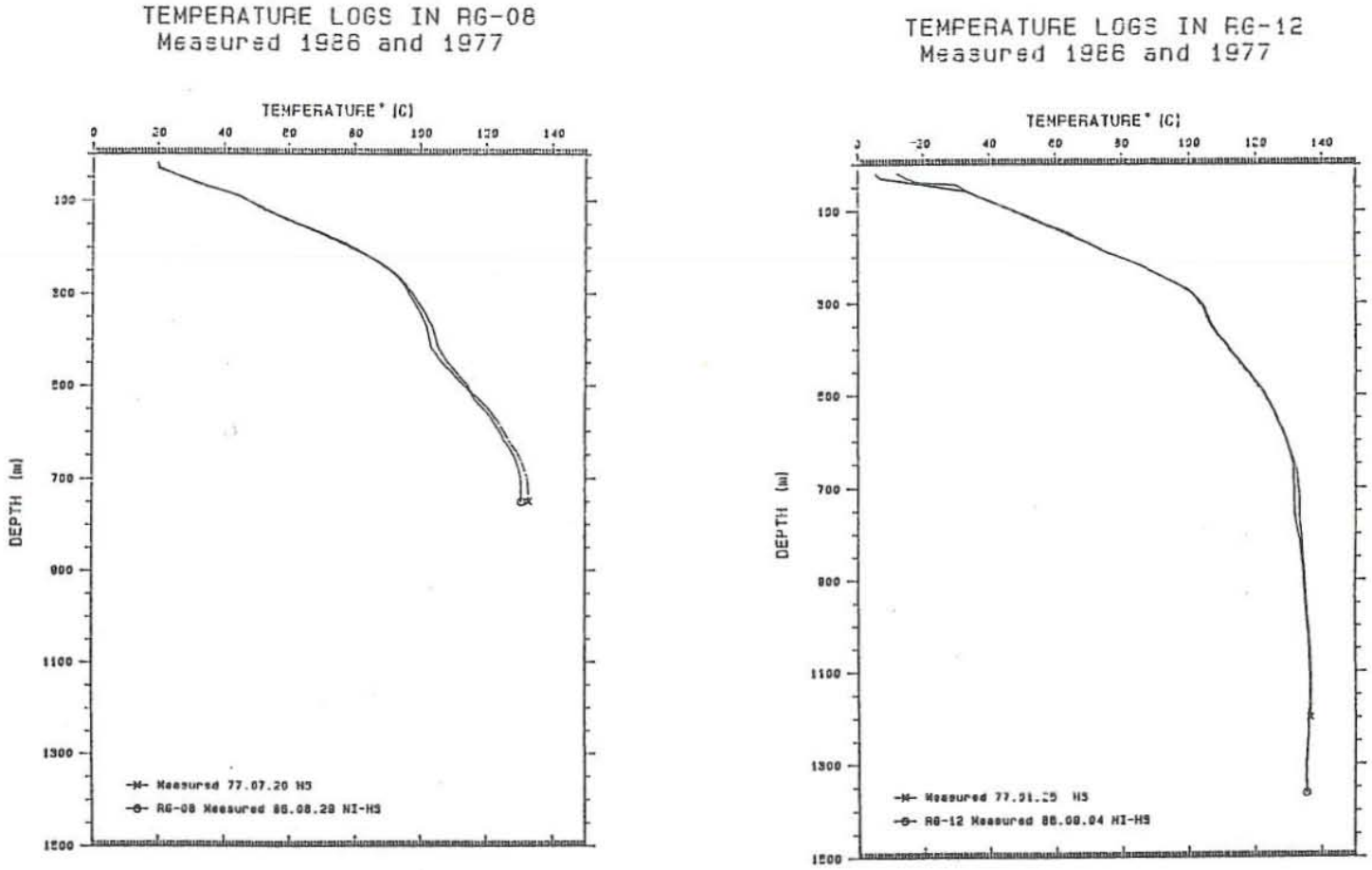
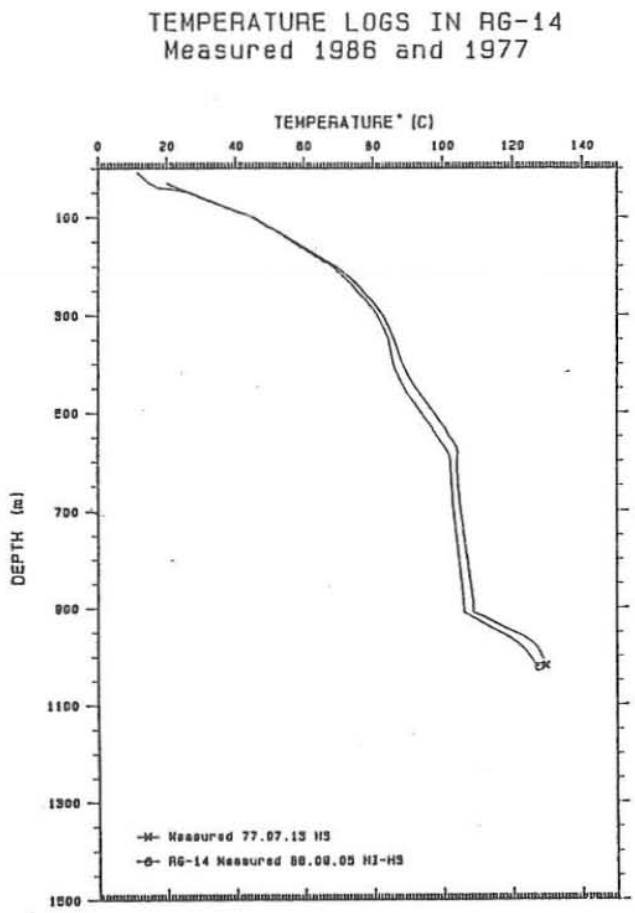


Fig 4. Temperature logs in RG-08 and RG-12 measured 1986 and 1977.



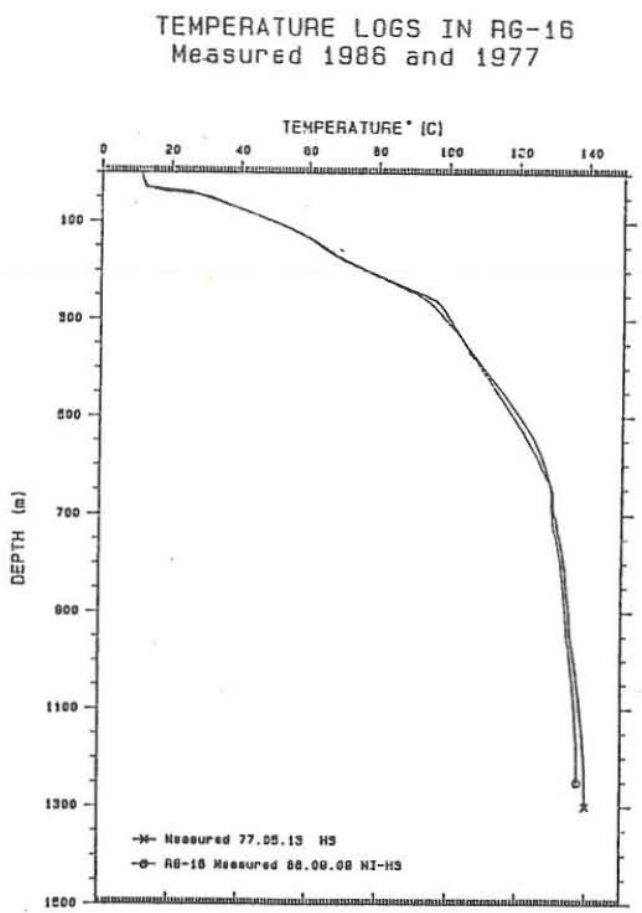


Fig 5. Temperature logs in RG-14 and RG-16 measured 1986 and 1977.

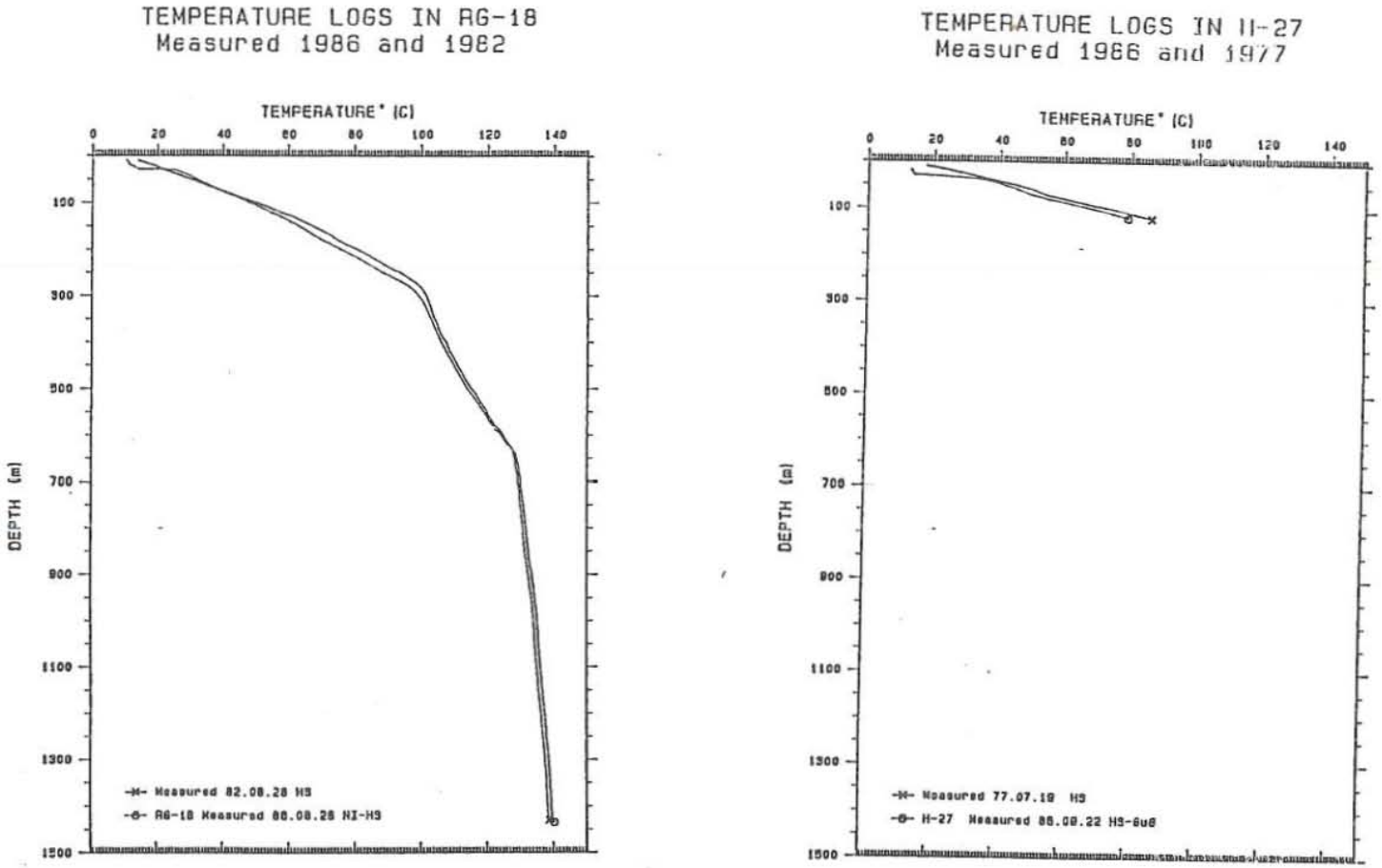
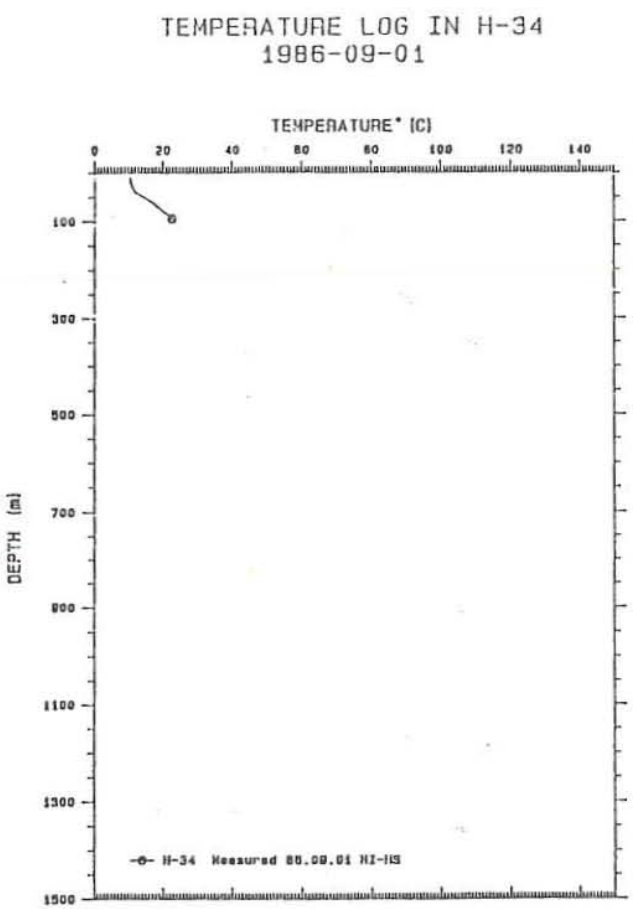


Fig 6. Temperature logs in RG-18 and H-27 measured 1986, 1982 and 1977.



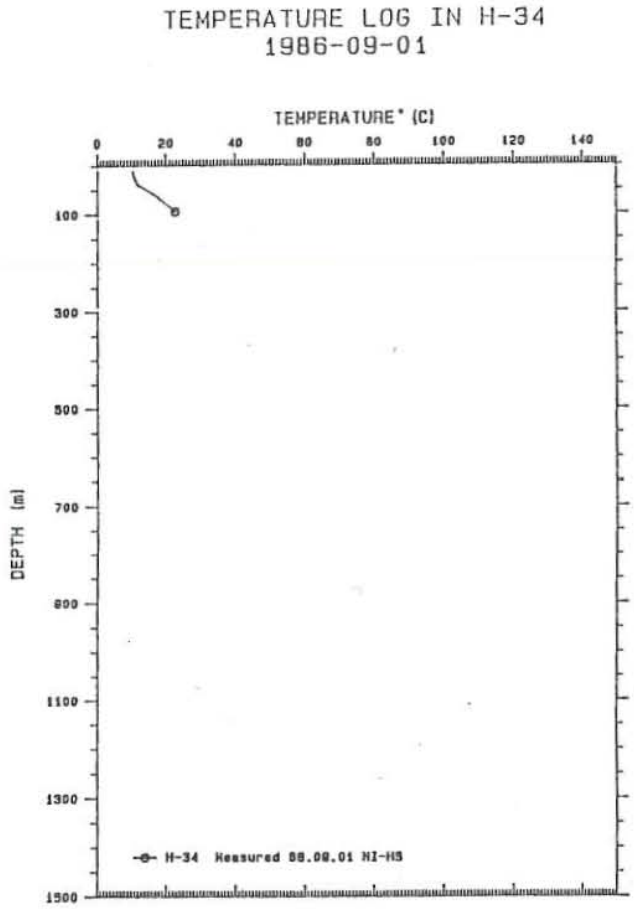


Fig 7. Tmeperature logs in H-19 and H-34 measured 1986.

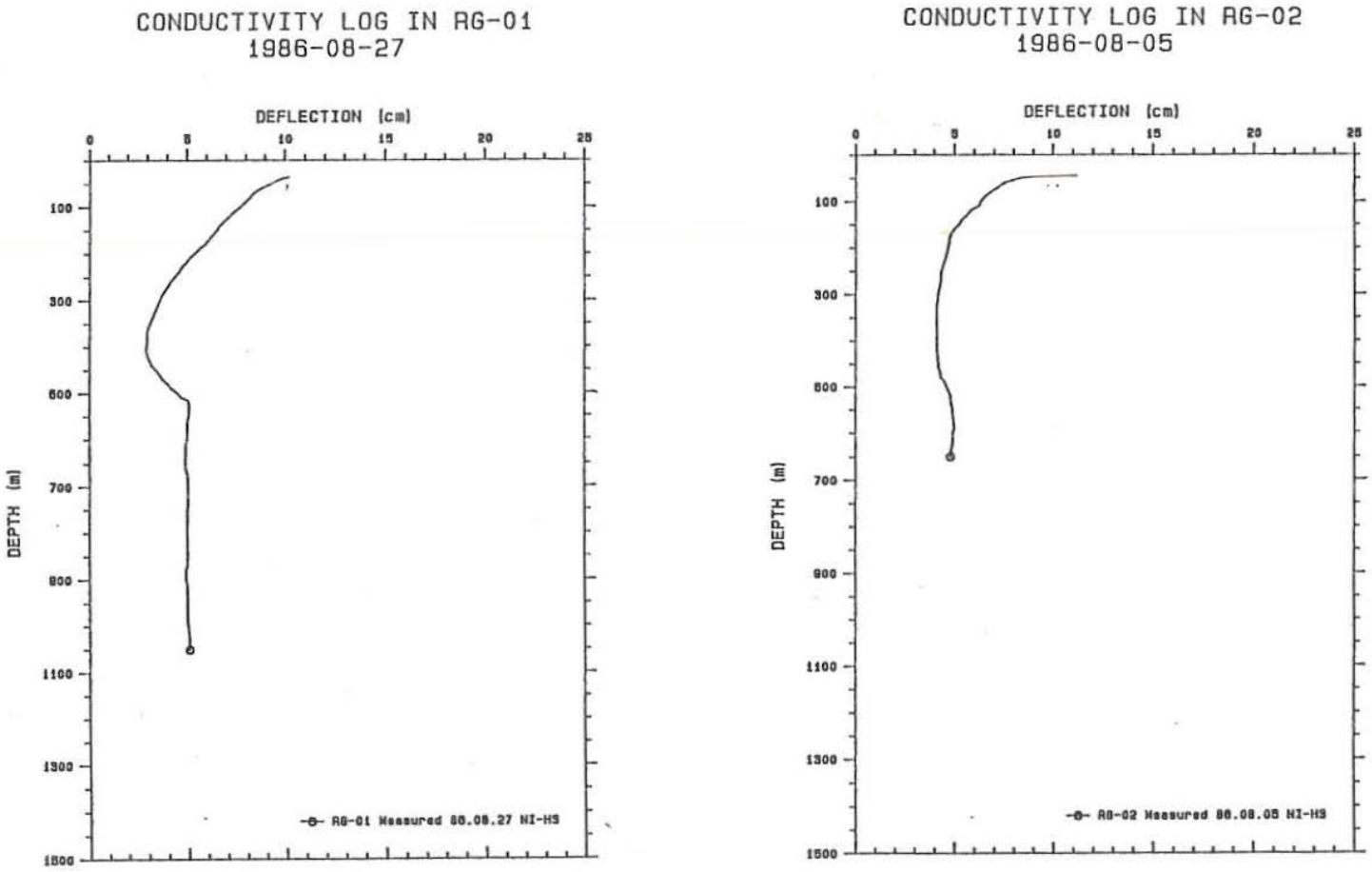


Fig 8. Conductivity logs in RG-01 and RG-02 measured 1986.

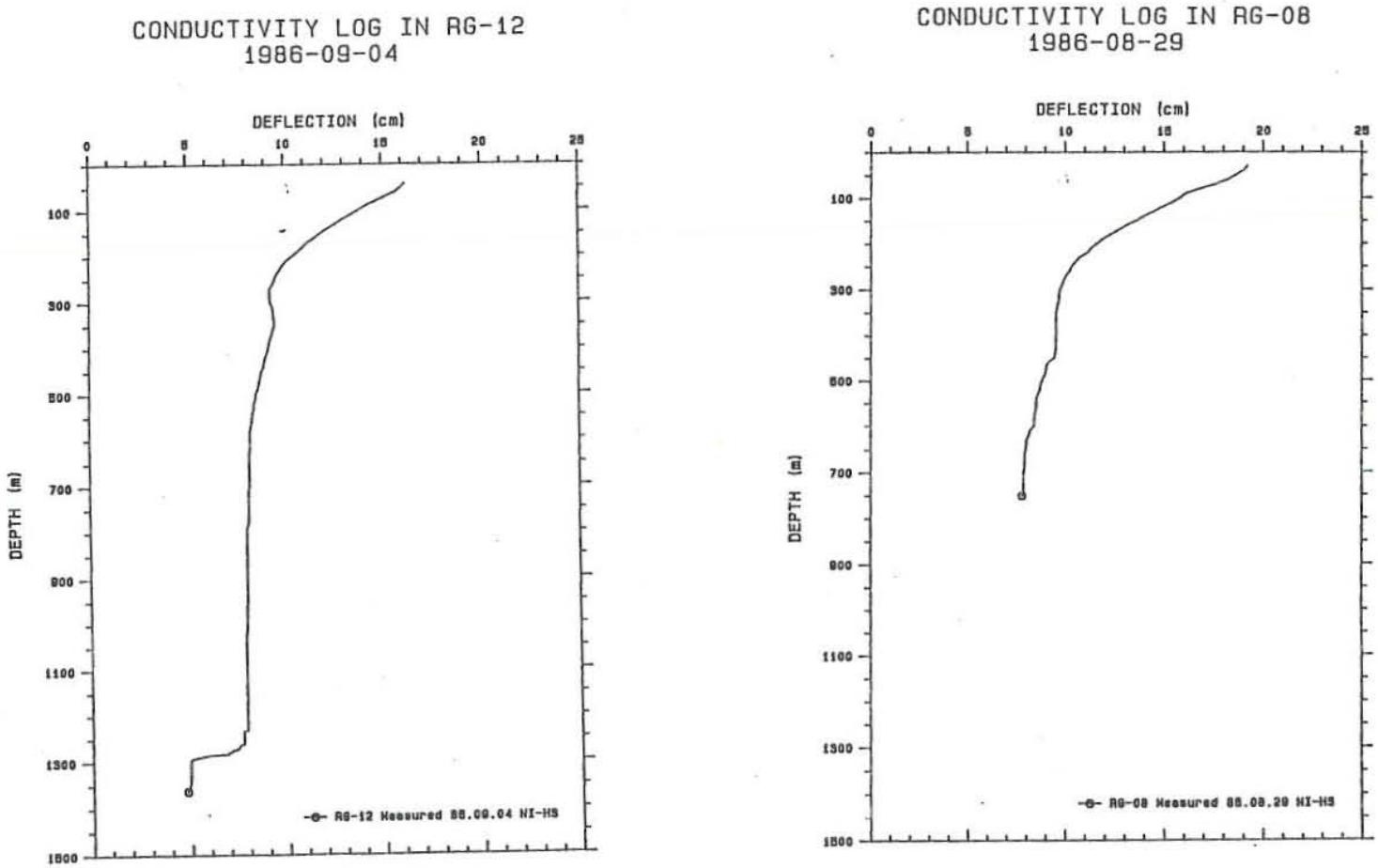


Fig 9. Conductivity logs in RG-08 and RG-12 measured 1986.

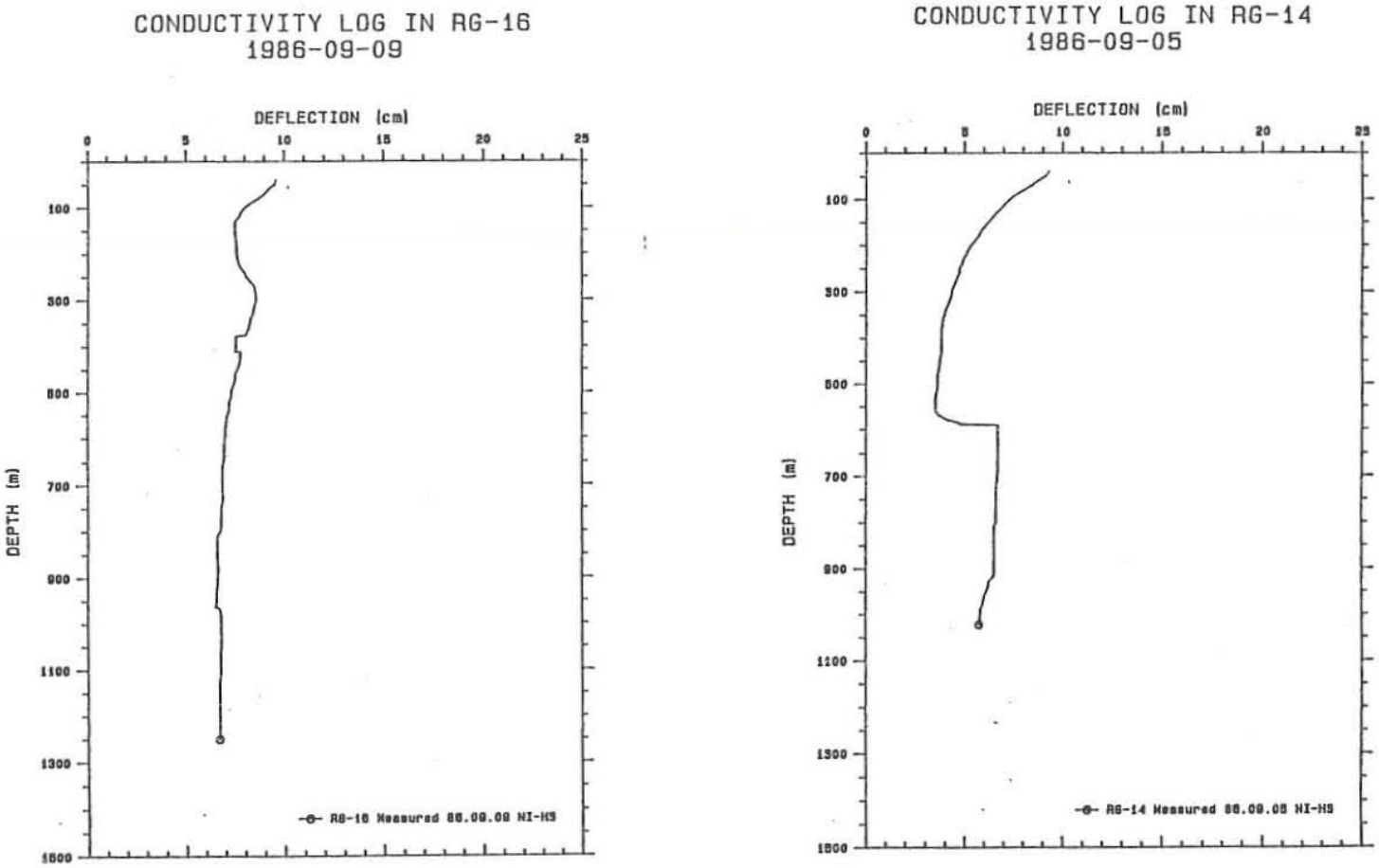


Fig 10. Conudctivity logs in RG-14 and RG-16 measured 1986.

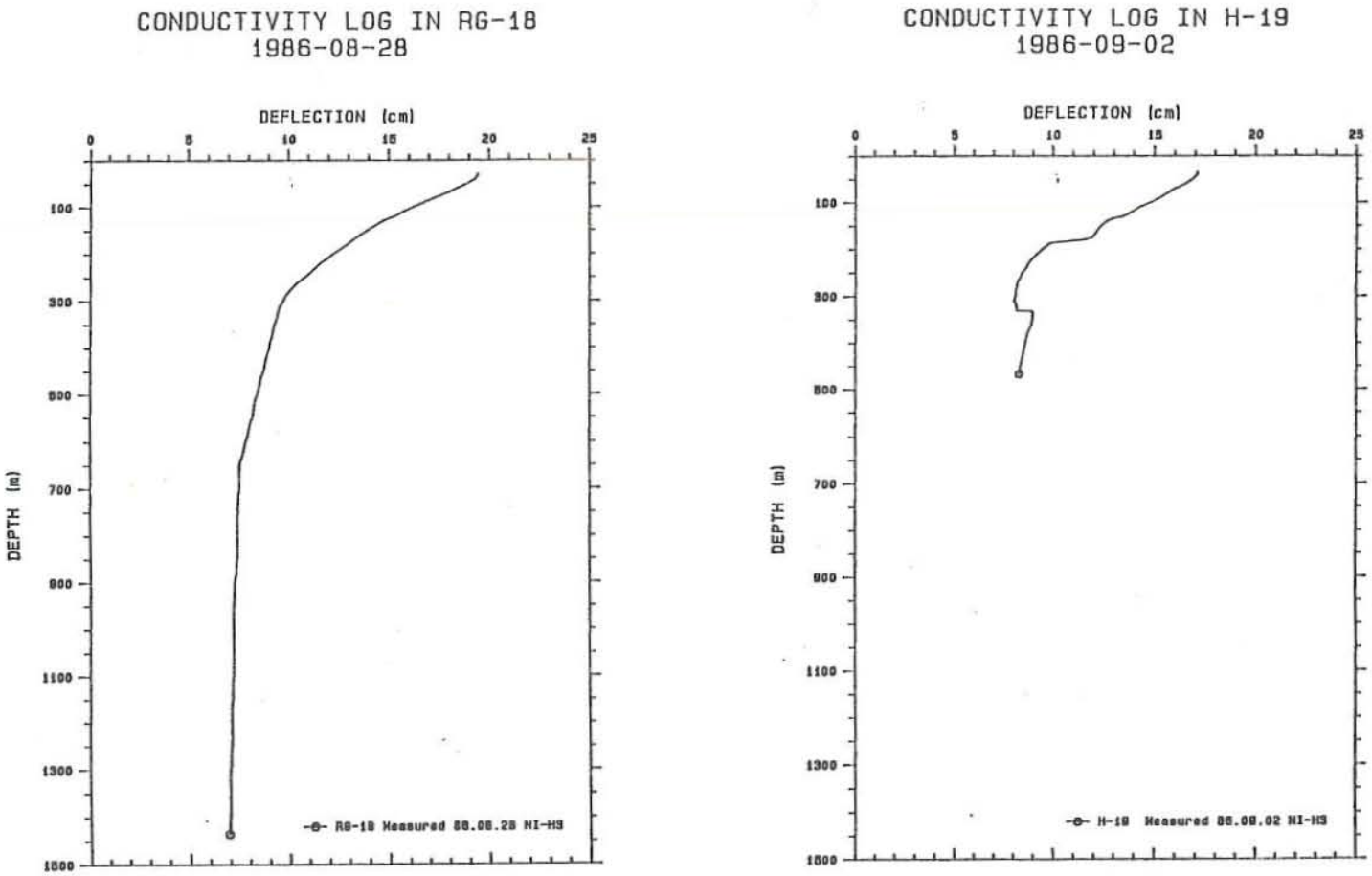


Fig 11. Conductivity logs in RG-18 and H-19 measured 1986.

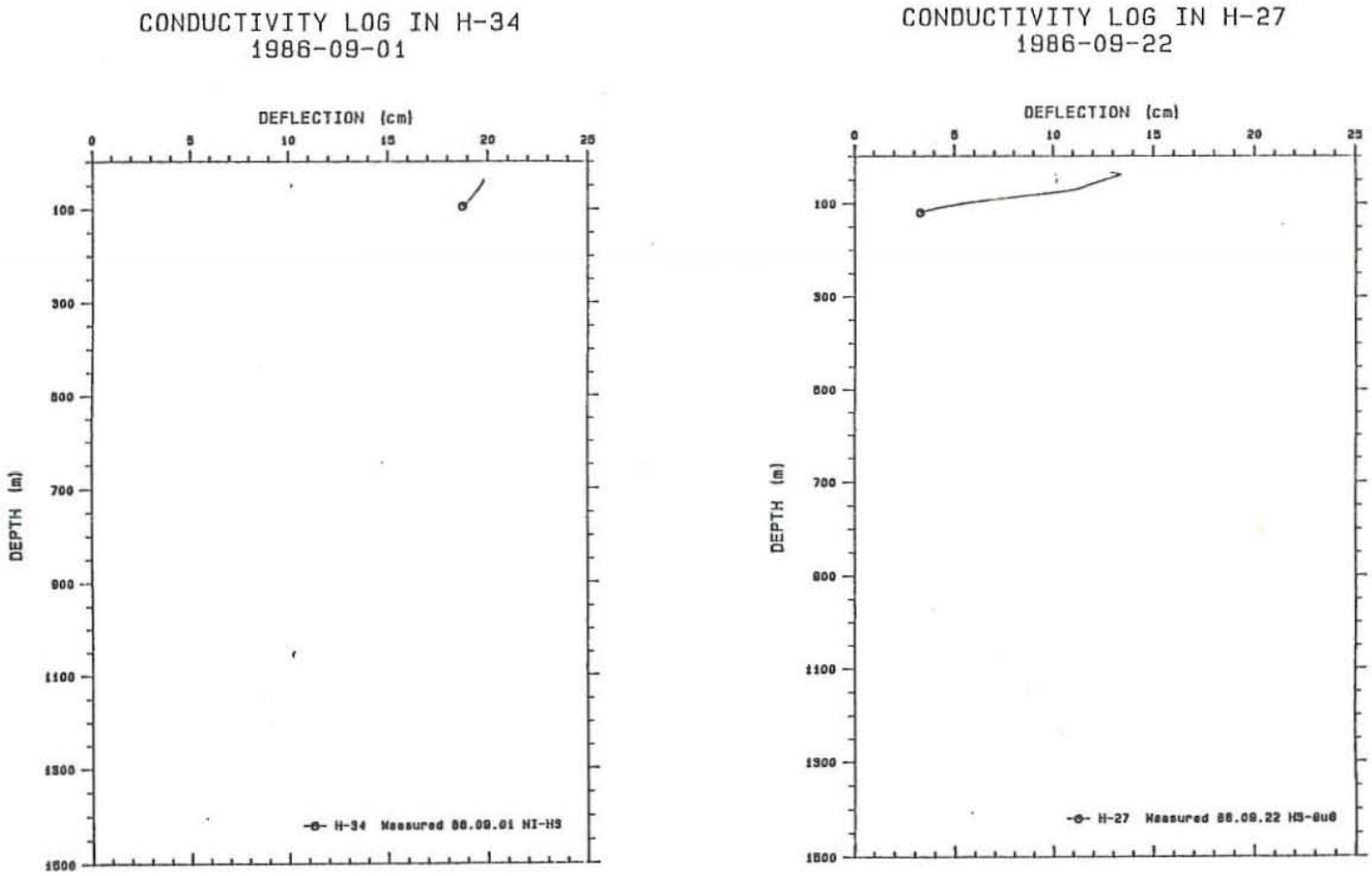


Fig 12. Conductivity logs in H-27 and H-34 measured 1986.

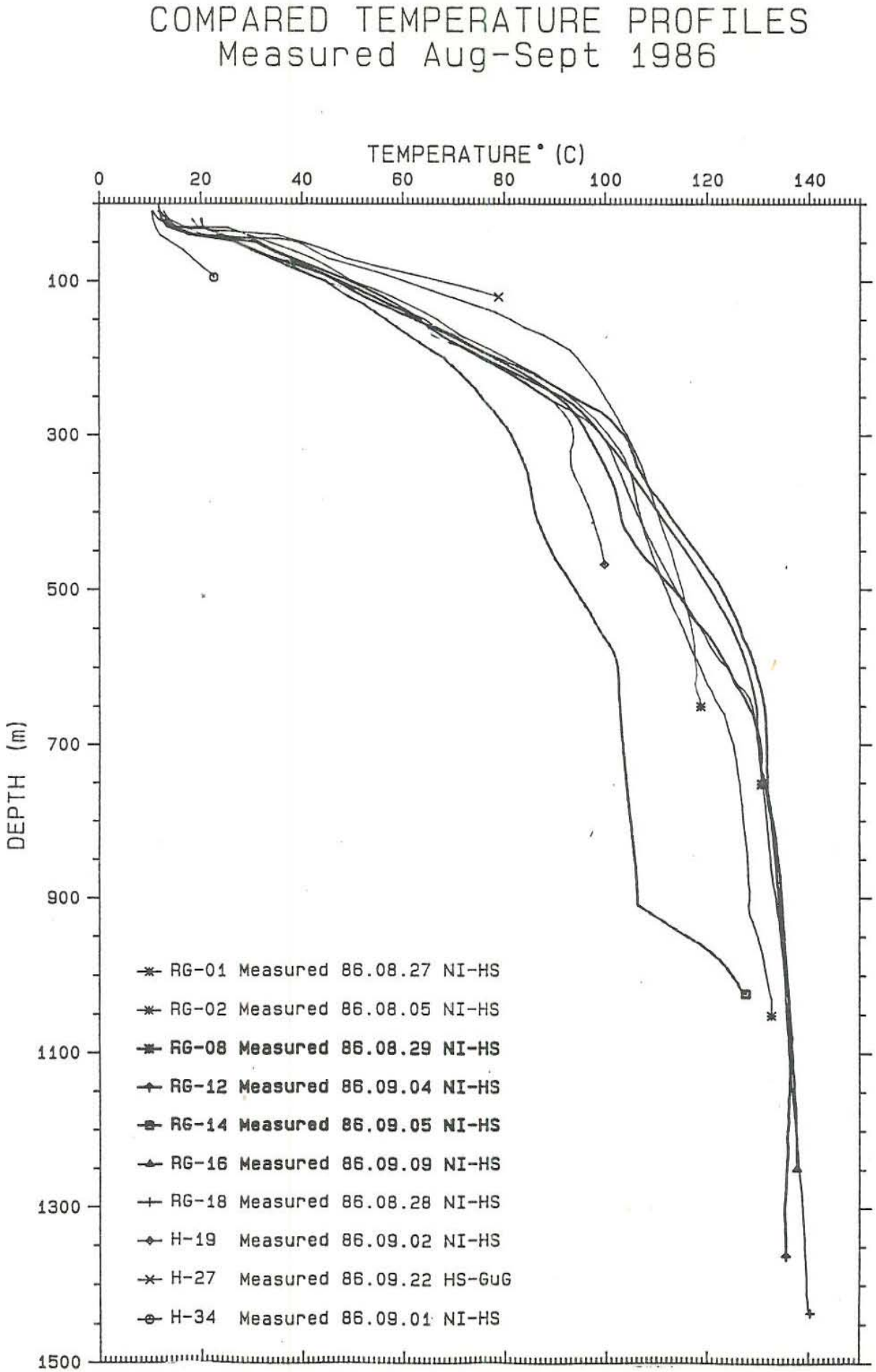


Fig 13. Compared temperature profiles: RG-01, RG-02, RG-08, RG-12, RG-14, RG-16, RG-18, H-19, H-27 and H-34.

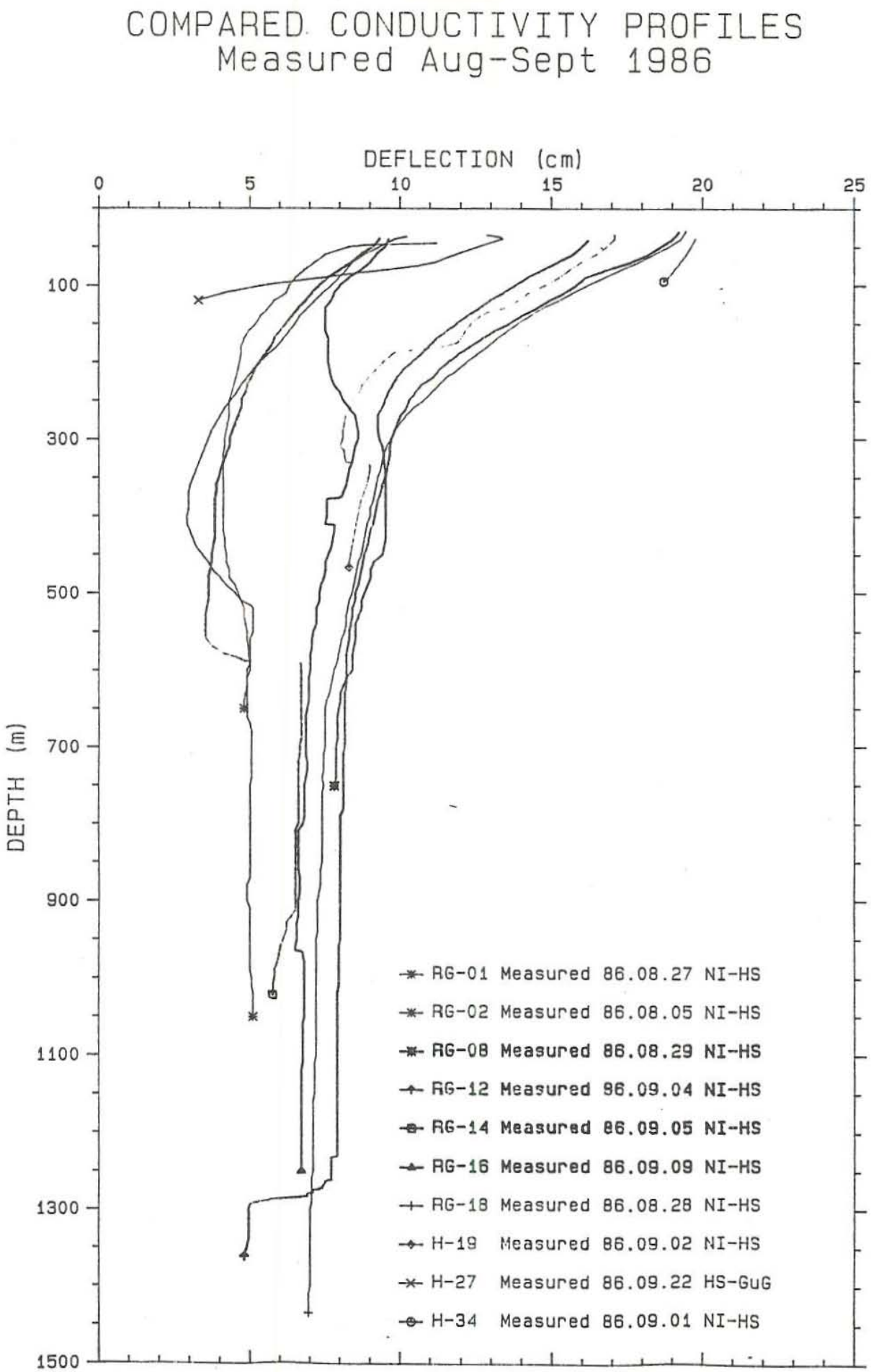


Fig 14. Compared conductivity profiles: RG-01, RG-02, RG-08, RG-12, RG-14, RG-16, RG-18, H-19, H-27 and H-34.

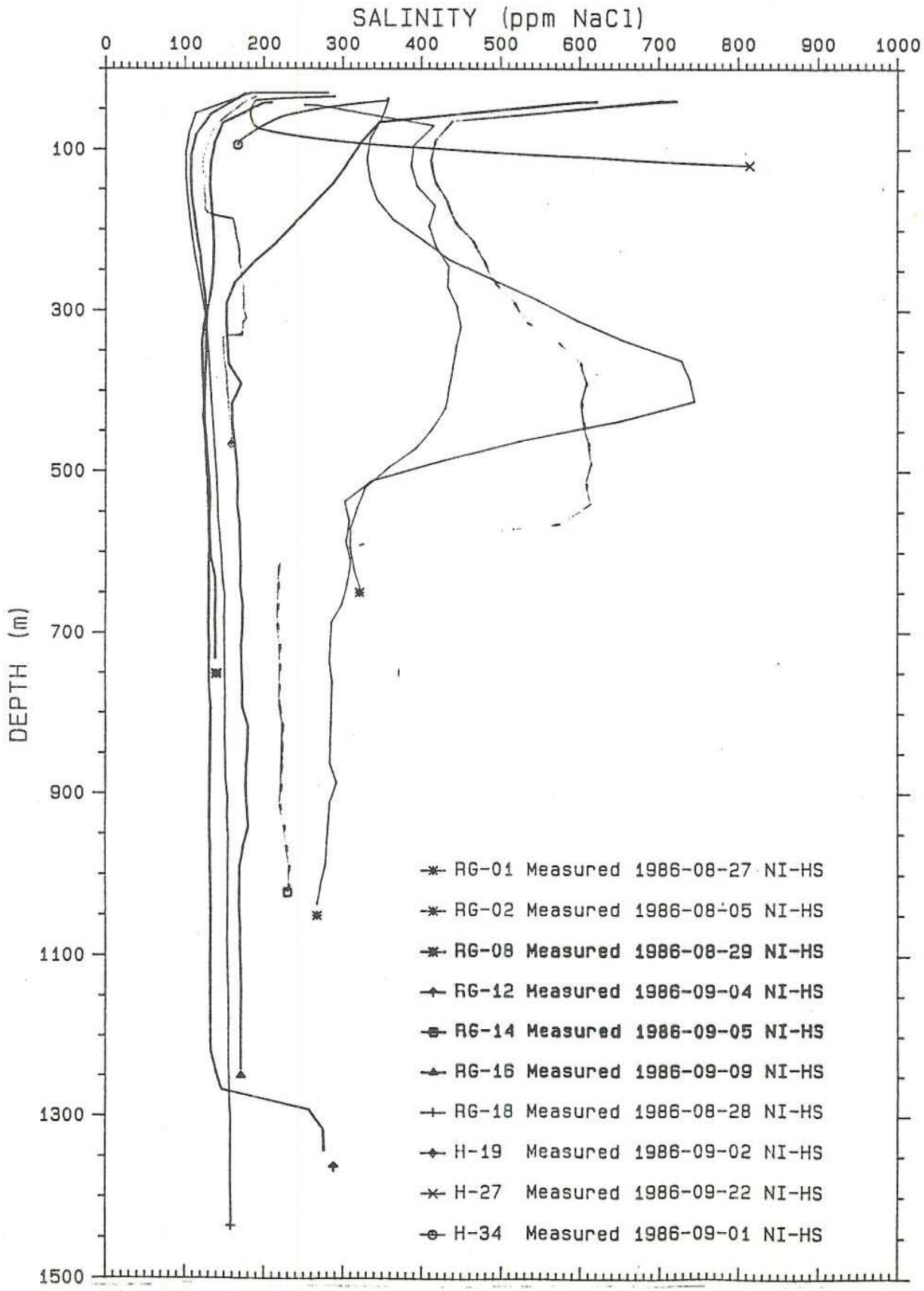


Fig 15. Computed salinity profiles: RG-01, RG-02, RG-08, RG-12, RG-14, RG-16, RG-18, H-19, H-27 and H-34.

Fig 16. Calibration of deflection (cm) into resistivity (ohmm).

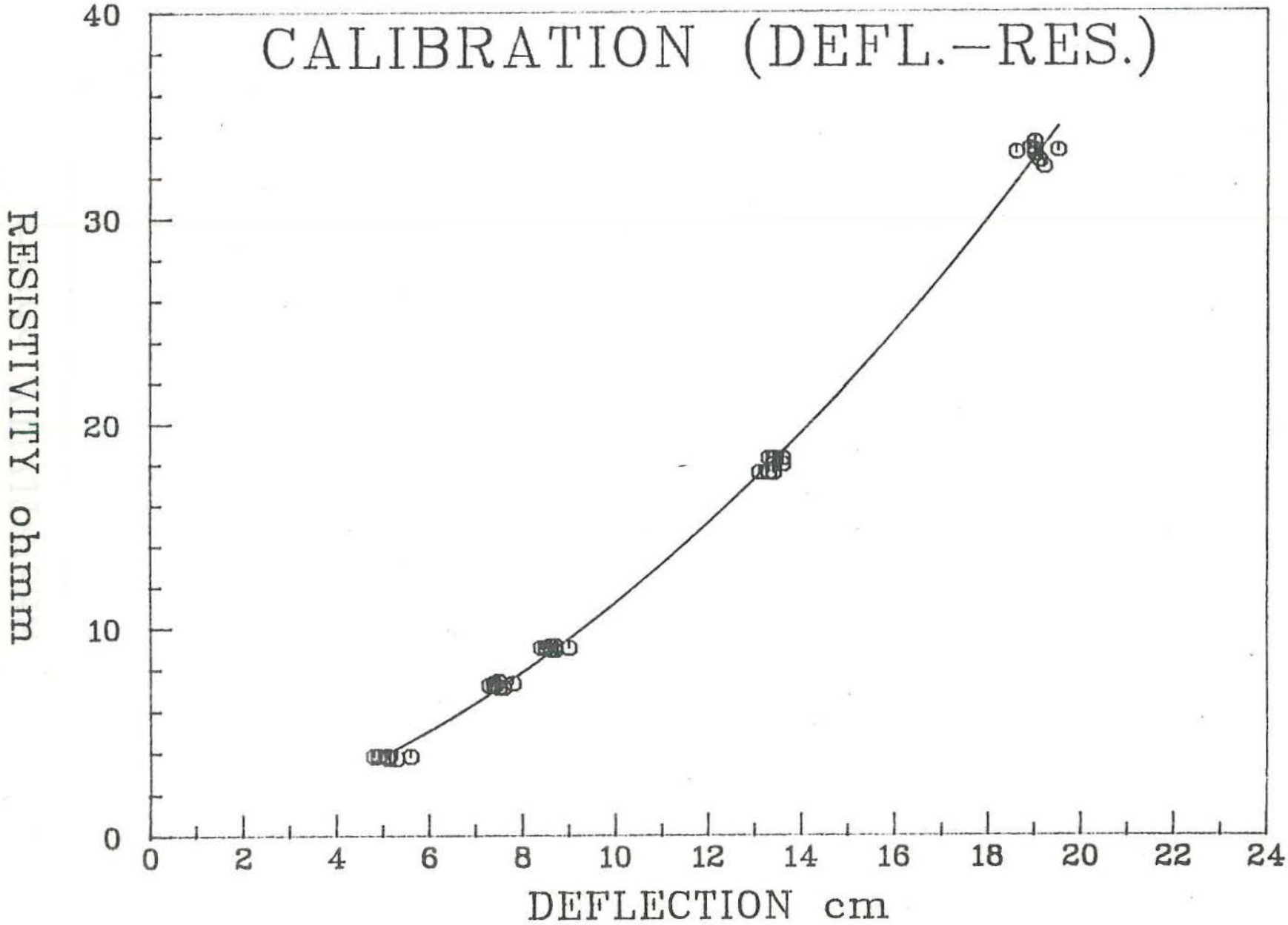


Fig 17. Calibration of deflection (cm) with changes of temperature from 20 to 60°C.

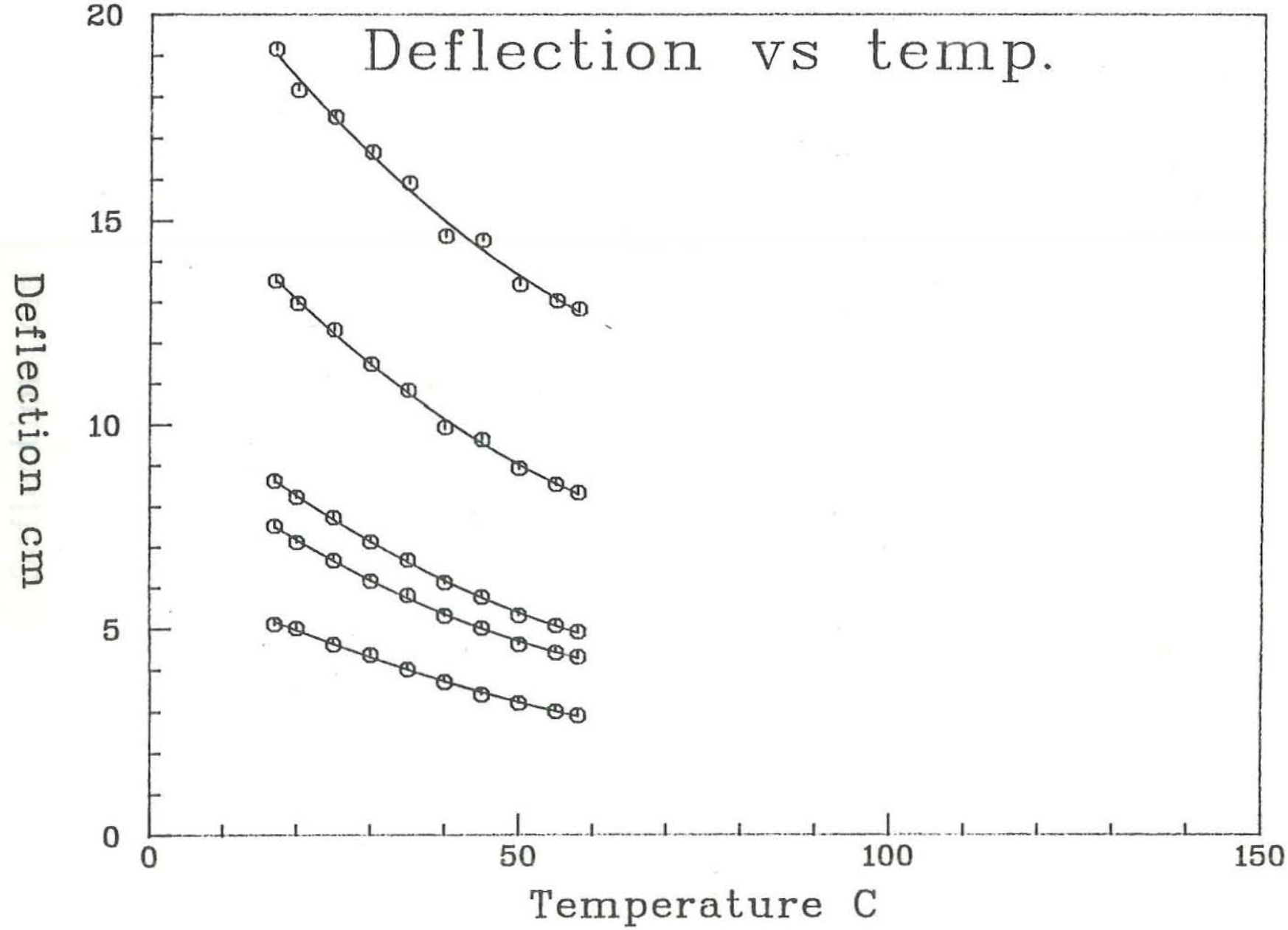
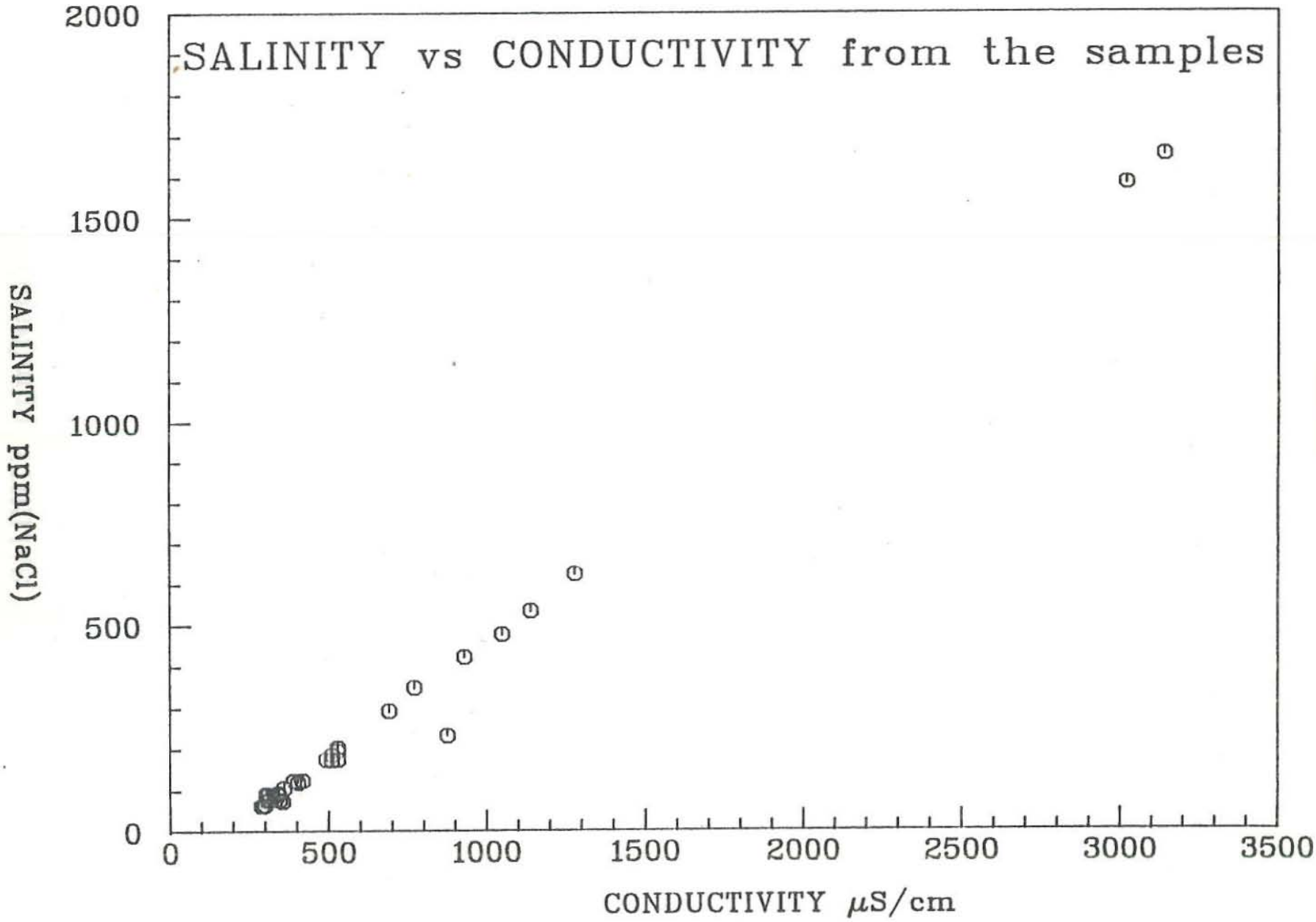


Fig 18. Salinity vs Conductivity from the samples.



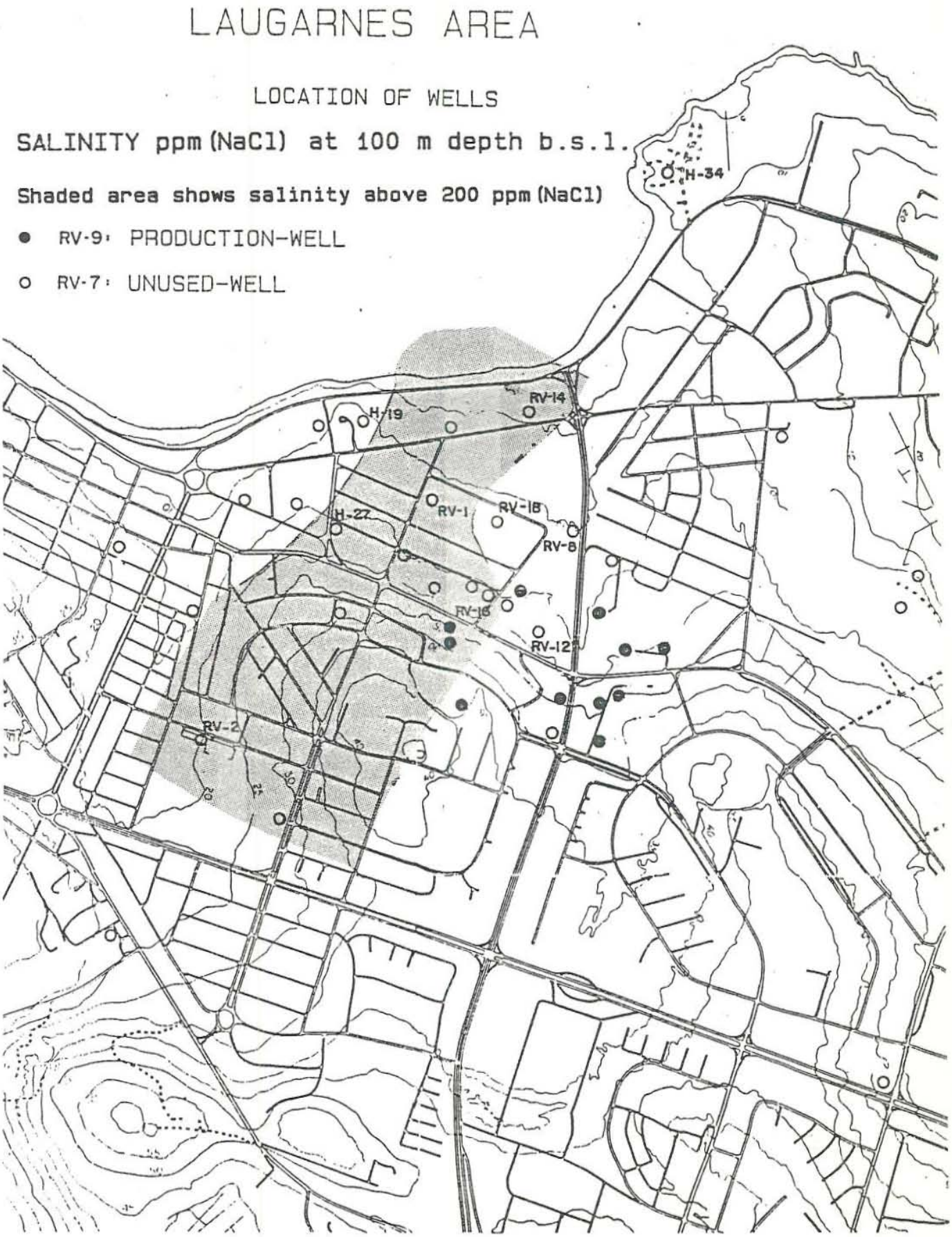


Fig 19. Salinity ppm(NaCl) at 100 m depth b.s.l.

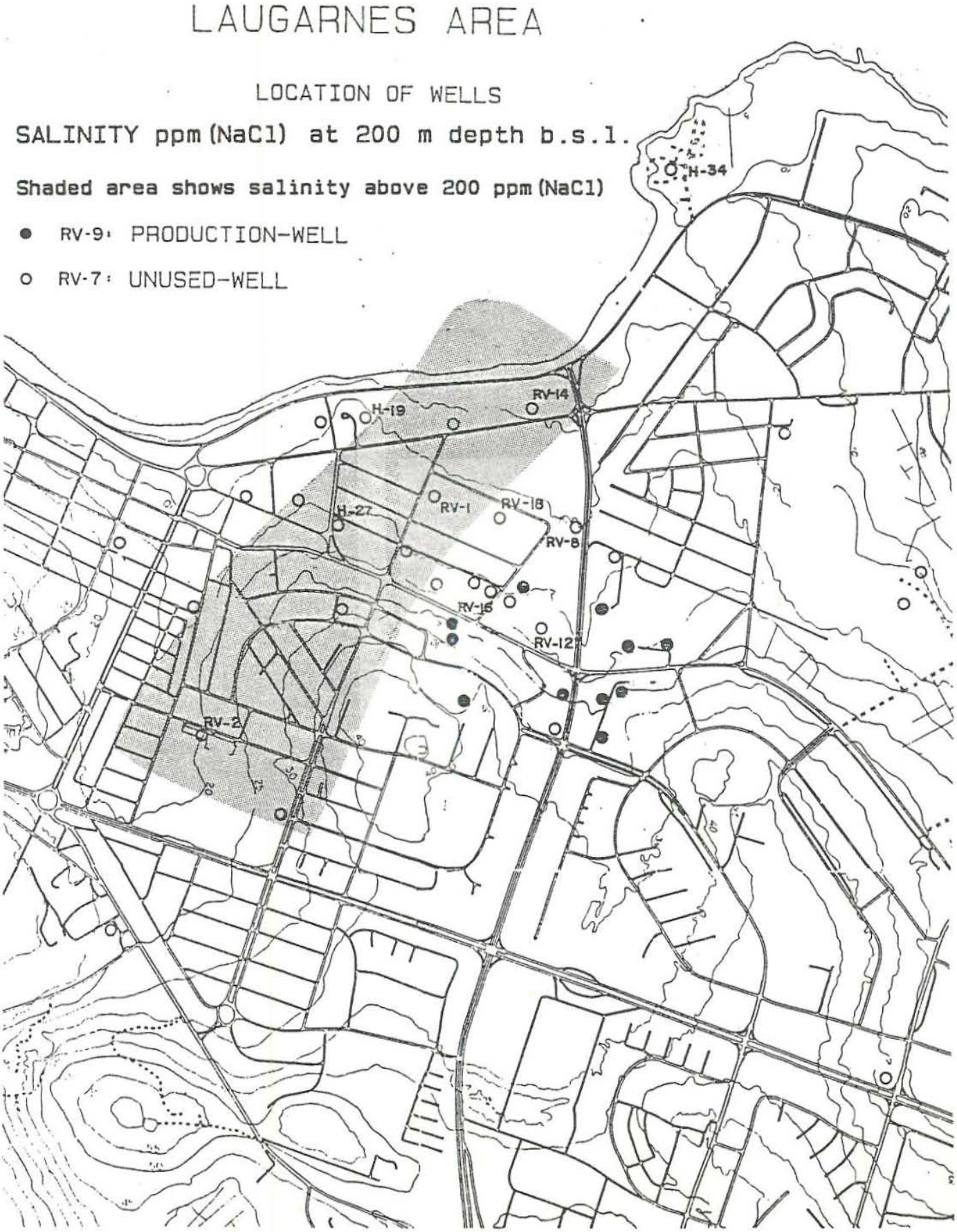


Fig 20. Salinity ppm(NaCl) at 200 m depht b.s.l.

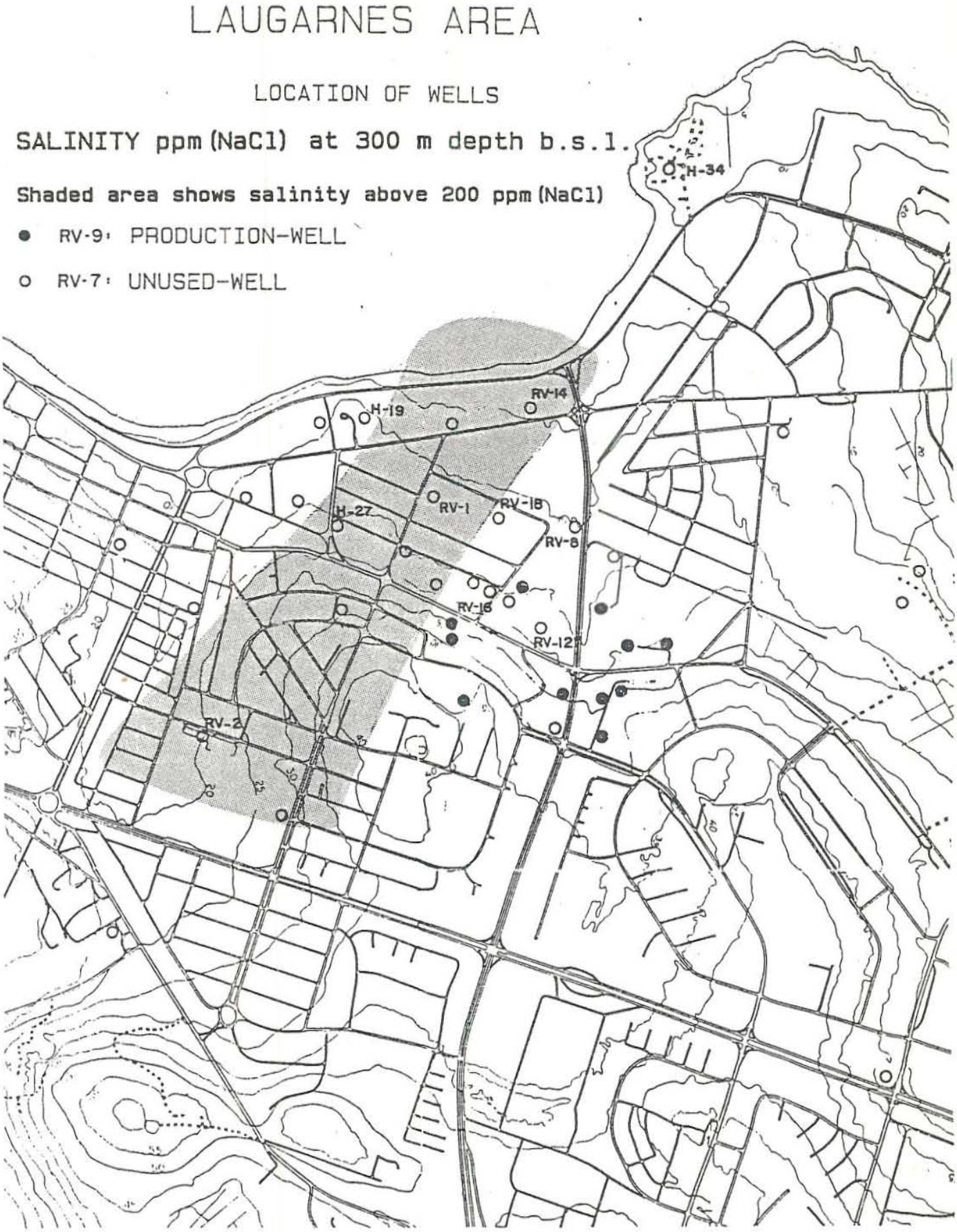


Fig 21. Saliniyt ppm(NaCl) at 300 m depth b.s.l.

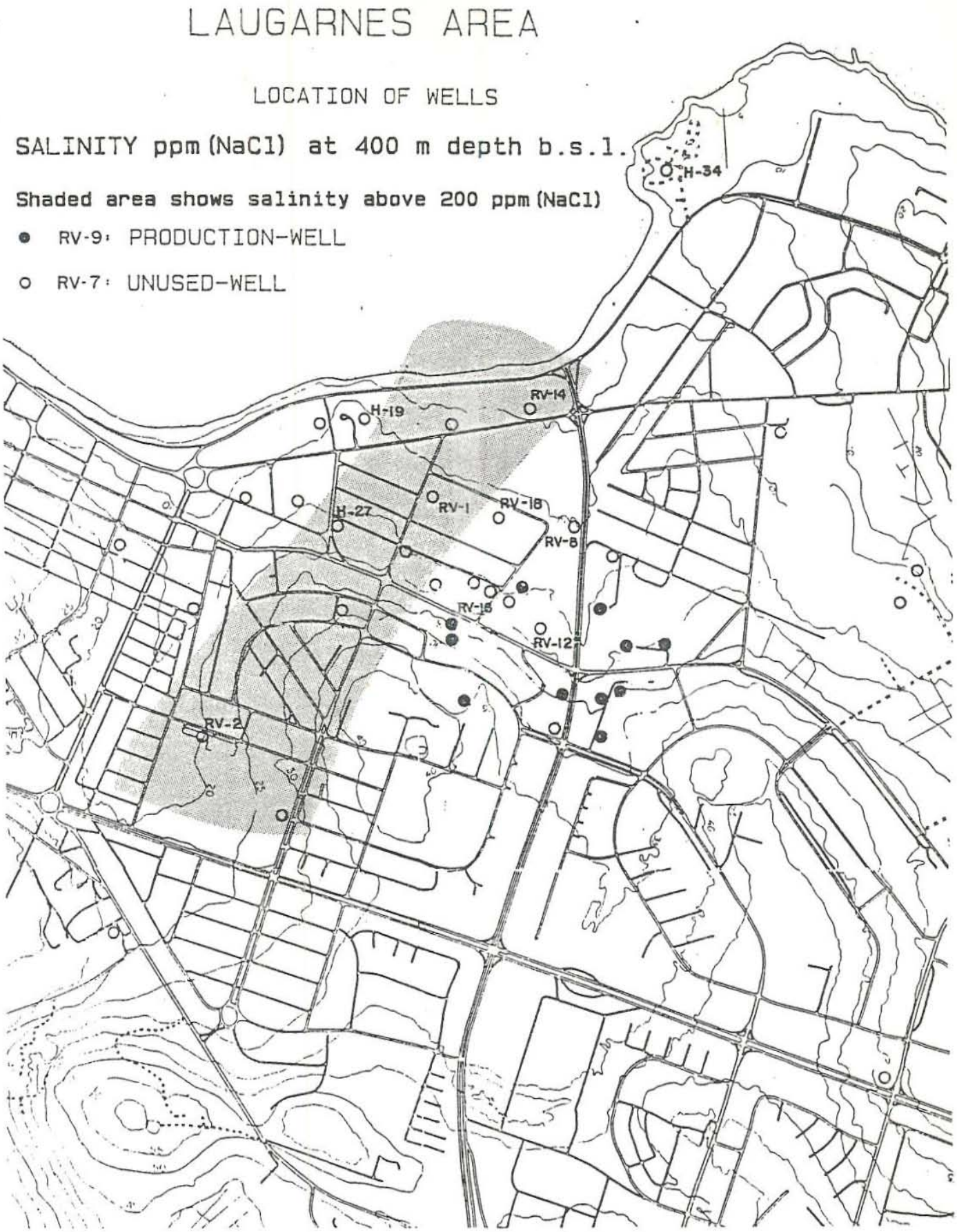


Fig 22. Salinity ppm(NaCl) at 400 m depth b.s.l.

Table 1. Depth of wells, elevation b.s.l., depth of casing and date logged.

Well no.	logged date Y.M.D	Elevation msl	Depth of well meters	Depth of casing meters	Depth logged Aug-Sept 1986
RG-01	86.08.27	12.04	1067	70	1054
RG-02	86.08.05	20.86	653	30	650
RG-08	86.08.29	11.01	1397	91	751
RG-12	86.09.04	17.74	1363	94	1363
RG-14	86.09.05	4.28	1026	101	1023
RG-16	86.09.09	16.78	1300	256	1250
RG-18	86.08.28	12.00	1442	--	1435
H-19	86.09.02	10.20	471.3	--	467
H-27	86.09.22	15.00	403	31	120
H-34	86.09.01	7.00	399.1	--	95

Table 2. Compared result from the samples and result measured in the wells.

	MEASURED IN THE WELLS				MEASURED AT 18 C IN LABORAT.		
WELL nr.	DEPTH	TEMP.	DEFLECTION	CALCULATED PPM(NaCl)	PPM(NaCl)	mS/cm.	OHMm
RG-2	50	39.5	8.3	372.16	1581.2	3020	3.31
RG-2	350	107.7	4.1	443.52	1652.4	3140	3.18
RG-2	645	118.7	4.8	321.27	532.6	1140	8.77
RG-1	50	33.7	9.3	361.2	232.1	875	11.43
RG-1	330	103.8	3.3	636.29	622.6	1280	7.81
RG-1	1000	131.6	5.0	273.12	203.4	528	18.94
RG-8	40	23.6	19.0	154.97	63.5	300	33.33
RG-8	150	62.4	13.6	107.05	61.2	292	34.25
RG-8	700	130.5	7.8	138.39	61.8	288	34.72
RG-12	50	31.0	16.0	156.75	106.0	360	27.78
RG-12	280	101.1	9.2	131.66	76.8	315	31.75
RG-12	1320	135.4	4.9	275.25	174.1	528	18.94
RG-14	50	27.0	9.1	466.60	421.8	930	10.75
RG-14	540	97.7	3.5	613.98	476.2	1050	9.52
RG-14	610	102.5	6.7	217.48	195.2	528	18.94
RG-14	890	106.2	6.5	221.18	185.3	510	19.61
RG-14	1000	125.0	5.8	230.21	174.1	492	20.33
RG-16	50	30.8	9.5	381.09	348.0	770	12.99
RG-16	130	58.7	7.5	301.04	291.9	690	14.49
RG-16	300	99.2	8.6	150.54	93.0	340	29.41
RG-16	430	113.6	7.7	158.32	89.0	342	29.24
RG-18	-	-	-	-	no water sample		
H-19	50	27.2	16.8	134.75	72.7	355	28.17
H-19	160	64.9	12.1	124.85	77.1	329	30.40
H-19	200	76.0	9.4	163.73	118.5	403	24.81
H-19	300	93.7	9.1	174.18	123.5	417	23.98
H-19	325	93.1	8.2	170.60	123.0	390	25.64
H-19	450	99.3	8.3	157.70	77.0	345	28.99
H-27	-	-	-	-	no water sample		
H-34	50	14.0	19.6	271.73	89.7	311	32.15
H-34	90	22.0	18.9	169.34	90.7	303	33.00