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# BURDEKIN DELTA UNDERGROUND WATER INVESTIGATION,

## NORTH QUEENSLAND 1962-1963

*by*

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## SUMMARY

A geophysical survey has been carried out in the Burdekin Delta, North Queensland, at the request of the Irrigation and Water Supply Commission, Queensland. Techniques used include gravity, seismic, resistivity, gamma-ray logging and radioactive tracers.

Gravity work has indicated a fault buried beneath deltaic deposits and also a remarkable negative anomaly for which a hypothetical structure has been computed.

Seismic refraction has been used to construct a bedrock contour plan, which shows a considerable deepening northwards from the river; to the south is a zone of relatively shallow bedrock. Deep drainage channels are indicated, showing in particular possible connections between the Barratta's and the Burdekin River to the west of Kelly's Mountain, and between the former and the Burdekin Delta to the north.

From the resistivity work contour maps have been constructed to show at various depths the extent of saltwater intrusion. Detailed resistivity investigations of one area over a period of 8 months in 1963 by depth probing and traversing suggest that saltwater intrustion is a very real problem. This fact is clearly shown in a comparison of some depth probes made in October 1964 with those taken at the same localities in 1962 and 1963.

By correlation of seismic, resistivity, borehole and other information, cross-sections have been constructed to show the structural form of the delta, the main lithological units, and the probable distribution of solutions within the deltaic deposits. A map has also been produced to show the distribution of permeable sub-surface deposits suitable for artificial recharge.

Auger drilling, gamma-ray logging and the use of radioactive tracers in pumping and tests have also contributed significantly to the study and correlation of near-surface deposits.

# 1. INTRODUCTION

## General

The Burdekin Delta (major town Ayr), covering an area of some 250 sq. miles, is one of the large sugar producing areas in Queensland. In 1962 the gross value of the sugar production was estimated at about 12 million pounds, and in 1963 at 15 million pounds. To keep up a high production, a large quantity of irrigation water is required, which is pumped out of the delta aquifers. However, a number of dry seasons have caused a lowering of the water yield of bores; and also local evidence of salt water encroachment and an increase in the acreage allocated to sugar production have caused some anxiety. Although hundreds of shallow bores and a number of deeper ones have been drilled, no bore logs were kept until about 1960 and most of the drilling information has been lost; thus whatever geological information is available is restricted to the near surface. The first step to improve matters was to assemble the available geological information, and this was done by Watkins and Wolff (1960). Since then the Irrigation and Water Supply Commission has started to drill a grid of observation bores (Map G.W.L. 574 I.W.S.C. dated 8.6.62). Some of the data was used in the preparation of a bore hole map (Plate 3, E55/B5-74).

Before any major engineering projects, such as artificially increasing the recharge, building storage dams, or dams to prevent inflow of salt water into the delta, can be envisaged, more information of a general nature was required. To supply this information the Irrigation and Water Supply Commission of Queensland requested the Bureau to carry out a geophysical investigation in an area between 545000 and 580000 yds E, and north of 2525000 yds N, referring to the Australian Military Grid 4-mile map series, zone 7.

Because of the complexity of the problem and the size of the area, the Bureau responded by sending several parties during 1962 and 1963, applying four geophysical methods. Following the suggestions of the Commission's officers, some areas with serious salt water encroachment problems were investigated to more detail (Merryplain Creek, Anabranch School, Sheepstation Creek, and Rita Island areas).

A network of North/South and East/West lines (Numbered $N_1 \ldots N_{10}$ and $W_1 \ldots W_{11}$) were drawn on the 1 mile to the inch base map of the Burdekin delta. The lines were used for the construction of sections and serve at the same time to indicate a locality, e.g. N3/W5 indicates a locality at or near the intersection of N3 and W5.

Aims

The present surveys were undertaken not only to collect information as efficiently as possible but also:

(i) to test methods, and their applicability to the problem,

(ii) to test which sequence of methods should be used,

(iii) to attempt to show how geophysical results may be integrated with geological and hydrological data and concepts to present a unified interpretation.

In November 1963, the Australian Atomic Energy Commission's radio isotope division and the Bureau carried out radio-active tracer tests close to pumping bores. The aim was to find out whether radio-active tracers could be efficiently used to estimate aquifer characteristics (Andrew, Ellis, Seatonberry and Wiebenga, 1965).

Climate

The following is based on a report of the area by Watkin and Wolff (1960, p.9).

The Burdekin Delta has a dry tropical climate with a marked summer rainfall. The average annual rainfall is about 43 inches, but with large variations in the yearly total. Cyclones may result in high daily falls (maximum recorded 18.8 inches) and monthly rainfalls as high as 55.2 inches (Calvert, 1959). More detailed rainfall data, including that for the years 1962-63 is contained in a Progress Report by the Irrigation and Water Supply Commission, Queensland, 1964.

The mean annual temperature is 74.2°F, ranging from 65°F in July to 81°F in January.

The Burdekin River is noted for large variations in flow ranging from 1,300,000 cusecs for short periods to less than 1 cusec in the dry season, measured near Home Hill.

## 2. GEOLOGY AND HYDROLOGY OF THE BURDEKIN DELTA

The geology of the Burdekin Delta (Plate 2) is described by Watkins and Wolff, (1960). The following passages are taken from their report.

"Whitehouse (undated), considering the geology of the Burdekin River Basin, pointed to the existence of three groups of rocks: the old granites; a series of interbedded lavas, tuffs and sediments; and later intrusive granites and prophyries. The delta comprises a system of aquifers of sands and gravels variously separated by aquicludes of silts, silty clays and clays. Bedrock, where located, has been shown to be mainly granite and related diorite. The coastal margin to the delta consists essentially of littoral deposits up to 3 miles wide. About 19 miles from the mouth of the Burdekin, Stokes Range and Kelly's Mountain, both 600 ft high, with an interconnecting bar across the river ("The Rocks"), form the western boundary of the delta. Stokes Range is thought to represent part of the Upper Devonian sequence of lavas and sediments known to the west. Mt. Inkerman, consisting mainly of granite, 8 miles south of Home Hill, forms part of the southern limit of the delta. Charlie's Hill, 3½ miles NW of Mt. Inkerman, consists of a hornfels mass protruding above the delta plains. The occurrence of limestone deposits (possibly shell banks or marls) were reported in several bores in the Iona area", (e.g. near $N_5/W_{10}$).

In the western part of the delta and around the outcrop areas are the flood plain deposits of the Northcote System (Christian, Paterson, Perry, Latyer, Stewart and Traves, 1953).

"The Burdekin River drains an area of slightly over 50,000 sq. miles; the delta consists of a broad alluvial plain generally less than 50 ft above sea level. During the dry season the river is greatly reduced, and often no surface water flows. During flood periods, part of the delta is occasionally flooded when floodwater overtops the naturally built up levees. Then the water flows to sea through creeks or lagoons, whidh formed old river beds (e.g. Sheepstation, Kalamia and Plantation Creeks). However, because of the permeability of the deltaic sedimemts, it is frequently observed that surface run-off reduces or disappears because water seeps into the subsurface formations. The deltaic sediments are considered to provide the principal storage; storage in the country rock or clay plain areas is thought to be negligible. Recharge is provided from the following sources: (i) Rainfall in the delta area, (ii) Runoff from marginal drainage towards the delta, (iii) Overtopping floods from the river, (iv) Outflow from the river through its banks during periods of high flow."

In 1962 the Commission started drilling a large number of bores in a regular grid. Part of the information is contained in Plate 3, and where applicable has been used in this report. Further, the Commission prepares eight groundwater level contour plans per year. Some of this water level data is shown on Plates 18-36.

## 3. METHODS APPLIED

Gravity methods depend on density contrasts. They may be used as a reconnaissance tool, and it was expected that the gravity data would picture roughly the bedrock configuration. Further, it was hoped that some information might be obtained about near surface formations. Hence, gravity work was carried out during 3 months in 1962 and during 6 months in 1963. The results are discussed in PART II, Section 8.

Seismic refraction methods depend on sound velocity contrasts between formations. With seismic methods bedrock (weathered or unweathered) depths may be determined with an accuracy of, say, 15 to 20% of depth, and in many cases conclusions about the nature of the formations may be made. Hence, seismic depth probes can, in many respects, replace drilling, and seismic depth probes may be used as controls for other methods such as resistivity.

Three months work of seismic refraction traversing were carried out in 1962 at the following places: (i) across the river bed at "The Rocks", between Kelly's Mountain and Stokes Range, with the objective of determining the bedrock profile. From this rough estimates can be made of the possible flow of water in the river and in the sands beneath. (ii) to the east of Kelly's Mountain to check whether a sub-surface river branch exists which flows northward; and (iii) west of "The Rocks", to check whether a subsurface river branch exists flowing northwards west of Kelly's Mountain. In 1963, 90 seismic depth probes were made in the Burdekin Delta, and 22 in the neighbouring Giru area. The information was sufficient to construct a bedrock contour plan.

With electrical methods the resistivities of subsurface layers are measured. Depth estimates are not certain; hence the combination with seismic methods, and borehole data which provide depth control, is essential.

The resistivity of a rock is dependent on porosity and on the resistivity of the pore solution, which is inversely proportional to salinity. Because the porosity of unconsolidated or semi-consolidated deposits varies between relatively narrow limits, the resistivity of unconsolidated deposits is a sensitive indicator for the presence of either saline, brackish or fresh water. In 1962 about 60 electrical depth probes were made in the Burdekin Delta; in 1963 another 480 were made in the delta, and in the neighbouring Giru area. A further 35 depth probes were made during October 1964 in selected areas to check on salt water encroachment.

Gamma-ray logs were taken in cased bore holes, and records were made of variations in natural radiation. In sediments these may be correlated with clays and sands.

During the investigation a Proline auger drill (auger diameter about 3½ inches) mounted on a Chamberlain tractor was used to drill shallow shot holes for the seismic refraction work, and bore holes down to 60 to 70 ft, to check the nature of the near surface layers and water.

## 4. GRAVITY METHOD

### General

The gravity observations were made with Worden Gravity Meter, serial number 61. The instrument was calibrated on the Melbourne Calibration Range in May 1963. The calibration factor of the instrument was found to be 0.09047 mgal/scale division. The consistency of the calibration factor was tested on the Townsville calibration Range, and by repeated measurements of the gravity interval between the Townsville pendulum station and the Ayr Base Station in July and December 1963. This gravity interval (20.33 mgal) was established by the 1962 gravity survey.

The observed gravity values were computed relative to the Ayr Base Station, established by the 1962 survey. Position of Ayr Base Station: centre of bandstand in the Ayr War Memorial Gardens, Latitude: 147°24'10", longitude: 19°34'40". The absolute value of observed gravity at the Ayr Base Station is 978,644.3 mgal, tied to the Townsville pendulum station in 1962, and assuming a value of 978,624.0 mgal at Townsville.

The positions of gravity stations were determined by using the 1" = 1 mile map produced by the Irrigation and Water Supply Commission.

315 gravity stations were observed by the 1962 gravity survey and 1394 by the 1963 survey. Thus the total number of gravity stations in the area is 1709. The average number of gravity stations per square mile is 6.

The gravity traverses were arranged so that they formed a closed network. The closing errors in the loops of the network were computed and distributed. The closing errors were generally small, the greatest being 0.13 mgal.

Elevation

The elevation of 718 stations were found by topographic levelling (See Plate 40). The elevation of 991 stations were obtained by use of the "Elevation meter" Model 204 (Western Geophysical Company). This instrument is an electromechanical device mounted on a vehicle. The instrument measures the instantaneous angle of inclination and the distance travelled by the vehicle and continuously evaluates the expression:

$$H = \int \sin \theta \, ds$$

where $H$ = relative elevation

$\theta$ = angle of inclination from the horizontal

$s$ = slope distance

112 benchmarks were used as fixed points. This gave a check on the accuracy of the instrument.

The greatest error found was 3.2 ft. over a distance of 2 miles; and the root mean square error was 1.5 ft. over an approximate average distance 2.4 miles.

Elevation and latitude corrections

The observed gravity values were reduced to sea level. The combined elevation correction factor is a combination of the free air correction factor and the Bouguer correction factor. The latter is directly proportional to the density of near surface rocks. To find this density Nettleton's "density profile" method was used (Nettleton, 1940, p. 48). The density obtained was 1.9 gm/cm$^3$. The corresponding elevation correction factor (0.0698 mgal/ft) was used.

Latitude corrections were made for the differences from the latitude of Ayr Base Station (Latitude: 19°38'40"), and a correction to the International gravity formula was applied for the latitude of Ayr.

Bouguer Anomalies

A contour map of Bouguer anomalies was produced on a 1" - 1 mile scale (Plate 4).

The accuracy of Bouguer Anomalies is affected by:

(1) Random error in observed gravity: $\Delta g$

(2) Error in elevation: $\Delta h$

(3) Error in latitude: $\Delta l$

(4) Systematic error in density: $\Delta \sigma$

The estimated errors are given below:

(a) Random errors

$\Delta g$ = $\pm 0.05$ mgal.

$\Delta h$ : $\pm 2$ ft. ($\pm 0.14$ mgal.)

$\Delta l$ : $\pm 0.1$ miles ($\pm 0.09$ mgal.)

Computing the square root of the sum of the squares gives the random error in Bouguer Anomalies: $\sqrt{\Delta g^2 + \Delta h^2 + \Delta l^2}$. This was found to be $\pm 0.17$ mgal.

(b) A Systematic error is introduced by the error in density used in the elevation correction. The magnitude of this systematic error equals:

$$2\pi G h \Delta\sigma$$

where G = gravitational constant

h = elevation

$\Delta\sigma$ = error in density

For $\Delta\sigma = \pm 0.2$ gm/cm$^3$ this systematic error is $\pm 0.00255$ mgal/ft. For maximum elevation difference of 93 ft observed this amounts to $\pm 0.24$ mgal.

Regional and residual gravity maps of the Burdekin Delta

The regional gravity values were computed by averaging Bouguer anomalies of eight points on a circle of radius (r) 1.6 miles. The average value was assigned to the centre of the circle. 295 regional gravity values were computed using intersection points of a one mile square grid. The regional gravity map, (Plate 5) was constructed by contouring the regional values. The residual gravity map was made by subtracting the regional values from the Bouguer anomalies (See Plate 6). The residual gravity map, resembles a second derivative (Swartz, 1954) map for the following reasons:

The curvature of a gravity profile (shown diagrammatically in section in Fig. 1) is $1/R\ d^2G/dZ^2$, where R is the curvature radius, G gravity acceleration, and Z the vertical direction. Where the curvature is zero, the residual is close to zero; where the curvature is either maximum downwards or upwards, the residual will be near maximum position or negative.

Also, subtracting regionals determined by using average values over a circle with radius r works like a filtering procedure. Gravity anomalies whose horizontal dimension is much larger than 2r are filtered out on the residual map; with horizontal dimension smaller than about 2r they remain in (See Swartz, 1954, p.57).

## 5. SEISMIC METHOD

### Equipment and procedures

The seismic refraction work was carried out using three different types of equipment. In 1962 a model 621 T.I.C. 24 channel reflection/refraction seismograph with (T.I.C. 20 c.p.s. geophones) was used in conjunction with two 12 channel "Seismod" variable area display units and a 48 channel camera. In 1963 a mid-Western 12 channel seismograph and also an S.I.E. 24 channel seismograph with "Seismod" were used. During 1962, the geophone spacings used were of 100 or 50 ft, but with only 50 ft separations during the following year.

Geophones are laid out in a straight line on the ground. Shots are fired at both ends of the line, and a photographic record is made of the arrival of the vibrations of the shot at each geophone. Where a Seismod is used the vibrations are displayed on the record in two different ways (see Fig. 2), both as an oscillating line, and as an expansion or contraction of a signal of normally constant width.

The line traces are used to pick the first arrival of energy at each geophone as shown in Fig. 2. A correction is applied to correct for the depth of burial of the shot, the delay in the firing of the detonator after the shot break is recorded, and the distance of the shot break from the nearest timing line on the record. The timing lines are at 10 millisecond intervals, with a heavier line every 50 milliseconds. The figures given on the record represent the time to the first break on the trace, which in this case is an upward movement.

The arrival times are plotted (Fig. 3), and the velocities are calculated from the gradient of the lines produced by joining the points together. To determine a velocity at least three points are required, although an approximate figure may be obtained from two points. It is possible however, to detect velocities from the seismod traces on the lower part of the record, by looking for alignments in events arriving after the first breaks. In Fig. 2 a velocity of 6,400 ft sec is shown on the seismod, which has been inserted on the time distance curve in Fig. 3.

The 1st event on trace 4, geophone 3 recorded on the seismod display can be correlated with the second events of the last three traces which lie on the 6400 ft/sec line. This is further supported by a similar velocity recorded on a neighbouring spread.

Calculations

The depth at each end of the spread may be obtained from the intercept times of the different velocities at the origin, which is taken at the shot point. In Fig. 3, the intercept times at the shot point 11 + 25', for the shot whose record is on Fig. 2, are given below with the velocities.

| Intercept time (milliseconds) | Velocity (ft/sec) |
|---|---|
| 21 | 1000 |
| 52 | 2000 |
| 69 | (6,400) 6,800 |
| | (17,500)17,000 |

The velocity of 6,400 ft may be considered as being due to the same material as the velocity of 7,500 ft/sec recorded in the reverse direction. The variation of velocity is due to one shot being fired up the dip of the layer, and the other down the dip. The same reasoning applies to the velocity of 17,500 ft/sec, which is considered with the velocity of 16,500 ft/sec. The true velocities of these layers are 6,800 ft/sec and 17,000 ft/sec.

Using a procedure described by Dobrin (1962) it is possible to calculate the thickness of each layer. The results for the figures Nos. 2 and 3 are given below:

| Velocity (ft/sec) | Thickness (ft) | Depth to bottom of layer |
|---|---|---|
| 1000 | 11 | 11 |
| 2000 | 32 | 43 |
| 6800 | 57 | 100 |
| 17000 | | |

The depth to the 17,000 ft/sec layer is 100 ft, and the time taken for energy to travel to this layer and back to the surface is 69 milliseconds; hence the average velocity is 2900 ft/sec from the surface to the 17,000 ft/sec layer.

Fig. 4 shows a diagrammatic representation of seismic wave paths, from shots fired from $S_1$ and $S_2$. When shot $S_1$ is fired a reciprocal geophone, RG1, is placed on $S_2$, and when $S_2$ is fired, a reciprocal geophone, RG2, is placed on $S_1$. The points marked as R.T. in Fig. 3 are the reciprocal geophone times on spread DE.

The path followed by energy from $S_1$ to geophone 6 is:-

$$a + b + d \qquad (1)$$

and to RG1 is:-

$$a + b + g + c + f \qquad (2)$$

The path followed by energy from $S_2$ to geophone 6 is:-

$$f + c + e \qquad (3)$$

and to RG2 is:-

$$a + b + g + c + f \qquad (2)$$

If (1) and (3) are added and (2) is subtracted from the sum we have:-

$$(a + b + d) + (f + c + e) - (a + b + g + c + f) = d + e - g \quad (4)$$

In a two layer configuration (i.e. velocity V1 in the upper layer and V2 in the lower layer), the wave from S1 for example, is refracted along the interface, the critical angle of refraction ($i_2$) being $90^\circ$. From Snell's law, and taking the case where

$$V_2 \gg V_1, \text{ then } d_1 \rightarrow 0,$$

$$d, e \rightarrow \text{thickness of } V_1$$

$$\text{and} \qquad g \rightarrow 0$$

From (4) the thickness of $V_1$ becomes in this case $= (d + e)/2$

The average velocity, Va to the lowest refractor is given by:-

$$Va = V2 \; V1/(V2^2 - V1^2)^{\frac{1}{2}}$$

and again, assuming V2 $\gg$ V1, as above.

$$Va \rightarrow V1$$

Therefore the depth is approximately given by $(d + e)/2$. V1.

In the time distance curve illustrated in Fig. 3, the reciprocal time is 148 msec. At Geophone 10, the time taken from 1-300 ft is 124 msec, and from 11 + 300 ft is 95 msec, hence the time taken to travel to and from the refractor at geophone 10 is 124 + 95 - 148 = 71 msec. The time to travel down to the refractor is $35\frac{1}{2}$ msec. The average velocity determined at geophone 11 is 2900 ft/sec, so the depth at geophone 10 is 2.9 x 35.5 ft = 103 ft.

By interpolating between the average velocity at both ends of the spread it is possible to compute the depth at each geophone.

Accuracy

The measurement of times on the record depends on the sharpness of the first breaks and the accuracy of the zero correction; an accuracy of 1 to 2 msec should be possible.

The determination of velocities from the time distance curve depends on the number of geophones that detect a layer of any velocity. The highest velocity refractor can generally be determined to ± 5%, but intermediate velocities may be subject to an error of ± 20% where they are recorded only on two geophones. Where it is possible to determine the velocities from later events shown on the seismod the error should be reduced to ± 10%. Thin layers may not be detected, and this is also possible where the velocity of an intermediate layer is lower than that of the overlying layer. This is called velocity reversal.

Therefore a thin layer of weathered bedrock on top of the fresh bedorock may not be detected as a first arrival in this area. In the continuous traverses shot in 1962 with 100 ft geophone spacing, a velocity of about 10,000 ft/sec was frequently detected on the seismod. The inclusion of this layer causes an increase in depth of about 15%. This layer was generally not observed in 1963, since much of the seismic work was carried out in areas where the lower velocity layers were thicker thus tending to mask the presence of the 10,000 ft/sec layer on the seismic records, and it is possible that this layer is present in some cases, but not observed. The errors are summarised in Table 1.

TABLE 1

ERRORS

| Source of error | Amount of error |
|---|---|
| Reading times off record | ± 5% |
| High velocity measurement | ± 5% |
| Intermediate velocity measurement without seismod | ± 20% |
| Intermediate velocity measurement with seismod | ± 10% |
| Weathered layer missed out | − 15% |

The total possible error will lie between the limits +16% and −22% assuming an equal probability of the seismod showing or not showing a given velocity.

Interpretation of Seismic Velocities

TABLE 2

INTERPRETATION OF SEISMIC VELOCITIES

| Velocity range, ft/sec | Material |
|---|---|
| 1000 - 2000 | Sands, clays, sandy clay and soils above the water table. |
| 2000 - 5700 (1) | Sands, clays, sandy clays and gravels, below the water table. |
| 5700 - 6700 (2) | Semiconsolidated sediments, or very weathered bedrock. |
| 6700 - 8500 (2) | Consolidated sediments or weathered bedrock. |
| 8500 - 14,000 | Slightly weathered bedrock, or limestone. |
| 14,000 - 20,000 | Fresh bedrock. |

Notes to Table 2

(1) Previous surveys (Wiebenga and Mann, 1962; Wiebenga, Polak and Andrew, 1963) have shown that in the range 2,000 to 5,700 ft/sec the velocity is related to clay content; the higher velocities being associated with low clay content, and the lower velocities with high clay content. Good aquifers have tended to show velocities in the range 4,500 to 5,700 ft/sec.

(2) Although seismic velocities may not indicate specifically good aquifers, these formations could still yield appreciable amounts of water.

The velocities of unconsolidated material beneath the water table and the velocities of bedrock material are shown on Plate 10.

Contour maps of the surface of consolidated material are shown on Plates 11 and 12.

## 6. RESISTIVITY METHOD

Several different resistivity meters were used during the survey; they were:-

A.C. Geophysical Megger, 0-30 Ohm, frequency 8-10 c.p.s.

A.C. Megger Earth Tester, 0-3000 Ohm, frequency 50 c.p.s.

A.C. Tellohm meter, 0-10 Kilo Ohm, frequency 110 c.p.s.

A.C. Yew Earth Resistance tester, 0-300 Ohm, frequency 95 c.p.s.

D.C. B.M.R. Type A Resistivity meter, 0-100 Kilo Ohm.

D.C. B.M.R. RM.1 Resistivity meter, 0-10 Kilo Ohm.

The Megger Earth Tester, Tellohm meter, and Yew meter were used mainly for traversing. The depth probes were measured using the A.C. Geophysical Megger, or one of the two D.C. meters.

Although the A.C. meters have less interference from contacts between the electrodes and the ground, and also from telluric currents, they have other disadvantages. The limit to which good readings can be obtained from any meter depends on the amount of current that is put into the ground, as the size of the measured potential determines the accuracy of the observed resistance. At large spacing a large current is required to produce measurable results. Of the A.C. meters only the Geophysical Megger generates sufficient current for use with spacings up to 3000 ft. between current electrodes. The Yew meter, Tellohmeter, and Megger Earth tester are accurate only out to a spacing of about 300 ft. between current electrodes, in the Burdekin area.

The types of resistivity method were used, resistivity traversing, and resistivity depth probing. The purpose of resistivity traversing is to determine the lateral variations of electrical resistivity, while the purpose of the depth probes is to determine the vertical variations in electrical resistivity.

Resistivity traversing

Four electrodes with constant spacing of 50 ft between them were moved over the ground, and readings taken at intervals of 50 or 100 ft. The variations of reading observed are due mainly to variations in resistivity in the top 30 ft of the ground beneath the traverse. The line of electrodes may be either along the line of the traverse, or at right angles to it, depending on the nature of the boundary that it is hoped to identify from the traversing.

The traverses carried out in the Burdekin survey were to determine salt water fronts at shallow depths. They are described in the section on detailed investigations.

Resistivity depth probing

The resistivity depth probes were made using three different electrode configurations - the Wenner configuration, the Lee configuration, and the Schlumberger configuration. They are shown diagrammatically in Fig. 6.

In the Wenner configuration, Fig. 6 (2), all four electrodes are moved for each reading so that the separation between electrodes for a total spread length 3a is a. In the Lee configuration, Fig. 6 (1), electrode $P_2$ is fixed and the other three are moved so that for any spread length 3a, $C_1P_1 = a$; $P_1P_2 = \frac{a}{2}$; $P_2C_2 = 3\frac{a}{2}$, and $P_2$ is always the centre point of the spread. In the Schlumberger configuration, Fig. 6 (3), the separation of the potential electrodes $P_1P_2$ is kept small compared with the separation of the current electrodes $C_1C_2$. The outer electrodes only are moved until the reading obtained between the potential electrodes becomes small, when the outer electrodes are left in place, the inner electrodes expanded and the reading repeated. The inner electrodes are then left in place and the outer electrodes expanded until the process has to be repeated. As a general rule the relation between the spacings in the Schlumberger configuration in the range is:-

$$\frac{2a}{5} > b > \frac{2a}{10}$$

Difference between electrode configurations

The difference between the Lee and Wenner methods is simple; the difference of potential between potential electrodes in the Lee configuration is exactly half the difference in potential between potential electrodes in the Wenner configuration, as the separation in the Lee configuration is a symmetrical half of the separation in the Wenner configuration. By doubling the reading obtained with the Lee configuration, the results can be treated in the same way as those of the Wenner configuration.

The difference between the Wenner and Schlumberger methods is described by Andrew and Wiebenga (1965). It is shown that for all practical purposes the shape of the master curves (used in the interpretation of field curves) is the same, with a shift of origin owing to the fact that the ordinate, a, is half the length of the spread in the Schlumberger case, and a third of the length in the Wenner case.

In this survey the same interpretational techniques were applied to all types of curve.

Results and interpretation

Figs. 7 & 8 show a selection of depth probe curves obtained in the Burdekin Delta. To obtain the curves for interpretation the readings are multiplied by a factor dependent on the electrode spacing and are then plotted as the log of reading times this constant (i.e. log of apparent resistivity) against the log of the spacing. It can be seen from the figures that there are a number of different types of curve, each representing a different subsurface layer configuration.

As the interpretation of resistivity curves involves the interpretation of a potential field, it is not possible to obtain a unique solution from resistivity depth probes alone. There are an infinite number of possible distributions of resistivity with depth that can give rise to the same depth probe curve. In this survey there was normally some depth control available from seismic or drilling results, which makes it possible to interpret the resistivity results with a greater degree of reliability.

Two methods of interpretation were used on the results of this survey.

(1) Repeated use of two layer Master curves (after Roman) for multi-layer problems. This technique is based on a set of two layer curves that have been prepared from equations for potential given by Parasnis (1962, p.72). A set of 2-layer type curves is shown in Fig. 9. Using these curves it is possible to obtain a solution for a simple case where two horizontal layers of different resistivity are present. Where more than two layers are present, the first two layers can be represented by 1 layer.

Considering thick layers only (meaning thick on log scale) two main groups of problems exist: (a) where a low resistivity layer is located between two layers with a relatively high resistivity, and (b) where a high resistivity layer is located between two layers of relatively low resistivity.

The problem of a low resistivity layer between two layers of higher resistivity is solved by using Hummel's principle (Guyod, 1947/48; Maillet, 1947), in which the 2 upper layers of thickness $h_1$ and $h_2$, with resistivities $\rho_1$ and $\rho_2$, are replaced by one layer of thickness $(h_1 + h_2)$, with resistivity $\rho_a$ according to the "parallel resistance" relationship (Fig.10):

$$(h_1 + h_2)/\rho_a = h_1/\rho_1 + h_2/\rho_2 \qquad ......(1)$$

Fig. 11 is a presentation of (1) on the log scale, giving $\log\left(\frac{h_1 + h_2}{h_1}\right)$ vs. $\log\left(\frac{\rho_a}{\rho_1}\right)$ for different values of:

$$K = (\rho_2 - \rho_1)/(\rho_2 + \rho_1)$$

For a low resistivity layer between two high resistivity layers $\rho_2 < \rho_1$, K is negative, and the left part of Fig. 11 is used. Equation (1) remains equally true if $h_2/\rho_2$ is replaced by $n\,h_2/n\,\rho_2$. viz the layer with resistivity $\rho_2$ and thickness $h_2$ may be replaced by a thicker layer of higher resistivity. A particular field curve can result from an infinite number of resistive layer configurations, and therefore to obtain an accurate interpretation, further control is necessary.

The problem of a high resistivity layer between two layers of lower resistivity is solved by using Maillet's principle, in which the two upper layers of thickness $h_1$ and $h_2$, resistivities $\rho_1$ and $\rho_2$, are replaced by one layer of thickness $(h_1 + h_2)$, resistivity $\rho_a$, according to the 'series resistance' relationship:

$$(h_1 + h_2)\,\rho_a = h_1\rho_1 + h_2\,\rho_2 \qquad \ldots\ldots\ldots\ldots(2)$$

The left side of Fig. 10 is turned symmetrically about the vertical axis so that $-\log \rho_a/\rho_1$ becomes $+\log \rho_a/\rho_1$ for positive values of $K = (\rho_2 - \rho_1) / (\rho_2 + \rho_1)$, giving a plot of $\log \rho_a/\rho_1$ vs. $\log (h_1 + h_2) / h_1$.

The same basic ambiguity, i.e. that found in the use of Hummel's principle, obviously applies also and confirms what was stated above; resistivity measurements cannot give accurate depths without additional controls.

The way in which the Roman curves are used in the interpretation is shown in Figs. 12, 13 & 14. In Fig. 12 the first part of the curve can be fitted to the Type curve K = + 0.5, with the Wenner origin at the point A. This gives a depth of 3.7 ft, and a resistivity for the first layer of 95 ohm metres from the origin of the curves, and to the second layer of 263 ohm metres from the asymptote of the line K = + 0.5. The origin of the Help curves is then placed at the point A, and the origin of the Type curves is moved along the Help curve for K = + 0.5, until another type curve fits a lower part of the observed curve; this happens at point B where Type curve K = + 0.5 fits the observed curve. This gives a depth to the bottom of the second layer of 17 ft and a resistivity for the third layer of 610 ohm metres from the asymptote of the curve for K = + 0.5. The origin of the Help Curves is then placed at point B, and the origin of the Type Curves is moved down the Help Curve for K = + 0.5 until a fit is again obtained at point C for Type curve K = - 0.65, giving a depth of 100 ft for the bottom of the third layer and a resistivity of 117 ohm metres for the 4th layer from the asymptote of type curve K = - 0.65. The result of the interpretation is expressed as a solid line on the histogram in the diagram on the right of Fig. 12. Fig. 13 shows another interpretation of a Wenner curve by this method; the interpretation is again given as the solid line on the histogram. The point C on the graph is of doubtful accuracy, owing to the limited amount of curve available to base it on. Fig. 14 shows a similar calculation carried out on a Schlumberger curve. In this case the Schlumberger origin and not the Wenner origin is used.

(2) Three layer master curves

Another interpretation technique was used based on a method described by Wetzel and McMurry (1936). In this method a series of three layer curves are used, calculated from assumed resistivities in thin layers of material. Fig. 15 shows some of the curves based on their calculations. A transparent print of the curves is superimposed on the observed curve, and the best fitting curve selected. For the curve in Fig. 12, the curve marked 2:6 in set E4 (Fig. 15) is the best fit, and depths of 11 ft. and 46 ft are obtained for the boundaries. The resistivity of the first layer is obtained from the zero line in the curve, which in this case gives a value of 130 ohm metres. The resistivity of the other two layers can be determined from the ratios given with the curves, in the case of E4 the ratio $\rho_1 : \rho_2 : \rho_3$ is 1:10:1, so the resistivity of the second layer will be 1300 ohm metres, and that of the third layer 130 ohm metres. The interpretation is shown as a dashed line on the histogram (Fig. 12). A three layer interpretation has also been made on the curve on Fig. 13, the results of which are again plotted as a dashed line on the histogram.

The interpretation obtained by the methods described above usually provide a rough limit to the range of probable interpretations. The three-layer results will tend to give depths that are too small, and the Roman curves will tend to give depths that are too large. The use of some depth control should lead to more accurate results.

Application of depth control

The seismic results should give depths to an accuracy of about 20% which is better than can be obtained from resistivity alone. At RE235, (Fig. 12) there is a seismic boundary at 57 ft between unconsolidated material and weathered bedrock. The water in the weathered bedrock is likely to be more saline than the water in the unconsolidated material, so this probably represents the lower boundary of the high resistivity layer. The depth to this layer from the three layer interpretation is 46 ft and from the multi-layer interpretation is 115 ft.

If the Maillet relation is used to modify the thickness of the high resistivity layer in the curve on Fig. 12 to end at 57 ft we get in the case of the three layer interpretation.

$$\text{Resistivity of layer} \times (57-11) = 1300 \times (46-11)$$

$$\therefore \text{Resistivity of layer} = \frac{1300}{46} \times 35 \text{ ohm metres}$$

$$= 990 \text{ ohm metres}$$

Using the Roman interpretation:-

$$\text{Resistivity of layer} \times (57-15) = 535 \times (115-5)$$

$$\therefore \text{Resistivity of layer} = \frac{525 \times 100}{42}$$

$$= 1220 \text{ ohm metres}$$

The results obtained for the resistivity are of the same order, but the one obtained for the three layer case is to be preferred, as the modification of depth required is smaller. This result is also plotted on the histogram.

In the case of the curve shown on Fig. 13, seismic control gives a depth of 45 ft to bedrock, which should have a high resistivity, and which should correspond to the layer indicated at 30 ft on the Roman interpretation and at 34 ft on the three layer interpretation. This is an unusual curve in that the depth determined from the Roman technique is less than that determined by the three layer technique. By carrying out a similar procedure to that shown above, an improved interpretation can be obtained, as shown on the histogram.

In Fig. 16, Hummel's principle has been used to modify the three-layer solution of depth probe 281. The three-layer solution and the multiple two-layer (Roman) solution are both shown. Seismic control gives a depth to bedrock of 50 ft.

Adjusting the three layer solution we get a resistivity $\rho_2$ where $\rho_2 = \rho_1 . h_2/h_1 = \frac{6 \times 42}{26} = 9.7$ ohm-metres.

From the multiple two layer solution:

$$\rho_2 = \frac{9.3 \times 47}{52} = 8.4 \text{ ohm-metres.}$$

The seismic boundary is nearer to the boundary found by the multiple two-layer solution, so the value of 8.4 ohm-metres is used.

Meaning of Resistivity values

The resistivity of a rock depends on the resistivity of the rock matrix and of the fluid that occupies the spaces within the rock matrix. Apart from material above the water table, almost all rocks carry interstitial fluids that have a low resistivity compared with that of the matrix. Even above the water table there is normally sufficient moisture present for the resistivity measured to be substantially lower than that of the rock matrix. The highest resistivity measured in this survey was at depth probe 555 where the top layer of dry, loose sand had a resistivity of 21,000 ohm-metres. The normal value obtained near the surface was not more than a few hundred ohm-metres, and often less than one hundred ohm-metres, where some moisture was present.

If the resistivity of the interstitial fluid is constant, the resistivity that is measured depends mainly on the porosity of the material. The porosity of unconsolidated material is in the range 20-40%. The highest porosities are in clays, and the lowest in unsorted sands and gravels. This means that for the same interstitial fluid the resistivity measured will be lower for clays than for sands and gravels. Wiebenga (1955) determined an empirical relationship, given below, between porosity V, resistivity of matrix and water $\rho_a$, and resistivity of pore water $\rho_w$ :

$$\log \frac{\rho_a}{\rho_w} = -1.25 \cdot \log V$$

The factor of 1.25 is dependent on the clay content and porosity, but for unconsolidated material it is acceptable. This relationship is shown in graphical form on Plate 13. There may be other effects involved in the case of clays, such as induced polarisation, which is known to cause a lower apparent resistivity for an alternating current than for a direct current. It is believed however that the porosity is the most important factor.

From the resistivity of water obtained by the method above the total dissolved salt content can be calculated from the relationship

$$\text{Log } S = 3.68 - .92 \text{ Log } \rho_w \qquad \text{(Dyson \& Wiebenga, 1957)}$$

Where S = Salt content in p.p.m.

If no other data but resistivity measurements are available the resistivity of water-saturated unconsolidated rock can be used to estimate the salinity of the groundwater. Table 3 compares the resistivity of the materials with the salinity of the pore solution.

TABLE 3

RESISTIVITY VERSUS SALINITY OF PORE SOLUTION

| Resistivity of material, ohm-metres | Total dissolved salts in pore solution, p.p.m. | Classification of water |
|---|---|---|
| Less than 6 | more than 3000 | Salt |
| 6 to 20 | 3000 to 1000 | Brackish |
| more than 20 | less than 1000 | Fresh |

The figures in this table are based on an assumed porosity of between 30 and 35% (See Plate 14).

From Plate 17, data taken by Bureau and Commission personnel shows that the fresh water samples commonly have a resistivity less than 60 ohm-metres. Assuming a porosity of 35%, the equivalent formational resistivity is about 230 ohm-metres (See Plate 13) (For a porosity of 25%, the formational resistivity would be about 170 ohm-metres). A formation with a porosity of 35% having a resistivity greater than 230 ohm-metres might therefore be assumed to be dry or partially dry.

Without drilling it would be difficult to estimate accurately the porosity of a formation at a particular depth, nor to collect a water sample at this level. Therefore, these figures can only be taken as a broad guide in the interpretation of cross-sections.

DIRECT MEASUREMENTS OF WATER RESISTIVITY

A number of measurements were made throughout the Burdekin delta by both the Bureau and I.W.S.C. on water samples collected at the surface and at various depths underground to determine their resistivities. These resistivity values may be also expressed in terms of salt dissolved per unit volume, i.e. grains per gallon (g.p.g), or parts per million (p.p.m.) - (see previous section).

The Bureau employed two methods in obtaining these measurements, the first of which is the basic approach also used by the Commission.

Method 1. Water samples were collected at the surface or from the surface of the underground water-table by lowering a suitably designed bailer into available boreholes. The resistance across the electrodes of a Wenner-type arrangement in a mud-cell was measured using a Megger Earth Tester. The resistivity (in ohm-metres) of the sample was then obtained by conversion from the measured resistance using the calibration constant for the mud-cell.

Method 2. Alternatively a small probe, designed by the Bureau on the principle of the mud-cell, was lowered into boreholes, and resistances were measured at varying depths, again using a Megger Earth Tester. A similar calibration constant was derived for the probe. See Plate 17.

The water temperature should be measured simultaneously with the resistivity measurements.

To calculate the resistivity of water samples at 20°C ($\rho_{20}$) from their resistivity ($\rho_t$) at a temperature (t), the following relationship is used:-

$$\text{Log}\,\rho_{20} = \text{Log}\,\rho_t - 0.9\,\frac{(20-t)}{100}$$ (Dyson & Wiebenga, 1957)

This relation holds in the range 10°C to 40°C and is plotted on Plate 14.

Bureau water resistivity data together with that collected by the Commission in December 1963 (see IWSC Progress Report, 1964) is shown on Plate 17. In this Report, the Commission expressed the quality of water samples in terms of conductivity at 25°C. A sample calculation is given below showing the conversion of conductivity, R (micromho/om) into resistivity values (ohm-metres), and then the correction from 25°C to 20°C.

Thus

$$\text{Resistivity} = \frac{1 \times 10^6}{R \times 10^2} \quad \text{ohm-metres}$$

$$= \frac{1}{R} \times 10^4 \quad \text{ohm-metres at } 25^\circ\text{C}.$$

Example. Consider IWSC Water Sampling Point S.107, AYR (see IWSC Progress Report 1964, Fig.4).

Water Conductivity at 25°C = 570 micromho/cm.

$\therefore$ Water Resistivity at 25°C = $\frac{10^4}{570}$ ohm metre

= 17.5 ohm metre

Reference to Plate 14 shows that:

$$\frac{\text{Resistivity of water at } 20^{\circ}\text{C}}{\text{Resistivity of water at } 25^{\circ}\text{C}} = 1.11$$

$\therefore$ From S.107 resistivity of water at 20°C = 17.5 x 1.11 ohm metres

= 19.4 ohm metres.

This is plotted on Plate 17 as the nearest whole number, i.e. 19 ohm metres.

Extraneous currents

When a system of electrodes is placed in the ground, and they are linked to form a circuit, even if no external current is applied to the circuit, a current may flow in the circuit. This current is made up from two components; one is of an electro-chemical nature, and the other is due to telluric currents in the ground itself (Mounce and Rust, 1945, and Wiebenga 1955).

The electro-chemical effect may be caused by one potential electrode in sand, sandstone or limestone, with the other in clay or shale. Assuming that the rocks are saturated with more or less saline water, a potential difference possibly in excess of 100 millivolts is set up at a boundary. If the circuit between the two potential electrodes is closed, a current will flow from the sand or limestone across the boundary with clay or shale. Experience shows that measured voltages due to electro-chemical current effects may decrease within short time intervals because counter potentials are formed where the potential electrodes touch the ground. This voltage variation can be made unimportant by using non-polarisable, copper-plated or brass potential electrodes. To improve ground contacts the number of electrodes may be doubled, and the 1" electrodes have to be hammered into the ground.

The telluric currents consist of a high frequency component of small amplitude superimposed on a low frequency component of relatively large amplitude. Fig. 5 shows some plotted measurements of telluric currents, measured over a separation of 1500 ft. With a D.C. meter the currents can be backed off prior to a measurement being made. In the Burdekin Delta current potentials of the order of 100 millivolts were present in the circuit on some occasions. From Fig. 5 it is plain that the variations in telluric current are insignificant within the short time intervals used for measurements.

In practice it was found that if the distance between current electrodes is in excess of 900 ft and the resistivity of the near-surface layer very low, small potential variations of a few millivolts per minute make it difficult to measure the apparent resistivity with one of the available D.C. resistivity meters. Under these circumstances a motor driven generator is necessary to produce large enough currents.

When the alternating current Geophysical Megger is used, the problem is not serious as the A.C. component of the stray currents is much smaller than the D.C. component, and the only limitation is the reading accuracy of the instrument.

## 7. GAMMA RAY LOGGING

A 500 ft Widco gamma-ray probe was used in conjunction with an Esterline - Angus recorder. The probe consists of a scintillation crystal and a pre-amplifier. The amplified pulses pass up the cable supporting the probe and at the surface they are counted and shown on a recorder. The results are presented as a graph of count rate against depth.

Interpretation

A typical gamma ray log is shown on Fig. 17. There is a greater amount of gamma radiation emitted from clay than sand, which means that high readings can be correlated with clay, and low readings with sand. In Fig. 17 there is sand to 27 ft, a thin layer of clay from 27 to 30 ft, probably sandy clay from 30 to 44 ft, clay from 44 to 54 ft, sandy clay from 54 to 62 ft, and then sand and gravel down to the base of the hole.

# PART II - RESULTS, BURDEKIN DELTA.

## 8. GRAVITY RESULTS

The contour map of Bouguer anomalies (Plate 4) shows a regional trend consisting of a decrease in gravity values from west to east. The main disturbance of this regional trend is a roughly circular negative anomaly west of Home Hill. The anomaly is asymmetrical, showing higher gravity gradients on the south and east of the centre of the anomaly and lower gradients on the west.

NW-SE and NE-SW sections were drawn across the anomaly. Subtracting the regional trend shown computed by averaging Bouguer anomalies the residual profiles were obtained (Plate 7). The possible source of the anomaly was interpreted by computing gravity anomalies produced by simple models of discs and comparing them with the observed anomaly. The method of computation used is described by Nettleton (1940).

A given gravity anomaly can be produced by a variety of mass distributions. Thus the interpretation of the gravity anomaly in terms of subsurface mass distributions does not give a unique solution.

The models were constructed from horizontal circular discs of varying thickness and diameter, the smaller discs lying on top of the larger ones. The centres of the discs were displaced horizontally to produce an asymmetrical model to account for the asymmetry of the observed anomaly. A density contract of 0.2 was assumed for the model.

A model which produced an anomaly similar to the observed anomaly is shown on Plate 7. The anomaly produced by the model along the NW-SE and SE-SW profiles is also shown.

The possible geological structure which is approximately equivalent to the model may be a relatively low density intrusion.

The Bouguer anomaly contour map shows a zone of high gravity gradients on the eastern side of the area (Plates 4 and 5). This zone crosses the line W1 at about half a mile west of W1/N6 and can be followed in a south-southeast direction towards N8/W6.

One simple model which produced a similar gravity effect is a semi-infinite horizontal slab, the geological equivalent of which is a fault. For unit density contrast one mgal gravity effect corresponds to a vertical throw of approximately 78 ft (Nettleton, 1940, p. 115). For a density contrast of $\sigma$ and gravity effect $\Delta g$ the throw of the fault (T) will be given by:

$$T \doteq \frac{\Delta g . 78 \text{ ft.}}{\sigma}$$

Three profiles (Plate 8) were drawn across the zone of high gravity gradients. Removing the regional trend the gravity decrease on Profile C is 26.3 mgal, on Profile D 14.4 mgal and on Profile F 6.0 mgal. The corresponding throws along the three profiles are shown below (downthrow to the east on each profile).

| Assumed Density Contrast | | Throw of Fault (Feet) | | | | |
|---|---|---|---|---|---|---|
| | | On Profile C | | On Profile D | | On Profile E |
| 0.2 | - | 10,300 | - | 5,600 | - | 2,300 |
| 0.3 | - | 6,800 | - | 3,700 | - | 1,600 |
| 0.4 | - | 5,100 | - | 2,800 | - | 1,200 |
| 0.5 | - | 4,100 | - | 2,200 | - | 940 |

The above results suggest that the fault is a hinge fault, the throw being greater in the north than in the south.

It can be shown that the maximum gravity gradient ($U_{xz}$) on a gravity profile produced by a semi-infinite horizontal slab is given by:

$$U_{xz} = \frac{2G\sigma T}{Z}$$ (Nettleton, 1940, p. 113)

where : G = gravitational constant

$\sigma$ = density contrast

T = thickness of slab (throw of fault)

Z = depth to centre plane of slab

The formula can be used to compute Z, although Bancroft, 1960 shows that it is only strictly applicable where T is relatively small compared with Z. $U_{xz}$ and Z for the three profiles are given below.

| Profile | Maximum gradient ($U_{xz}$) MGAL/MILE | Depth to centre of fault (Z) FEET |
|---|---|---|
| C | 8 | 5,500 |
| D | 4 | 6,000 |
| E | 4.5 | 2,200 |

Summarising: The gravity results show a regional gravity trend consisting of a decrease in gravity from west to east. A roughly circular gravity low west of Home Hill disturbs the regional trend. The gravity low may be produced by a relatively low density intrusion. The zone of high gravity gradients in the eastern part of the area suggests a fault traversing the country in a NNW - SSE direction. This appears to be a hinge fault, the throw being greater in the north than in the south.

## 9. SEISMIC RESULTS

### Bedrock contour plan

Plate 12 shows the bedrock contour plan constructed from seismic depth probes and seismic traverses. Bedrock is here defined as rock with longitudinal seismic velocities equal to or greater than 6700 ft/sec. This includes consolidated sediments and weathered igneous rocks which are believed not to be sufficiently porous and permeable to act as good aquifers. Probably because of their higher clay content, weathered bedrocks are aquicludes which may contain appreciable amounts of salt, and which cannot easily be flushed out by fresh water. Hence the upper layers within the bedrock, but above the "fresh" bedrock, are indicated in many cases as low resistivity layers in depth probing.

The bedrock contour plan shows topography with many subsurface drainage channels (indicated by arrows) and ridges. For instance, the Burdekin has cut a subsurface channel back to "The Rocks" (N1/W9) which may be observed by following the zero contour. Further north-east, near N3/W8, the subsurface channel splits into two : one branch going north and one going north-east until it joins the channels coming from Charlies Hill. Between N5/W5 and N6/W6 the contour lines can be drawn in various ways: the plate gives one likely version suggesting a subsurface channel in a northeasterly direction and one towards the north.

West of "The Rocks", along Traverse S (cross section W10) the seismic work suggests the presence of a subsurface channel which may be up to 100 ft deep. The bedrock configuration in this locality should be clarified because it is of importance to the water potential of the Burdekin River passing through "The Rocks".

If the interpretation shown on Plate 12 is approximately true, the bedrock 'bar' across the Burdekin River at "The Rocks" may serve to divert much of the flood waters into the Barrattas system to the west. An alternative possibility is that the bed of the river cut back along its course, at some time capturing much of the original flow into the Barrattas system. The contours suggest the presence of a fairly deep subsurface channel from the Barrattas system into the Burdekin delta close to $N_1/W_5$. Part of the delta recharge may thus come through this channel.

It is believed that many of the drainage channels could have been formed during the last Pleistocene glaciation period (Fairbridge, 1961) when the sea retreated, resulting in a maximum sea level drop of about 330 ft relative to the present sea level (the 325 ft depth contour on Plate 12). The assumptions made here are that the coastal area has been stable, and that eustatic changes in sea-level occurred on a world-wide basis.

During the glaciation period, the downward water level gradient in the erosion channels must have been relatively steep and hence the water velocities relatively high, so that in the main only the coarser sands and gravels would be deposited. Therefore it may be expected that the erosion channels contain formations with coarse material. As the sea level rose in post-glacial time, these channels became buried with deltaic sediments with the shoreline later advancing steadily seawards.

If sufficient fresh water comes into the delta by natural causes (rain and floods) the subsurface channels carry fresh water and the salt water is flushed out. But when the fresh water resources are depleted by artificial and natural causes during the dry season, the same subsurface channels will form entrance channels for salt sea water, the extent of penetration being a function of sea-levels and the elevations of the subsurface channels. The zero contour line forms a kind of natural boundary of the delta. If all the fresh water is taken out (or pumped out) of the delta, sea water will eventually reach the zero contour line, bordering Charlies Hill, Stoke's Range, The Rocks and Kelly's Mountain. The movement of saltwater in the delta will largely be a function of the Ghyben-Herzberg relation (see Part II, Section 10).

The upper layers of the subsurface ridges consist of weathered rocks and consolidated sediments which form aquicludes. In resistivity depth probing they may be indicated as "low resistivity layers" in comparison with the high resistivity bedrock below (e.g. near W8/N2 to N3, W8/N7

Note - there is no page 37



to N8 and W4/N6).

No correlation has been found between the bedrock contour map based on the seismic work (Plate 12) and the Home Hill negative gravity anomaly. This can be explained by the fact that the deepest refractor detected by seismic work is only a few hundred feet deep. The Home Hill gravity low on the other hand is probably due to an igneous intrusion which is considerably deeper, though a small part of it may come near the surface (see Plate 7).

Plate 11 gives the approximate depth of bedrock below ground surface, which may be of practical use in a drilling programme. Summarising: The Bedrock Contour plan shows the presence of subsurface channels and ridges, possibly formed during the Pleistocene glacial period. These channels probably contain good aquifer material i.e. Sands and gravel, which may act as limited entrance ways for saltwater when the fresh water resources are depleted. At the "Rocks", the subsurface topography suggests that only part of the water is fed into the delta. The remainder flows northwards into the Barrattas system. The Burdekin delta may also be partly recharged from the Barrattas through a subsurface channel located about 7 miles north of "The Rocks", and about the same distance west of Ayr. If the fresh water were completely pumped out from the delta without recharge through subsurface channels, salt sea water would creep further inland until approximately the zero bedrock contour was reached.

Seismic velocities in bedrock

Plate 10 shows the approximate seismic velocities in the fresh basement rock which generally range from 14,000 to 20,000 ft/sec. Seismic control is better in some areas than others so that contours may be more definite in some areas. Variations in seismic velocities can be correlated with variations in rock porosity; the lower the seismic velocity the higher the porosity.

A remarkable zone of lower seismic velocity is centred west of Home Hill around N4/W7, indicated by hatching on Plate 10. This zone may be associated with the gravity "low" explained by the occurrence of a lower density igneous intrusion or a volcanic pipe, e.g. the lower bedrock velocities may be associated with volcanics or dykes and veins. A zone of minimum velocities located through FK, AA, DG, DH and DM coincides with a subsurface erosion channel (W6-8/N3).

Zones of relatively low bedrock velocities which are probably associated with subsurface channels or valleys are located near N6/W10 (BE and BK) and N9/W9 (BL, BR and BQ).

Another zone where bedrock velocities are slightly lower than in the surrounding area is located between EE and FF, north-east of the fault suggested by a gravity anomaly. Possibly this zone could be associated with the fault.

Summarising: The bedrock velocities considered above do not add valuable information to the hydrology of the area. However, the association of lower bedrock velocities with geological features based on gravity and seismic data confirms the validity of the general interpretation.

Seismic velocities in water saturated unconsolidated sediments above the bedrock

On Plate 10 the seismic velocities in the refractor immediately above the bedrock (defined as material with longitudinal velocity $\geq$ 6700 ft/sec.) are shown in brackets at the respective seismic stations; these velocities occur in the range between 4000 and 6700 ft/sec. In unconsolidated sediments the velocities in water-saturated clay, or sand and clay mixtures are generally between 2000 and 4500 ft/sec depending on the amount of clay in the mixture. Water saturated coarse sands and gravels usually have velocities in the range 4500 to 5700 ft/sec. Between 5700 and 6700 ft/sec the material represented may be semi-consolidated, or very weathered bedrock.

In the Stokes Range area and the area to the south of Home Hill the refractors above bedrock commonly have seismic velocities between 5700 - 6700 ft/sec. probably representing very weathered bedrock material. Plate 10 shows a number of examples where the higher velocity aquifer zones (i.e. with velocities 4500 - 5700 ft/sec.) coincide with subsurface channels indicated on Plate 12, e.g.

(i) Between N1/W5 and N3/W5, where a subsurface channel from the Barrattas system to the Burdekin Delta is indicated.

(ii) Near N4/W8, between DD and BG, where a subsurface erosion gully towards the east is present. Bedrock is shallow so that the material in the refractor above the bedrock may be very weathered. However since a subsurface channel has been defined here on Plate 12, it seems likely that the infilling material is coarse sand or gravel.

(iii) Near N6/W9, between BV and BK; near the latter station bedrock is relatively shallow. This zone may therefore in part be very weathered bedrock (about BK) and in part unconsolidated or semi-consolidated coarse aquifer material.

## 10. RESISTIVITY RESULTS

### 1962/63 depth probe data.

Plate 16 shows, in the form of a contour plan, the location and depth of formations containing brackish and saline water as determined from resistivity results. For the purpose of this plan any water with more than 1000 ppm of total dissolved salt is considered as saline, so that areas which are brackish are shown as well as those with true saline conditions. The results were obtained over a period of 18 months from

August 1962 to December 1963, though most were obtained between March and July, 1963. This means that at any given time the boundaries may not be exactly as shown, but the variations should not be excessive. It should be noted that without stratigraphic control it is often difficult to differentiate between a clay and a brackish water sand or sandy clay in resistivity data. Therefore, some areas shown as brackish or salty may represent clay formations. There are several examples of this on Plate 16, one of which occurs to the north-east of Home Hill (i.e. N5/N6-W6/W7). Here the low resistivity formation is representative rather of a clay than a saline water sand; another example is shown at N3-W6 to the west of Plantation Creek; whilst further south near Stokes Range and Kelly's Mountain there are small scattered areas which probably represent brackish clays derived from near-surface bedrock, rather than of a truly marine origin. It should be noted that in a freshwater environment these clay zones stand out clearly, but of course in a saline area this is not so. This matter is also referred to in Part II Section 12 where impermeable subsurface formations are discussed. Further, distribution of data over the delta is not uniform, and therefore some boundaries may be drawn more accurately than others. Restraint should therefore be exercised in subsequent deductions. Non-shaded areas may also contain either freshwater or may be dry. This aspect is further explained in the chapter discussing the cross sections.

The use of the hatching for a given range on the map means that saline water is present within the range, but it is possible that some fresh water is also present. The location and numbers of the depth probes which were used to construct this plan are shown on Plate 15.

If the topographical elevation contour plan (Plate 40), is superimposed on the salinity plan (Plate 16) a tendency may be observed for fresh ground water to be located in the higher areas, and the lower parts or the lagoons tend to be saline. This can partly be explained by reason of the surface encroachment of saltwater inland along channels for a limited distance (dependent on changes in sea-level and on elevation of the channels); partly by the flushing-out of higher ground by rainwater or by flooding; but probably also by an effect of the Ghyben-Herzberg Relation, which relates saltwater encroachment to the head of freshwater above the sea-level (Fig.26). This states that in the case of a homogeneous coastal aquifer, at a point inland where the freshwater table is distance hf above sea-level, then the top surface of the encroaching saltwater wedge at that point will be approximately a distance $hf/(\rho_s - 1)$ below sea level, $\rho_s$ being the specific gravity of saltwater. This is dependent on the relative densities of fresh and salt water, on the homogeneous nature of the unconfined aquifer, and the absence of marked flow within the freshwater body (Todd, 1959, p.279). For $\rho_s = 1.025$, $hf/(\rho_s - 1) = 40$ hf

Examples of localities where salt water appears to come in along topographical depressions are near N2/W3, between N4/W3 and N5/W3, N6/W3, N6/W4, and from the Burdekin River (N6/W6) and the Anabranch (N7/W5).

Examples of localities where there is fresh water through a large part of the section at places where the ground is relatively higher are near N1/W4, between N3/W4 and N4/W4, between N5/W3 and N6/W3, near N6/W5 and N6/W7.

Some of the features of Plate 16 can be correlated with features shown on the bedrock contour plan (Plate 12). The area of salt water below 75 ft only to the north-east of N6/W5 is along the line of a major valley in the bedrock. This suggests that the valley contains highly permeable material and that fresh water flowing out of the valley is flushing out the saltwater near the surface, leaving the saltwater only below 75 ft depth. This mechanism operates simultaneously with the saltwater encroachment as described by the Ghyben-Herzberg relation. If readings in valleys or lagoons were taken at the end of the dry season there would probably be saltwater present throughout the stratigraphic section, as in the absence of any quantity of fresh water, the salt water would be able to encroach from the sea.

The isolated low resistivity areas to the south of Home Hill between W10 and W11 are probably caused by salts in the weathered bed-rock, (probably partly limestone or shell banks). These shell banks would give rise to carbonate-rich water as opposed to the chloride-rich sea water (see below). The isolated saline areas elsewhere, e.g. near N3/W6, N4/W8 and N5/W7, are probably due to remanent salt in clay, which is unlikely to affect irrigation water drawn from more permeable horizons. Whilst there is a tendency for clay to absorb salts, flushing-out of the material will be slow because of its low permeability, but also will be impeded by base exchange, which causes deflocculation and a reduction in permeability.

<u>1963 water resistivity data</u>

Plate 17 shows the distribution of saline, brackish or potentially brackish water based on water samples collected by both the Commission and the Bureau. Zones of freshwater, but containing a significant amount of dissolved salts, (6-12 ohm m) are also defined. The distribution of data is uneven over the delta, and contains information collected during a period of several months in 1963. No precise information with regard to the depth at which subsurface samples were collected is given. Hence care should be taken in interpreting the distribution of water quality as shown on Plate 17. The surface encroachment of salt water is, however, clearly shown on the seaward edge of the delta. South of the Burdekin River, water with resistivity 6-12 ohm-metres, extends in a broad zone roughly east towards Charlie's Hill from Stokes

Range. This is taken as a direct reflection of the shallowness of bedrock.

__1964 depth probe data.__ During October 1964 Bureau personnel made 35 further depth probes in the Burdekin Delta to check on the extent of saltwater encroachment. From this data four supplementary cross-sections were drawn (Traverses 1964/1-4, Plates 41-44), comparing 1964 information with that obtained in the two previous years. The location of the depth probes and traverses is shown in Plate 15.

__Traverse 1964/1__ (Plate 41). The first 50 ft of depth probe 611 (hereafter denoted as RE.611 etc.) probably represents a moist or dry sand, which overlies saltwater. Comparison with nearby RE.338 shows a clear depletion of available freshwater.

RE.610 indicates saltwater invasion to a depth of 30 ft, but with a reasonably freshwater body beneath.

At RE.632 there is a freshwater formation to a depth of 70 ft overlying saltwater.

A dry formation to a depth of 50-80 ft is indicated at RE.631, again overlying saltwater. This shows a marked deterioration when compared with RE.335.

RE.633 and 634 are similar to RE.105, the near surface zone being indicative of a brackish clay formation. Depth probes not shown on Plate 41 include RE.614 (saltwater to 30 ft, overlying brackish water); RE.635 (60 ohm metres to a depth of 110 ft, overlying a low resistivity weathered bedrock zone, or alternatively a formation containing saltwater - this shows no appreciable change in the area).
Summarising: Along Sheepstation Creek, by October 1964 saltwater had encroached to about 2½ miles north-west of Brandon (RE.610), with a marked increase in salinity at depth.

Traverse 1964/2 (Plate 42). RE.625 probably represents a clayey formation down to 70 ft depth, the top 10-15 ft being dry; this overlies a freshwater zone of considerable thickness. RE.626 and 203 have similar configuration to depths of 75 ft or more, and may be correlated with borehole data such as I.W.S.C. borehole D.7, which indicates clay or sandy clay to a depth of 64 ft. No clearly defined saltwater encroachment between May 1963 and October 1964 is indicated. Clays and sandy clays tend to have low resistivities because of their salt content, or by virtue of the salinity of their pore solutions. They are also often nearly impermeable, which could account for the small change in 1963 and 1964.

At RE.623 is a freshwater body down to 70 ft depth (moist or dry towards the top 20 ft) which overlies saltwater. The Commission recorded the water table at a depth of about 20 ft in October 1964, but by the following month pumping had lowered this to 55 ft.

RE.600 indicates a freshwater body to a depth of 55 ft, but again most of the upper part of this is moist or dry. This does not differ markedly from RE.381, but shows a sharp rise in the fresh - saltwater interface compares with RE.31 (Sept.1962).

Much of the high resistivity formation to a depth of 30 ft at RE.602 is probably dry; beneath is a saltwater formation. This correlates well with nearby depth probes 531 and 259.

RE.629 shows a freshwater body overlying a saltwater formation at 55 ft; nearby I.W.S.C. borehole F.10 records mainly sand to about 40 ft. This zone appears to be a freshwater aquifer of reasonable size, although replenishment is entirely by rainfall.

Depth probes not shown on Plate 42 include RE.601 (mainly dry to 60 ft, overlying saline water - this compares with RE.256, (May 1962), which indicates a freshwater formation from 19-52 ft overlying saltwater; and RE.630 (mainly dry to 40 ft, overlying saltwater - compare with RE.260 (May 1963), which indicates freshwater to 90 ft overlying saltwater). These latter two depth probes show clearly that much of the near-surface freshwater has been pumped out. Possibly clay aquicludes are impeding the rise of the saltwater interface.

Summarising: The cross-section between Plantation Creek and Anabranch suggests that brackish to saltwater clay formations (characterised by low resistivity layers) are located near the surface about Plantation Creek. Towards Anabranch the saltwater clays and sands are overlain by a high resistivity layer, probably dry in the upper zone. Freshwater may be fed into the aquifer, probably from Anabranch, since a low level dam downstream prevents inflow of saltwater at the surface in the dry season. It is possible that some water from the same source is fed into Rita Island, but to a limited extent. A number of depth probes show a thin brackish formation at the surface; this is interpreted as a result of irrigation.

Traverse 1964/3 (Plate 43). At RE.628, much of the upper high resistivity formation, extending to a depth of 58 ft, is probably moist and dry. This zone overlies a saline formation, and indicates a notable deterioration when compared with RE.206 and 386.

RE.627 is similar to 628, except that the upper zone is probably drier, and the underlying formation is brackish rather than saline. Serious depletion of available freshwater has taken place in the period April 1963 - October 1964 (compare with RE.205).

At RE.624 a dry zone overlying saltwater extends to 50 ft depth; this again compares unfavourably with RE.28 (Sept. 1962).

Comments on RE.623 have been made in the section of Traverse 1964/2. There is no major change from the configuration of nearby RE.85 (March 1963), this depth probe being made before the major rains of 1963.

Correlation of RE.622 data with borehole evidence from I.W.S.C. $L_2B_2$ indicates a partly dry sand to a depth of 85 ft overlying a brackish formation. This is similar to RE.84, except that the available freshwater in the high resistivity layer had decreased substantially. Private bores in the region show sand to a depth of 30 or 40 ft overlying silty clay. It is possible that the brackish formation at the base of RE.622 and 84 may represent clays saturated with a brackish pore solution.

RE.609 shows a top layer with resistivity of about 30 ohm-metres to a depth of 27 ft, and correlation with I.W.S.C. borehole Line E, S.1 indicates that this is a clay or sandy clay saturated with freshwater. This overlies what is probably a freshwater sand formation.

RE.617, similar to RE.300, shows a thin low resistivity layer near the surface (probably due to irrigation), overlying a thick high resistivity freshwater layer.

Other depth probes in the Home Hill area are RE.607 (freshwater to 22 ft depth overlying a brackish formation); RE.608 (7ft of freshwater overlying a brackish or possibly clay formation); and RE.606, which is mainly a freshwater formation.

Summarising: North from the Burdekin River depth probes 628, 627, 629 and to a lesser extent 623 indicate a rise in the saltwater level of at least 50 ft in the period early 1963 to October 1964. The high resistivity layers to a depth of 50-60 ft indicate dry formations. Whilst on the northern bank of the river a rise in resistivity in the layer above 70 ft indicates drier conditions, the salinity of lower levels remained stable. This would suggest that the formations below 70 ft are largely impermeable, with a high clay content. South of the river clay or sandy clay extends to a depth of 30 ft, with good sand sections beneath; there is no evidence of deterioration of freshwater supplies about RE.617, to the north-east of Home Hill.

Traverse 1964/4 (Plate 44). RE.603 is located near RE.74 and 375, and also close to I.W.S.C. bore hole C.9. In this region saltwater is present at depths from 10 to 25 ft. From March to June 1963 the underlying saltwater became less saline, presumably as a result of seasonal rains; but the salinity increased once more by October 1964.

RE.604 suggests a mainly moist or dry sand formation to a depth of about 60 ft, overlying a saltwater body. Comparison with adjacent RE.34 suggests that the freshwater body has been depleted somewhat and that the fresh-saltwater interface has risen in the two years following Sept. 1962.

RE.600 (see comments on Traverse 1964/2) clearly represents a mainly dry formation to 55 ft depth, overlying saltwater. Comparison with nearby depth probes 381 and 31 indicates that the major saltwater encroachment at this point took place in the period Sept. 1962 - June 1963, with slight deterioration thereafter. The Commission's borehole E.8 and private bore logs indicate the section to be mainly sand to 60 ft depth or more.

Most of this traverse south of the Burdekin River contains sections largely brackish or saline. RE.614 indicates a reasonable freshwater body to a depth of 40 ft, below which is a brackish formation. There is no clear change from depth probes made in 1963.

RE.616 indicates a high resistivity layer to 100 ft depth; which may mean that brackish water has been replaced by a freshwater zone, or possibly that this layer represents a moist brackish zone.

RE.618 is mainly brackish, with a freshwater formation 0 to 17 ft depth. This is comparable with data taken at nearly locations in 1962 and 1963.

Other depth probes not shown on Traverse 64/4 are 615 (freshwater to 30 ft, brackish formation beneath); 619 (brackish or saline to below 30 ft depth); 605 (similar to 619); and 620 (brackish due to irrigation to 7 ft, dry formation to 23 ft depth, overlying a saline formation).

Summarising: north of RE.600, the sparse 1964 data indicate that conditions have not changed appreciably since September 1962. To the south of the Burdekin River, the bedrock is much shallower, and the lower values of resistivity away from the river may reflect the carbonate content in the water (proved in several shallow boreholes).

Whilst available borehole information indicates the presence of clay along the banks of the Burdekin River to depths of 30-50 ft, there is no evidence that the clay extends in depth continuously to bedrock.

## 11. DESCRIPTION OF CROSS-SECTIONS

Cross-sections N1-9 and W2-11 contain a great deal of seismic, resistivity, gravity, geologic and water-level data. Seismic velocities are used to define bedrock or weathered bedrock topography, and also to classify broadly materials into velocity ranges in the manner indicated on the legends, and in the section on seismic velocities (Part 1, Section 5). The great amount of resistivity interpretations displayed on these cross-sections requires, as explained in the relevant sections on the resistivity method, correlation with neighbouring depth probes, borehole information, water quality data, and also with seismic evidence. The interpretation of the resistivity value of a given layer must take into account all relevant information, so that the relations as displayed on Plates 13 and 14 for example, will indicate the approximate porosity of the formation and the nature of its pore solutions. The descriptions of sections will be restricted in the main to define potential areas of artificial recharge, though it is not suggested that all will prove practical propositions. The most easily defined recharge areas are those where extremely high resistivity layers can also be shown to have a high permeability by comparison with bore hole information. These are generally interpreted as dry, or partially dry sand or gravel layers. Highly permeable zones, saturated with brackish and salt-water solutions in whole or in part, may be suitable for recharge with fresh water. In this context, as shown in the section of salt-water intrusion (Part II, Section 10), it may be stressed that it is often difficult to differentiate between a sand saturated with salt-water, and a brackish clay formation; further, a brackish clay may be a result either of a clay deposited in a saline environment, or alternatively may represent a water-saturated weathered bedrock profile.

Geological information shown on the sections is based on boreholes sunk by the Commission, and by the Bureau, and also on private borehole data furnished by Watkins and Wolff (1960). All the Bureau bores were drilled with a Proline rotary auger drill during 1962. The Commission data includes information available up to December 1964. Where necessary, these geological logs have been slightly simplified, so as to clarify presentation, whilst not detracting from the interpretation of the data. For example, thin alternating layers of sand and clay were called sandy clays. Water levels are shown at the intersections of cross-sections where available. This information was interpolated from water level contour charts constructed by the Commission, some of which are shown in their Progress Report (1964).

Cross-section W2 (Plate 27)

Borehole data (A2, BH216, $A_3$, $B_4$ and $A_4$) prove surface or near surface aquifers west of $N_3$. Depth probes east from RE.356[B] to RE.407 indicate freshwater aquifers, but RE.356-356[A] and RE.611 indicate that these are moist or dry in part. Limited recharge might be desirable here. Sands and gravels overlain by clays are indicated at $AH_3$, $AH_6$ and BH190, but east of Kalamia Creek at PR11, BH252 and $A_6$ are good surface aquifers with which RE.163 may be correlated. Later in the dry season this zone may be largely dry, and would be suitable for recharge. Further recharge aquifers, though overlain by a relatively thin clay bed, occur at $A_7$ and $B_7$ near $W_2/N_6$; these can be correlated with RE.366 and RE.613 respectively. The resistivity data suggests that the aquifers are largely saturated with fresh-water near the surface (RE.613, Oct. 1964).

Cross-section W3 (Plate 28)

As with $W_2$, the bedrock is so deep as to have no effect on near surface hydrogeological conditions. West of Sheepstation Creek borehole $C_2$ and low resistivity near surface layers indicate mainly brackish or saline clay. BH.196 and $L_2$ B9, together with RE.324 show near surface aquifers largely saturated with fresh water, but with RE.44, BH.92 and RE.432 suggesting near surface clay zones. A mainly freshwater zone with aquifers such as that in $L_2$ $B_8$ extends east, but a good zone of surface sands and gravels exists between $C_6$ and RE.37. Depth probes in this area commonly show a very high resistivity layer overlying a brackish formation, which suggests that the surface aquifer body is largely dry and presents a good potential recharge zone. Within a mile east of $N_7$ depth probes indicate a good freshwater zone overlying brackish or saltwater. Immediately west of $N_7$, $B_3S_2$, BMR.79 and BH 279 together with RE.209 show that the surface aquifer body is largely devoid of freshwater, but with saltwater at a depth of 15 to 20 ft. Recharge would be desirable in this limited zone, which is probably largely influenced by the proximity of Plantation Creek.

Cross-section W4 (Plate 29)

Bedrock is generally very much greater than 80 ft deep, and has no significant effect on aquifer formations. West of Plantation Creek are few good near surface aquifers, although depth probe data indicates that many of the near surface formations are dry (e.g. the high resistivity layers of RE.104, 106,434, 141 etc.). Resistivities of formations are variable in the range 0-50 ft, but the lower values can be correlated with the abundance of clays and sandy clays revealed by borehole data (e.g. CHRIS. 2, CD3-5 etc.).

About $N_5$, $L_2B_5$ and $L_2B_4$ indicate a good aquifer 0-40 ft; although depth probe data here is sparse RE141 indicates that much of this maybe dry; RE.625 however indicates that between November 1963 and October 1964 there has been an incursion of saltwater probably along the line of Plantation Creek. Other depth probes (e.g. RE.344, 343 and 345) in this area also indicate brackish or saline conditions in the range 0-70 ft. East of RE.345, the basal saltwater layer comes closer to the surface, with borehole and depth probe data indicating predominantly clay formations, these sometimes dry in the near surface region.

The best area for recharge is about $N_5$, although an excellent thick aquifer is proved at CD4, this unfortunately being overlain by 55 ft of clay deposits.

Cross-section W5 (Plate 30)

West of RE.97 the surface layer 0-50 ft is generally dry, and between N1 and N2 predominantly sand and gravel 0-60 ft. This is clearly a good recharge zone. Between BMR 8 and D6A borehole evidence (e.g. DE 4-8, D5, E6) indicates an extensive aquifer in the range 0-65 ft.

Note: There is no page 53 or page 54



Most depth probes in this region (e.g. RE.93, 440, 91, 90 etc) have high resistivity values in the same range, which means that the aquifer may be mainly dry or moist and hence artificial recharge would be desirable and practical. Similar evidence supports the presence of dry near-surface aquifers between RE.87 and PR6, although about the latter borehole is good depth probe evidence of saltwater encroachment from the Anabranch to the east. Similarly, on Rita Island, a dry aquifer 0-30 ft is indicated by BMR 66A, B, D9 and depth probes RE.601 to RE.252; these depth probes clearly define the saline formations beneath.

Cross-section W6 (Plate 31)

West of $N_3$ weathered bedrock is about 70 ft deep; apart from the area RE.136 to 154, the section consists largely of low permeability material between N1 and Anabranch. I.W.S.C. borehole E5 (near W6/N4) shows sand 0-35 ft depth, and correlation with RE.2 suggests that this is mainly dry. Nearby depth probe RE.136 indicates that this aquifer may extend west to borehole L3 B4. East of Plantation Creek near W6/N4, high resistivity near-surface layers (see RE.136, 2 and 154), represent a dry aquifer suitable for artificial recharge.

Depth probe RE.600, made more than a year after RE.381, indicates that whilst the basal low resistivity layer is slightly closer to the surface, the mainly dry 500 ohm-metre layer of RE.381 had become completely dry. East from RE.600, a series of high resistivity near surface layers may be correlated with BMR 37, E.9, BMR 38 BMR 71, which prove sands and gravels in the range 0-45 ft on Rita Island. Therefore it is here, where the aquifer is underlain by saltwater, that artifical recharge is desirable.

Cross-section W7 (Plate 32)

Whilst the depth to the bedrock profile is variable, an excellent near-surface aquifer between N2 and the Burdekin River is shown by boreholes F3-2, BMR 27, F4, F4A etc. in the range 0-65 ft depth; (an exception is at RE.200). This aquifer appears to be largely dry, as indicated by the high resistivity layers at depth probes RE.199, 198, 113, 119 etc. It would represent a large area for potential recharge, which could be accomplished with relative ease. Between N4 and N7 proven aquifers near the surface are thin, or are overlain by clays and sandy clays. An exception is BMR 73, where sands and gravels occur in the range 5-50 ft. The aquifer is probably a limited one since RE.306 and 311 indicate brackish clays. On Rita Island there are sands and gravels 0-43 ft, and part of the lower aquifer is saturated with saltwater.

Cross-section W8 (Plate 33)

Between $N_2$ and the Burdekin River, the resistivities of the near surface layers are generally very high, thus indicating a dry formation. Geological control is good with boreholes BMR 36, FG3A, BMR 53, FG4, BMR 51, and BMR 50 all proving good aquifer bodies in the range 0-60 ft depth. Recharge here obviously is desirable. Borehole Line A, S8 indicates a similar dry, sandy zone, and high resistivity near surface layers at intervening depth probes (e.g. RE.424, 145 etc.) suggest that this extends eastwards to RE.146. An exception is RE.150, where the brackish layer may be correlated with the sandy clay section in BMR 40. (Water levels west of N6 are commonly in the range 35-40 ft depth for the period Jan - Dec 1963). East of BMR 40, clay is more predominant, and formations are commonly brackish or saline in the main. An exception is at G7A, where there is a good aquifer 38-93 ft depth. The 500 ohm-metre layer of RE.212 correlates well with this, but this high value is indicative more of a moist rather than a saturated aquifer. To the east, apart from a thin surface sand at BMR 43, the section appears to be composed of brackish or saline clays in the main, although sands and gravels are recorded at PR3 from 0-40 ft.

Cross-section W9 (Plate 34)

Proven aquifer bodies thin beneath and to the west of the Burdekin River, e.g. GH4A. BMR 55 proves an excellent aquifer 5-68 dt, which can be correlated with GH5A if one accepts the reasonable interpretation that the high resistivity layers of the intervening depth probes (e.g. RE.266, 292, 65 and 70a) represents a good aquifer, but largely dry. This would be an excellent artificial recharge zone. Note that the water level at $N_3$ in December 1963 was at 43 ft depth.

The next known aquifer of importance occurs at and west of GH7A, at a depth of 25-87 ft. Neighbouring depth probes suggest that this aquifer is saturated with poorer quality freshwater, which contrasts with the brackish or saline clay formations indicated by depth probes between RE.227 and RE.216, further west.

East of N7, borehole and depth probe data indicate that the section consists largely of brackish clays and sandy clays, although at borehole H8 sand occurs at a depth 15-40 ft. This sand may extend east to H9, but this zone more probably consists of brackish clay.

Cross-section W10 (Plate 35)

To the west of the Burdekin River sparse resistivity and borehole data both indicate a predominance of brackish clays above the relatively shallow bedrock defined on seismic evidence. Boreholes between RE.269 and 286 prove thick aquifers between 0-70 ft, although at $H_4$, HJ4A and HJ5 the aquifers are overlain by 10-15 ft of sandy clay. At $N_3$ the water-level varied between 40 and 47 ft below surface and together with the corresponding high resistivity layers at depth probes RE.269, 270, 289, 277 and 60, the aquifers appear to be largely dry. If the surface sandy clay can be effectively penetrated, the area would be eminently suited to artificial recharge. The only other thick near-surface aquifer is proven at HJ7, which may be dry in part, but further east RE.321, probably represents a brackish clay; and it is likely that this depth probe, and those recorded further to the east, generally represent saline clay or sandy clay.

Cross-section W11 (Plate 36)

Bedrock is less than 70 ft deep throughout the section, and appears to give rise to a number of brackish formations.

The only notable near surface aquifer has been located by boreholes BMR 48 and J6, which indicate sand and gravel 0-40 ft. Water-level data and the presence of a very high resistivity layer in depth probe RE.239 both indicate that throughout much of 1963 this aquifer was largely dry. It seems likely from resistivity data of neighbouring depth probes, that the aquifer extends between RE.61 and 241.

Cross-section N1 (Plate 18)

Resistivity data is sparse and borehole data indicates a predominance of clays and sandy clays. Sand 0-33 ft depth is recorded at A2, below 37 ft depth at B3, and from 4 to 27 ft depth at B2. Apart from this, the only significant aquifer occurs at W5, where D2-5 and DE3 prove sands and gravels 40 ft thick lying between 10 and 70 ft below surface. Both are overlain by impermeable layers and depth probes RE.309 and 102 indicate that the aquifers may be dry, at least in part.

Cross-section N2 (Plate 19)

North of the Kelly's Mountain region (where bedrock is very shallow) there are good extensive near surface aquifers between W7 in the south and L2 B9 in the north (e.g. boreholes BMR 18, D3, DH 138, C3).

The aquifer contains a band of clay at C3, but this is absent in DH 116 and DH 166; in the latter case however the aquifer is overlain by 35 ft of silt. It seems probable that recharge between W4 and W5 will also recharge the aquifer proven by DH 166. Depth probe RE.53 near DH 166 indicates that the aquifer may be partly dry, although southwards it appears to be saturated with salty or brackish pore solutions (RE.333). RE.336 suggests a dry near surface aquifer, whilst RE.335 indicates a good freshwater body. RE.631, however clearly demonstrates that in the period May 1963 - October 1964, the freshwater had become greatly depleted, with marked saltwater encroachment at a depth of about 60 ft. Depth probes between W4 and W6 (i.e. RE.107, 230, 231, 98, 232 and 235) all indicate dry near surface conditions. The zone between DH 166 and W7 should therefore be an excellent area for artificial recharge, i.e. recharge by the whole Sheepstation Creek system.

There are two other small areas which might benefit by recharge. The first is near W7 where boreholes F3-2 and BMR 27 record sand and gravels from 0-50 ft depth, and where depth probe RE.229 indicates the aquifer to be dry. The second lies between Kelly's Mountain and the Burdekin River where depth probes RE.202 and 185 suggest the presence of a partly dry near surface aquifer body.

<u>Cross-section N3</u> (Plate 20)

Apart from dry sand (7-37 ft depth) recorded at A5, depth probe data southwards to W4 indicates brackish or saline formations at depth. A thick sand and gravel aquifer is recorded at boreholes CD4, 4A and 4B, although this is overlain by 55 ft of dry and sandy clay. Depth probes RE.133 and RE.5 both indicate the aquifer to be saturated with freshwater, and the latter clearly differentiates between the overlying clay formation and the freshwater body beneath. A number of depth probes south of CD4 etc. indicate that this freshwater body extends southwards to PC13, beyond which is a zone of saline clays. A further aquifer (15 to 65 ft depth) occurs at F4A; RE.351 and RE.113 indicate that this may be partly dry, so that recharge at this point should be considered. At W8, borehole FG4 shows an aquifer 0-35 ft (mainly dry - see RE.128), which may extend further southwards to the river. To the south of the Burdekin River depth probes RE.267 and 268 indicate a thick freshwater body. But at H4, where sand and gravel is proved to extend 15-70 ft depth, the nearby depth probe RE.270 suggests that this is largely dry. Providing the relatively thin overburden of clayey material can be penetrated, artificial recharge on a small scale might be desirable.

Cross-section N4 (Plate 21)

North of W4 the near-surface formations are predominantly clayey in composition, and these layers may be saline or brackish. Between W4 and W6, depth probes have high resistivity near surface layers (e.g. RE.141, 328, 142, 189, 440 and 154) which are indicative of dry sands and gravels. This appears to be confirmed by 35 ft of sand at D5. Further south, aquifers are recorded at E5, EF5-2, EF5-4, FG5, FG5-2, and G5, but the only significant near-surface aquifer occurs at near G5. At W9 however there are sands and gravels 0-90 ft recorded in GH5A. Depth probes RE.290 and 66 suggest that this represents a thickening of the aquifer recorded in G5. It is probably dry in part, and extends as far as RE.71. From H5 southwards this aquifer is somewhat thinner. However both HJ5, HJ5A, and BMR 47 and HJ5-2 all prove excellent aquifers in the range 0-70 ft depth. Depth probes RE.228, 60 and 71 support this and indicate further that the aquifer is largely dry. It seems likely that the zone between G5 and HJ5-2 would be ideal for artificial recharge.

Cross-section N5 (Plate 22)

Although a very thick near surface aquifer is recorded at borehole B3 S1, it is probably more or less permanently saturated by brackish and saltwater. This subsurface encroachment is evident as far south as RE.176, where a basically freshwater formation overlies saltwater at a depth of 70 ft. Extending south from A6 is a near-surface aquifer generally less than 40 ft thick (see also PR12, C6, L2B5, L2B4, D6 and E6). Depth probes south from C6 indicate the aquifer to be dry in part (e.g. RE.175, 532, 190, 29 and 156). The area from A6 to RE.156 should be in the main suitable for artificial recharge. To the south of the Burdekin River sands (0-45 ft depth) occur at line A, S.8 and S.9. Depth probes RE.395, 424, 48 and 285 all indicate dry or partially dry aquifers in the region; again recharge would seem desirable at this point. The southward extent of this aquifer is limited by the clay formations indicated by BMR 75 and 76, and by depth probes RE.228, 227 and 226A. H6 proves a thickness of 45 ft of sand, largely dry if correlated with the high resistivity layer of RE.236. A clay zone separates this aquifer from that recorded at HJ6-1 further south. Again, RE.238 can be correlated with HJ6-1, where at the depth probe the 1200 ohm metre layer represents a dry aquifer. This extends to boreholes BMR 48 and J6, and RE.239 also indicates the dryness of the near surface layers. A further potential recharge zone is therefore proposed.

Cross-section N6 (Plate 23)

North of Plantation Creek, the geological sections are variable in composition, and sand up to 30 ft thick is recorded at a number of boreholes in the depth range 0-42 ft (e.g. A7, B7, AH5 and C7). The resistivity of this layer is variable; some depth probes (RE.429, 366, 184) indicate freshwater sand; some (e.g. RE.173) indicate clay and others (e.g. RE.39, 37 and 38) suggest a dry aquifer. Beneath the freshwater zone, there are brackish and saline fornations, representing saltwater encroachment. At D6A are sands and gravels 0-67 ft depth; RE.30 suggests that this is partly dry, as does RE.193. Depth probes RE.88, 194 and 84, however, suggest this to be a good freshwater body capable only of limited artificial recharge. Between W7 and W8 are sands overlain by clay; nearby depth probes suggest that these aquifers are probably dry. Here again, limited recharge may be possible. At HJ7, 45 ft of sand and gravel are overlain by 5 ft of clay. Known water level data indicate that this aquifer must be partially dry. Depth probes RE.416 and 415 both can be correlated with a freshwater aquifer, the former indicating some degree of dryness. At K7, 15 ft of near-surface sand is recorded, and at this depth nearby depth probes RE.447 and 448 both have very high resistivity values indicating a dry aquifer. This may or may not have practical importance.

Cross-section N7 (Plate 24)

To the north of the Burdekin River brackish or saline formations are generally indicated at depth beneath dry or freshwater saturated layers by resistivity depth probe data. The depth to the saltwater interface is variable, possibly due to the presence of clay formations. Near surface sands and gravels occur at B3S2, CD7A, D8 and E8, but in the latter case the sand is overlain by 15 ft of sandy clay. However, C8 indicates predominantly clay near the surface. Between boreholes CD7A and E8 it would be desirable, and may be possible, to carry out recharge, although except near E8, and W4 the near-surface beds are saturated in the main. South of the river, the relatively shallow bedrock may be responsible for the low resisitivy clay layers at some depth probes between W7 and W8. A thick aquifer overlain by

25 ft of sandy clay or clay occurs at GH7A, and this might well be continuous with the aquifer 7-40 ft at H8. The very high resistivity layer of RE.422 can be correlated with the dry surface layers of GH7A, as can RE.360 with those of H8. The brackish layer of the intervening depth probe RE.397 is probably a clay. South of Charlies Hill depth probes RE.221 and 318 both indicate largely dry near surface aquifers which can be correlated with the two-level aquifer proven by borehole J8. This zone of limited extent might prove a useful recharge area, although it could prove impractical by virtue of its location in the delta, and be limited by clay zones to the north. (e.g. NJ7A)

Cross-section N8 (Plate 25)

Brackish and saltwater formations are present near the surface and at depth from $W_3$ to $W_6$, as indicated by depth probe data. Near-surface aquifers occur at boreholes C9, B1S3, D9 and E9 north of the Burdekin River; between $W_4$ and $W_7$ the near surface layer is usually represented by high or fairly high resistivities. (See depth probes RE.535, 379, 539, 411, 255, 256, 257 and 264). Much of this aquifer zone appears therefore to be dry, and would be suitable for artificial recharge. Generally in the area south of the Burdekin River, where bedrock is 50 ft deep or less, borehole and resistivity data indicate fresh or brackish water clays, with some minor aquifers close to the weathered bedrock surface. Artificial recharge would therefore be confined to the north of $W_7$.

Cross-section N9 (Plate 26)

As with cross-section N8, salt and brackish water formations are present beneath freshwater or dry zones throughout most of the section, e.g. Rita Island. South of the Burdekin River, there is much clay near the surface. Apart from depth probes RE.251A and 260, resistivity data shows that the saltwater interfaces are mainly less than 50 ft deep. Over most of the section, borehole information has proved extensive near surface sands and gravels. e.g. D10, B5S4, E10, F10, G10, and H10. Exceptions are PR1 and PR2 near W9 where there is 60 ft of saline sandy clay. The near-surface resistivities at depth probes RE.393A, 251A, 26, 630, 394, 530, 555 and 551 all indicate the sands and gravels to be mainly dry. Artificial recharge, in the absence of large existing freshwater bodies, is obviously desirable on Rita Island, although the practical solution of the problem might be difficult and uneconomical to achieve.

## 12. PERMEABLE SUBSURFACE FORMATIONS FOR RE-CHARGE (Plate 9)

In planning artificial recharge projects where fresh groundwater is, or may become depleted, the Commission requested a plan indicating zones of high permeability. In making this plan only formations deeper than 10 to 15 ft below the surface were generally considered. Surface formations are often contaminated with salts, and generally it is difficult or not possible to interpret resistivity data of surface formations. Also, it is believed that in many recharge projects channels or furrows penetrating through the top soil are used.

In addition to the principles noted in PART I, Chapter 6 (Resistivity Methods, the Meaning of Resistivity values) the following was observed during fieldwork:

Formations near the surface with resistivities in excess of say 260 ohm-metres are dry or partially dry. These formations consist mainly of dry permeable sands.

Clays, or clayey formations because of their low permeability largely retain their pore water during prolonged dry periods.

Further clays, deposited in a saline environment absorb salts which can only be very slowly flushed out as freshwater passes through the clay formation. Hence, no clays were observed with resistivities as high as those of dry sands.

In the intermediate resistivity range of say 20 to 260 ohm metres the clays usually occupy the lower end of the range. Unambiguous distinction of clays from sands in this range may require additional information on the resistivity of the ground water. The following examples may illustrate the principles used. If, in a specific locality depth probes are made in the wet and dry seasons, resistivity values of clayey formations will remain approximately the same; however, resistivity values of sandy formations will rise markedly during the dry season because of water depletion. Generally varying resistivities for different seasons indicate sandy formations; approximately constant resistivities indicate low permeability clays.

In a limited locality, the resistivity of the groundwater should not vary greatly. If, however, the resistivity depth probes indicate large variations of formation resistivity in the intermediate range (20 to 260 ohm metres), vertically and laterally, the lower resistivities may be correlated with clays, and the higher resistivities with sands. The explanation is that clays have retained a large part of the original salt content whereas in the sands the salt was largely flushed out.

In the low resistivity range below 20 ohm metres the above principles may sometimes still be used, but for very low formation resistivities, i.e. less than 6 ohm metres, it is mostly not possible to distinguish between saltwater sand and saltwater clays. In the latter case only direct drilling solves the problem.

Therefore, the following instances may be recognised in resistivity depth probing:

(a) Resistivities greater than 260 ohm-metres, dry sand or gravel formations.

(b) Resistivities 20 to 260 ohm-metres, clays and sands usually may be recognised by applying the above mentioned rules. The formation water is generally fresh.

(c) Resistivities 6 to 20 ohm-metres, clays and sands may still be recognised although it is more difficult and sometimes not possible. The formation water is brackish.

(d) Resistivities of 6 ohm-metres or less, salty clays generally cannot be distinguished from saltwater sands by resistivity methods only.

Plate 9 shows a regular pattern of subsurface sand zones suitable for recharge, separated by clay zones. The sand zones probably represent old river courses; the clay zones old natural levee banks. Clay zones along the Burdekin and Anabranch represent natural levees of the present Burdekin river. Sheepstation Creek and Kalamia Creek are located in sand zones; Plantation Creek is in a sand zone until it enters the clay zone one mile east from Ayr.

Fig. 7 of the pro gress report on "The Water Resources of the Burdekin delta" (Irrigation & Water Supply Commission, 1964) gives in a contour plan the rise of goundwater during the wet season from 20 January to 23 April 1963. It may be expected that after the water level has receded in the river, the water level in a clayey formation would fall more slowly than in a sandy formation. Hence in the time interval considered, the water level in clay formations has risen in comparison with that level in sandy material.

An inspection of the Commission's Fig. 7 shows that places of maximum groundwater rise over the period January to April, 1963 are located in the clay zones indicated on Plate 9 that is north west from Home Hill, 3½ miles south west from Plantation Creek, 3 mile east from Ayr near Plantation Creek, and 1½ miles south east from Home Hill.

Based on Plate 9 and also taking into account the bedrock contour plan (Plate 12) but disregarding technical or financial considerations, the best localities to recharge the delta probably would be:

(1) For the area north and south of Ayr, pump water into Plantation Creek near RE.341, N4/W7;

(2) for the area north west of Anabranch take water to between N6/W5 and N7/W5;

(3) for the Sheepstation Creek zone pump water into Sheepstation Creek north of Kelly's Mountain, near N2/W7 and near N2/W5 (from Plantation Creek);

(4) for Rita Island pump water to Rita Island;

(5) for the Home Hill area pump water to RE.266 between N3/W9 and N4/W9;

(6) and for the sand zone south of Home Hill to RE.238 near N5/W10.

In this connection the Sandpit Lagoon Diversion scheme (proposed by the Commission in their report 'Replenishment of Underground Water Supplies, Burdekin Delta, Stage 1, 1964) might be modified in the light of Plate 9. Further, water known to collect annually at the Lake Plain might also be diverted towards RE.238, further facilitating recharge of this area.

# PART III - DETAILED INVESTIGATIONS

## 13. MERRYPLAIN CREEK AREA

### Introduction

This area (See Plate 38) was investigated in detail to discover why the water from two bores with pumps (Bores 1 and 2) had become saline between June 1962 and June 1963.

According to the local farmer Bore 1 (depth about 30 ft) started as a freshwater bore used for irrigation. Since then the water has become saline, and the sugar yield per acre has dropped by about 30%. The area is bounded in the north-east by the Burdekin River while Merryplain and Macdonald Creek cross the area from west to east. Information on the area is given in the following Table.

| Hole No. (Plate 38) | Source of information | Comments |
|---|---|---|
| 1. | Farmer | Bore water went saline June 1963, after rain; 18 ft. to water, possibly brackish before. |
| 2. | " | Bore water went saline at end of 1962; possibly brackish before. |
| 3. | I.W.S.C. | Hole drilled 1963 November, water - 1000 ppm. |
| 4. | Farmer | Bore water - 700 ppm. |
| 5. | " | " " -1000 ppm. |
| 6. | " | " " - 700 ppm. |
| 7. | " | Unsuccessful test hole, salt water only. |
| 8. | " | Bore useable water, but brackish - 1000 ppm. |

| Hole No. (Plate 38) | Source of information | Comments |
|---|---|---|
| 9. | Farmer | Bore useable water, but brackish - 1000 ppm. |
| 10. | " | Bore useable water - 600 ppm. |
| 11. | I.W.S.C. | Salt water only in hole. |

The area between Merryplain Creek and the Burdekin River forms a naturally built-up levee of the river. North-east of Merryplain Creek the ground is between 20 and 30 ft higher than south-west of the creek. According to the local farmers the surface sediments north-east and south-west of Merryplain Crrek consist of sands, or sands with clays. The aerial photos indicate that east of Merryplain Creek the surface drainage is northward to the Burdekin River, and west of the creek it follows the creeks and lagoons in a general south-easterly direction.

Results

Resistivity Traverses C, D and E, resistivity depth probes, and bore hole information show that west of Merryplain Creek salt water has penetrated inland near the surface and at depth as far as Traverse D. North of Traverse D, along Traverse C, resistivity values are higher and the layer of fresh water above salt water becomes thicker, as shown by a shallow bore and resistivity depth probe RE.560. Between the two creeks near RE.557 and 558 is a thick fresh water layer above salt water, indicated on Plate 38 as a zone of fresh water above saline. However, further west towards RE.314 near the creek, the fresh water layer becomes thin again.

Resistivity Traverses A and B near Bore 1 indicate that resistivities are low where lagoons cross the traverses i.e. these lagoons allow salt water to move inland assisting encroachment.

The distribution of salt and fresh water suggests that rain water soaks into the ground to form the fresh water layer in the wet season. With excessive pumping at the end of the dry season fresh water is drawn out, and salt water comes in through the sub-surface. Possibly the creeks and lagoons function as important entrance channels for salt water, especially during high tides or tidal floods. (The predicted maximum tide level variation at Townsville is about 13 ft, not taking into account variations due to cyclonic storms). In the following rainy season fresh water soaks into the ground and depresses the fresh/salt water interface as is required by the Ghyben-Herzberg relation. (See Fig. 26).

In the area between Merryplain Creek and the river (see RE. 554 and 555), the higher level of the ground surface leads to an increase in thickness of the layer of fresh water that lies on top of the salt water. This area is not cultivated and is very sandy, so that a fairly high proportion of the local rainfall will permeate through to the water table. There are at least three irrigation pumps (Bores 8, 9 and 10) operating in this area at present, which produce water with a salinity of the order of 800 ppm. It is suspected that at the end of the dry season, or after a long period of pumping, this salinity increases, but water should be replenished with fresh water by rain during the wet season. During tidal floods this area tends to remain above water.

Summarising: The distribution of salt and fresh water suggests that creeks and lagoons act as important channels for salt water encroachment. Rain water probably forms the main source of recharge. Hence, if more fresh water is pumped from the aquifer than comes in by rainwater soaking into the ground, salt water encroachment takes place. This has caused the salting up of bores 1 and 2. The remedy is to adjust the amount of pumping to the annual intake from rainfall in the area. Small dams made with a bulldozer during the dry season across the downstream parts of Merryplain and Macdonald Creeks, may prevent tidal inflow of salt water.

## 14. ANABRANCH SCHOOL AREA

### Introduction

This area (Plate 37) was investigated in detail by taking a series of resistivity depth probes and traverses and repeating the measurements at intervals of several weeks. A study was made of the variation of resistivity while a pump was operating, and a fixed series of probes in the ground were measured at intervales to see how the salinity of the ground water varied. A series of shallow holes was also drilled. From BMR 17 to BMR 3 the section down to 30 ft is predominantly sandy; from BMR 2 to BMR 5 the section consists predominantly of clay or mud.

### Resistivity traverses

The results of the traverses are shown on Plate 37. To the north-east of RE.74 the values obtained are all very low. West of RE.74 the readings rise to a peak. This is probably due to two factors: firstly a rise in the level of the ground surface, leading to increase in the thickness of dry ground above the water table; and secondly a decrease in the salinity of the ground water. The highest reading at this peak was obtained on 18th September 1963. At this time the surface of the ground was drier than on 12th and 15th August, but not as dry as on 30th October, which implies that the salinity of the ground water had increased between September and October.

The first generally low area beyond the peak (1600 ft S.W. from RE.74) is associated with a creek course, which although not active above the ground, appears to act as a source of saline water below the ground. The next peak near RE.75 is again associated with a slight topographic high, but between RE.75 and RE.76 there are no significant, consistent, variations in resistivity, apart from a general increase in resistivity indicating an improvement in water quality as RE.76 is approached.

Repeated resistivity depth probes

During 1963 depth probes at some locations were repeated in an attempt to detect changes in resistivities of sections as a result of salt water encroachment.

RE.73 (Fig. 18). Between 12th March and 29th April the resistivity at all levels increased, probably as a result of the heavy rain that fell during this period. Although the measurements made on 30th October are of poor quality they are good enough to indicate that the resistivity of the ground water fell by a factor of at least 10 over a period of 6 months, indicating a major encroachment of salt water.

RE.74 (Fig. 19). Between 7th March and 29th April the value of the resistivity fell, suggesting that more saline water was washed into the area as a result of the rain. This is possible, as this depth probe is situated alongside a creek which is active during the wet season, and is in contact with tidal inlets close by. By 11th November the quality of the water had improved, though it was still inferior to the quality in March. The depth probe interpretations are given at the bottom of Fig. 19: 260/3'/48/13'/31/170'/115 means 260 ohm-metres to 3 ft, 48 ohm-metres to 13 ft etc.

RE.75 (Fig. 20). Between 7th March and 11th November the water quality improved considerably. The resistivity below 50 ft increased from 1 ohm-metre (representing a salinity of 9000 ppm in the water in the material) to 38 ohm-metres (representing a salinity of 800 ppm).

RE.76 (Figs.21 and 22). Between 7th March and 15th August there was little change, apart from a lowering of the level and a decrease in the salinity of the salt water. On 16th September, there was a considerable difference; the top part of the curves showed a higher resistivity due to the drying out of the near surface material, while at intermediate depth there was a decrease in resistivity, indicating an increase in salinity. A number of readings were taken of this depth probe on 16th and 17th September, while the adjacent pump was operating. The results of this series are discussed below under "Pumping Investigation."

Unrepeated resistivity depth probes

RE.72. This was read only in March. It indicates salt water at a depth of only 8 ft, compared to 32 ft at D.P. 73.

RE.373, on 14th June 1963. Salt at 15 ft.

RE.375, on 14th June 1963. This shows salt water from 10ft downwards.

RE.376, on 14th June 1963. Saline water.

RE.377, on 14th June 1963. Freshwater indicated down to 56 ft and then saline water beneath.

RE.535, on 21st November 1963. This depth probe shows a thin veneer of salt water down to 7 ft, followed by fresh water to about 115 ft, beneath which the water again becomes saline.

Fixed probes

Fixed probes, consisting of bared wires wound round a 1" x 1" wooden pole at 1 ft intervals, were placed vertically in the ground. Fig. 23 shows a plot of resistivity reading against depth for bore BMR 4 at various times. Readings above 7 ft are erratic, being above the water table. The readings between 7 and 17 ft show the progressive build-up of salt content in the water after the wet season. Another fixed probe was used in conjunction with the pump test described below.

<u>Pumping investigation</u>

There is an irrigation pump adjacent to the centre of RE.76. On 16th and 17th September 1963 readings were taken at the depth probe while the pump was operating. The results of the readings are shown on Fig. 22. The curve obtained before pumping and the two obtained while pumping was proceeding were used to calculate the average curve for 16th September. (The other two readings were taken 1 hour and 2½ hours after pumping started). After 10 hours pumping on 16th the pump was stopped at 8 p.m., and restarted at 6 a.m. on 17th September. The two readings on 17th were taken at 9.30 a.m. and at 3.45 p.m. It can be seen from the figure that initially the resistivity at depth increased, as saline water from the last time the pump had been used was flushed out. Thereafter the resistivity decreased again to below that of the initial level, indicating that salt water was once again being drawn into the aquifer from which the water was being pumped.

The salinity of water at a depth of about 50 feet increased from about 1100 ppm to about 2000 ppm in the course of the pumping.

A fixed probe was put in the ground about 100 ft from the pump, and the change of readings at various depths is plotted against time of pumping in Fig. 24. No significant event is recorded on the probe at a depth of less than 13 ft. This is consistent with Fig. 22 as the changes in the pumping bore occur at depths below 30 ft.

Conclusions

This detailed investigation of a small area brings out four points:

1. The quality of water in the ground varies considerably with time, indicating that there is encroachment and recession of salt water into fresh water aquifers.
2. The mouth of the Burdekin River and surface creeks within the tidal zone may act as a source of salt water both at and below the ground surface.
3. Where salt water lies beneath fresh water without an aquiclude to separate it from the fresh water, pumping water from the ground will cause a rise in the salinity of the ground water.
4. The results suggest that detailed investigations of the nature described above should be correlated with pumping data of neighbouring pumps and rainfall data.

15. SHEEPSTATION CREEK - NORTH JARVISFIELD (Plate 39)

Introduction

The small area under consideration is situated about 4 miles N.W. of Brandon, bordering the litteral mud-flats on the northern edge of the Burdekin Delta, and was investigated during 1963.

For those plots situated close by the creek, irrigation water is pumped from the bed of the flood channel, over which little water flows in the dry season, and which is dissected by a number of minor channels as well as the meandering main channel. The quality of water pumped from these sources deteriorated sharply in the last quarter of 1963.

Work carried out included a constant-spacing resistivity traverse, depth probes, and water sampling. The table below summarises the information locally obtained.

TABLE

| Bore Number | Source of information | Comments |
| --- | --- | --- |
| Bore 1 | F. Castellango - farmer | Depth of spear 18 ft. |
| Bore 2 | " " | " " 30 ft. |
| Bore 3 | M.A. Toll - farmer | Depth of spears 30 ft. Water table 4-10 ft. Pumping at 50,000 g.p.h. |
| Bore 4 | " " | Depth of spear 35 ft. Water table 4-14 ft. Pumping from minor creek at 30,000 g.p.h. Water quality in early winter 342 p.p.m. |

Results

Good quality water at depths down to 100 ft was shown to exist at $RE.356^{A}$ in May 1963. In general however, by November 1963 the area was one of brackish to salty water, particularly in and close to Sheepstation Creek, with freshwater in places at depths of 13 to 35 ft. The resistivity traverse $TS_1$ demonstrates a correlation between resistivity highs and topographic highs across the stream channels which comprise the Sheepstation Creek system at this point. East of the main channel the traverse data suggest saline or brackish waters close to the surface, this generally being 10 ft lower than the topographic highs to the west. A pump is situated on the west bank of the main channel, from which brackish water is extracted at a depth of about 25 to 30 ft. The area is probably not tidal, except in the sense that tides may well force more brackish waters up the channel in a southwards direction.

Such freshwater as exists in the immediate subsurface layers is probably replenished by both rain and by flood waters in the early months of the year, these effects being progressively obscured towards the end of the dry season. As in other areas marginal to littoral flats, the rate of pumping and the arrangement of spears is of critical importance to the rate of deterioration of water quality.

## 16. RITA ISLAND RESISTIVITY DEPTH PROBE NEAR PUMPING BORE

A resistivity depth probe adjacent to a pumping bore (Pegoraro, Lot 41) was read 7 times during a period of 24 hours pumping. Salt water was present beneath the pump, but after 23 hours pumping there was no significant change in the salt water level. The curve after five hours pumping showed a slight decrease in resistivity, but this decrease was not so large after 23 hours pumping (see Fig. 25).

## 17. CONCLUSIONS

The results of the geophysical survey carried out in the Burdekin Delta have shown the relative merits of the different techniques employed in this type of problem. The use of the gravity method, although of interest for a scientific point of view, has not furnished the practical information for which it was employed - namely that of showing the form of the bedrock topography.

Seismic work has provided a great deal of information by delineating the bedrock topography, and also in indicating the thicknesses and nature of consolidated bedrock, weathered bedrock, and potential aquifer layers. The depth to bedrock information generally agrees well with the available borehole data, and provides further control for the resistivity interpretations. The method of making seismic measurements at selected points rather than by using continuous traversing has enabled the whole area to be studied in sufficient detail, at the minimum of cost.

Aided by seismic and stratigraphic control, resistivity has been used to differentiate between those areas suitable for artificial recharge (sands), and the contrasting low permeability clay areas. Difficulty was experienced in differentiating between saline clays and sands, except where the salinity of the pore-solution is known, or where borehole information is available to provide both depth and porosity control. Repetition of resistivity work at selected marginal areas of the delta provides valuable information on saltwater encroachment; the use of fixed conductivity probes is also of value in this connexion. Useful information has also been obtained by making gamma logs in cased boreholes.

The contour plan of the bedrock (Plate 12) shows several channels within the delta which may be suitable for the distribution of any water put into them. It also shows that there is a possibility of water flowing from the Burdekin River into the Barratta system to the west of Kelly's Mountain. A future drilling programme could resolve the nature and extent of such subsurface channels. There also appears to be a channel linking the Burdekin delta area with the Barratta system between $W_3$ and $W_4$ on section $N_1$. Recent results from radioactive tracer tests indicate the water in this channel to be flowing in a north-easterly direction. (Andrew, et al 1965)

Zones recommended as being suitable for artificial recharge are indicated on Plate 9, where clay subsurface zones are differentiated from aquifers, and particularly from dry or largely dry sands and gravels. Desirability of recharge of such areas will be influenced by technical and economical considerations.

A number of surface dams already constructed, blocking off creeks and river channels, have proved effective in helping to create freshwater zones by restricting the flow of freshwater outwards to the sea, and in some cases in restricting salt water movements in tidal creeks.

It is significant that in 1963, which was a year of above average rainfall, there appears to have been a net increase in the amount of saltwater encroachment. To avoid further encroachment more freshwater will have to get into the aquifers. At present it appears that, even in times of flood, comparatively little water goes from the Burdekin River into the aquifers, because of clay zones extending along part of the river.

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# APPENDIX 1

## GRAVITY DATA, BURDEKIN DELTA

| Station | Latitude | Longitude | Elevation (ft. above M.S.L.) | Observed Gravity (MGAL) | Latitude correction (MGAL) | Elevation correction (MGAL) | Bouguer Anomaly (MGAL) |
|---|---|---|---|---|---|---|---|
| AB 80 | 19°40'40" | 147°26'05" | 26.8 | -2.10 | -5.55 | +1.88 | -5.77 |
| AC 34 | 19°41'40" | 147°32'10" | 8.5 | -6.05 | -6.59 | +0.60 | -12.04 |
| AE 71 | 19°41'20" | 147°20'50" | 58.2 | +2.48 | -6,88 | +4.06 | -0.34 |
| AE 89 | 19°37'15" | 147°30'15" | 18.6 | -17.99 | -2.50 | +1.30 | -19.19 |
| AG 27 | 19°35'35" | 147°23'55" | 37.1 | -2.19 | -0.81 | +2.59 | -0.41 |
| AG 73 | 19°34'35" | 147°29'50" | 14.5 | -19.42 | +0.04 | +1.02 | -18.36 |
| AH 68 | 19°32'20" | 147°27'20" | 15.6 | -11.65 | +2.21 | +1.09 | -8.35 |
| AI 42 | 19°34'30" | 147°24'15" | 33.6 | +0.24 | +0.11 | +2.34 | +2.69 |
| AJ 25 | 19°33'15" | 147°21'20" | 26.0 | +6.59 | +1.41 | +1.82 | +9.82 |
| AL 3 | 19°35'40" | 147°20'10" | 29.8 | +0.51 | -1.08 | +2.08 | +1.51 |

Observed gravities are given relative to Ayr Base.

Absolute value of gravity at Ayr Base : 978644.4 mgal.

Latitude corrections were applied to the latitude of Ayr Base "(19°34'40") and a correction was applied for the theoretical value of gravity on the International at this latitude.

Elevation correction constant : 0.069816 mgal/ft.

Location descriptions:

STATION AB 80 : Northeast corner of Woods Road and Darvenizas Road intersection. At Bench Mark No. 57.

AC 34 : H.A. Shand Memorial Fountain at Groper Creek Landing.

AE 71 : On Up-River Road at fence of Osborne School. At Bench Mark No. 70.

AE 89 : Northwest corner of road junction on Switchback Road 0.5 mile north of Rita Island School. At Bench Mark No. 138.

AG 27 : Southeast corner of intersection of Ayr-Home Hill Road with Kilrie Road. At Bench Mark No. 35.

AG 73 : North corner of intersection of Wilsons Road and Jordans Road. At Bench Mark No. 129 at fence of Anabranch School.

AH 68 : On Ardmillan Road at fence of Ardmillan School. At Bench Mark No. 84.

AI 42 : In Ayr, northeast corner of intersection of Mackenzie Street and Graham Street. At Bench Mark No. 28.

AJ 25 : Outside the main entrance of the Imperial Hotel in Brandon. At Bench Mark No. 121.

AL 3 : Northeast corner of Ivorys Road and Fiveways Road intersection. At Bench Mark No. 123.

Note : Bench Marks referred to above are Ayr Shire Council Bench Marks.

# APPENDIX 2

## RESISTIVITY DEPTH PROBE RESULTS NOT SHOWN ON CROSS-SECTIONS

| Depth probe No. | Nearest sections | Interpretation | Month/ Year |
|---|---|---|---|
| 6 | N3, W4 | (89) 3, (1500) 190, (25000) | |
| 12 | N2, W6 | (22) 2, (26) 12, (76) 24, (2) 28, (36) | 9/62 |
| 16 | N2, W6 | (34) 5, (1600) 66, (348) | |
| 17 | N3, W4 | (35) 2, (53) 12, (17) 145, (152) | |
| 18 | N2, W8 | (30) 5, (3000) 22, (90) | |
| 19 | N1, W6 | (56) 23, (6) 46, (560) | |
| 20 | N1, W8 | (49) 6, (66) 47, (1380) | |
| 21 | N1, W6 | (27) 2, (52) 16, (12) 50, (305) | |
| 22 | N2, W10 | (14) 3, (85) 14, (132) 60, (630) | |
| 23 | N2, W10 | (17) 2, (93) 18, (14) 32, (32) | |
| 24 | N2, W10 | (14) 2, (27) 35, (17) 62, (180) | |
| 28 | N6, W4 | (21) 2, (14) 8, (280) 200, (130) | |
| 34 | N7, W5 | (36) 3, (1800) 15, (200) 74, ($\rightarrow 0$) | |
| 35 | N3, W3 | (55) 3, (80) 26, (1600) 120, ($\infty$) | |
| 36 | N5, W3 | (39) 35, (1830) 39, (1410) 246, ($\infty$) | |
| 38 | N6, W3 | (13) 2, (123) 2, ($\infty$) | |
| 40 | N5, W2 | (89) 7, (1830) 143, (450) 200, ($\infty$) | |
| 42 | N3, W3 | (11) 3, (26) 16, (71) 200, (46) | |
| 44 | N2, W3 | (7) 4, (22) 12, (36) 90, (50) | |
| 46 | N3, W9 | (10) 4, (250) | |
| 47 | N4, W8 | (48) 6, (20) 24, (170) 80, (90) | |
| 51 | N3, W7 | (21) 4, (2100) 7, (63) | |
| 52 | N3, W7 | (33) 10, (220) 37, (2000) 120, (570) | |
| 54 | N1, W1 | (25) 13, (10) 63, (20) 186, (9) 220, (4) | |

| Depth Probe No. | Nearest sections | Interpretation | Month/ Year |
|---|---|---|---|
| 57 | N4, W6 | (163) 3, (87) 40, (23) 223, (186) | |
| 58 | N4, W6 | (150) 3, (250) 38, (32) 214, (710) | |
| 76 | N7, W3 | (51) 2, (200) 54, (1) | |
| 79 | N7, W4 | (120) 2, (13) 6, (240) 132, (98) 220, (240) | 3/63 |
| 85 | N6, W4 | (39) 3, (280) 50, (8) | |
| 86 | N6, W4 | (15) 15, (40) 160, (5) | |
| 115 | N3, W7 | (63) 8, (1198) 417, (384) | |
| 116 | N3, W7 | (53) 4, (997) 347, (354) | |
| 120 | N3, W6 | (60) 2, (140) | |
| 121 | N3, W6 | (160) 5, (650) 21, (41) 40, (540) 150, (5) | |
| 135 | N3, W5 | (38) 3, (350) 10, (280) 155, (45) | |
| 139 | N2, W8 | (59) 10, (530) 80, (4400) | 4/63 |
| 143 | N3, W4 | (71) 2, (640) 100, (100) | |
| 152 | N5, W8 | (18) 2, (100) 18, (6) 100, (120) | |
| 153 | N5, W8 | (5) 2, (15) 28, (5) 71, (58) | |
| 157 | N5, W4 | (33) 3, (295) 95, (41) | |
| 158 | N4, W3 | (26) 2, (224) 35, (52) 56, (795) 132, (18) | |
| 169 | N5, W3 | (100) 53, ($<$ 5) | |
| 174 | N6, W2 | (4) 5, (16) 73, (9) 224, ($\rightarrow$ 0) | |
| 177 | N5, W3 | (29) 4, (13) 32, (16) 166, (1) | |
| 182 | N5, W2 | (93) 2, (370) 75, (4) | |
| 183 | N5, W2 | (54) 2, (480) 89, (2) | |
| 195 | N6, W5 | (69) 2, (206) 16, (6200) 56, (30) | |
| 204 | N6, W4 | (39) 3, (118) 48, (12) | |
| 207 | N6, W3 | (9) 4, (22) 89, (4) | |
| 208 | N6, W3 | (113) 4, (16) 53, (1) | |
| 217 | N6, W9 | (356) 25, (6) 22, (11) | |
| 218 | N6, W9 | (34) 2, (142) 11, (47) 42, (154) 71 (25) 210 (66) | |
| 225 | N5, W9 | (10) 3, (600) 85, (37) | |

| Depth Probe No. | Nearest sections | Interpretation | Month/ Year |
|---|---|---|---|
| 236 | N4, W9 | (21) 3, (440) 100, (100) | |
| 280 | N1, W10 | (47) 2, (31) 7, (195) 11, (110) 60, (560) | 5/63 |
| 281 | N1, W10 | (49) 3, (9) 55, (178) | |
| 289 | N3, W9 | (37) 4, (750) 70, (1780) 250, (178) | |
| 291 | N4, W8 | (26) 2, (75) 17, (380) 350, (69) | |
| 317 | N5, W10 | (17) 3, (114) 6, (35) 14, (1000) 70, (35) | |
| 327 | N3, W4 | (2700) 48, (5700) 100, (100) | |
| 329 | N3, W4 | (570) 4, (5300) 14, (3100) 33, (710) 148, (100) | 6/63 |
| 353 | N1, W2 | (60) 4, (6) 25, (18) 65, (2) 100, (35) | |
| 370 | N5, W4 | (25) 2, (63) 7, (10) 100, (2) | |
| 384 | N5, W4 | (15) 2, (274) 5, (12) 37, (25) | |
| 391 | N7, W6 | (10) 2, (23) 7, (4) 7, (11) 164, (3) 330, (28) | |
| 392 | N7, W5 | (45) 3, (266) 37, (3) 316, ($\infty$) | |
| 402 | N7, W10 | (870) 4, (457) 63, (125) 455, (>1000) | |
| 405 | N7, W11 | (.5) 2, (2) 6, (11) 25, (120) 66, (18) 120, (120) | |
| 408 | N2, W2 | (13) 2, (71) 4, (12) 13, (7) 46, (1) | |
| 410 | N8, W4 | (10) 2, (42) 38, (1) | |
| 420 | N6, W9 | (22) 1, (11) 7, (70) 25, (36) 90, (370) | 7/63 |
| 449 | N6, W11 | (20) 2, (430) 21, (1000) 40, (47) | " |
| 540 | N7, W5 | (15) 14, (130) 150, (20) | 11/63 |

Resistivity values in brackets, ohm metres; other figures depths in feet.

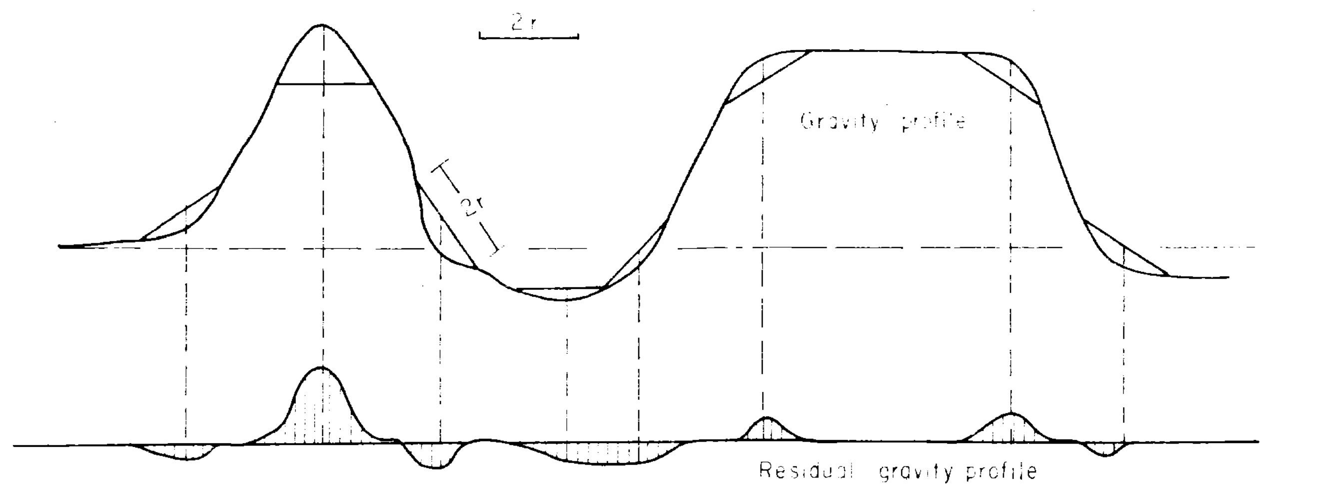
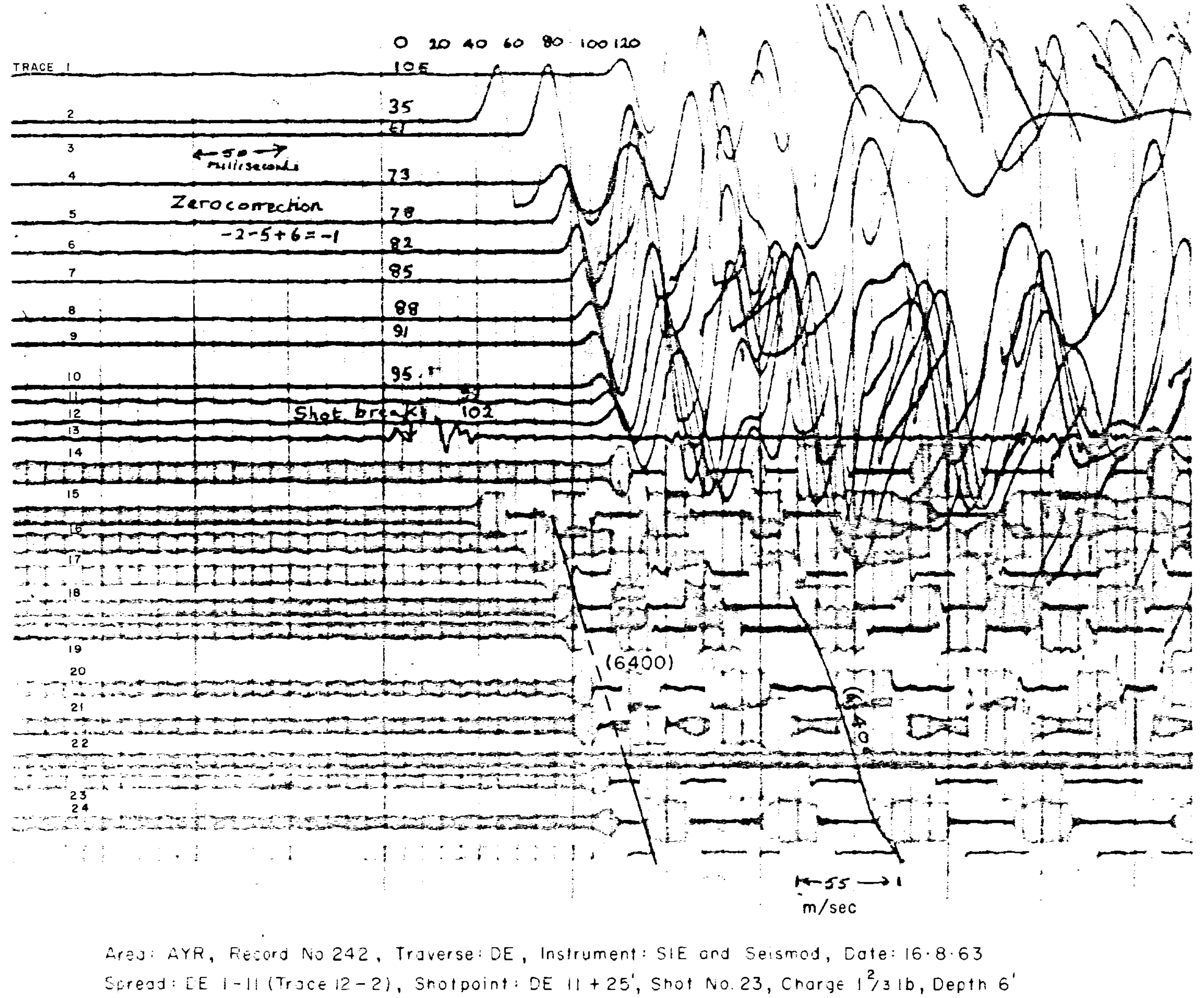



Figure 1 Illustrating construction residual gravity profile




Area: AYR, Record No 242, Traverse: DE, Instrument: SIE and Seismod, Date: 16-8-63
Spread: DE 1-11 (Trace 12-2), Shotpoint: DE 11+25', Shot No. 23, Charge 1⅔ lb, Depth 6'
Geophone interval: 50', Reciprocal geophone: DE 1-25' on Trace 1

FIGURE 2: TYPICAL SEISMIC REFRACTION RECORD

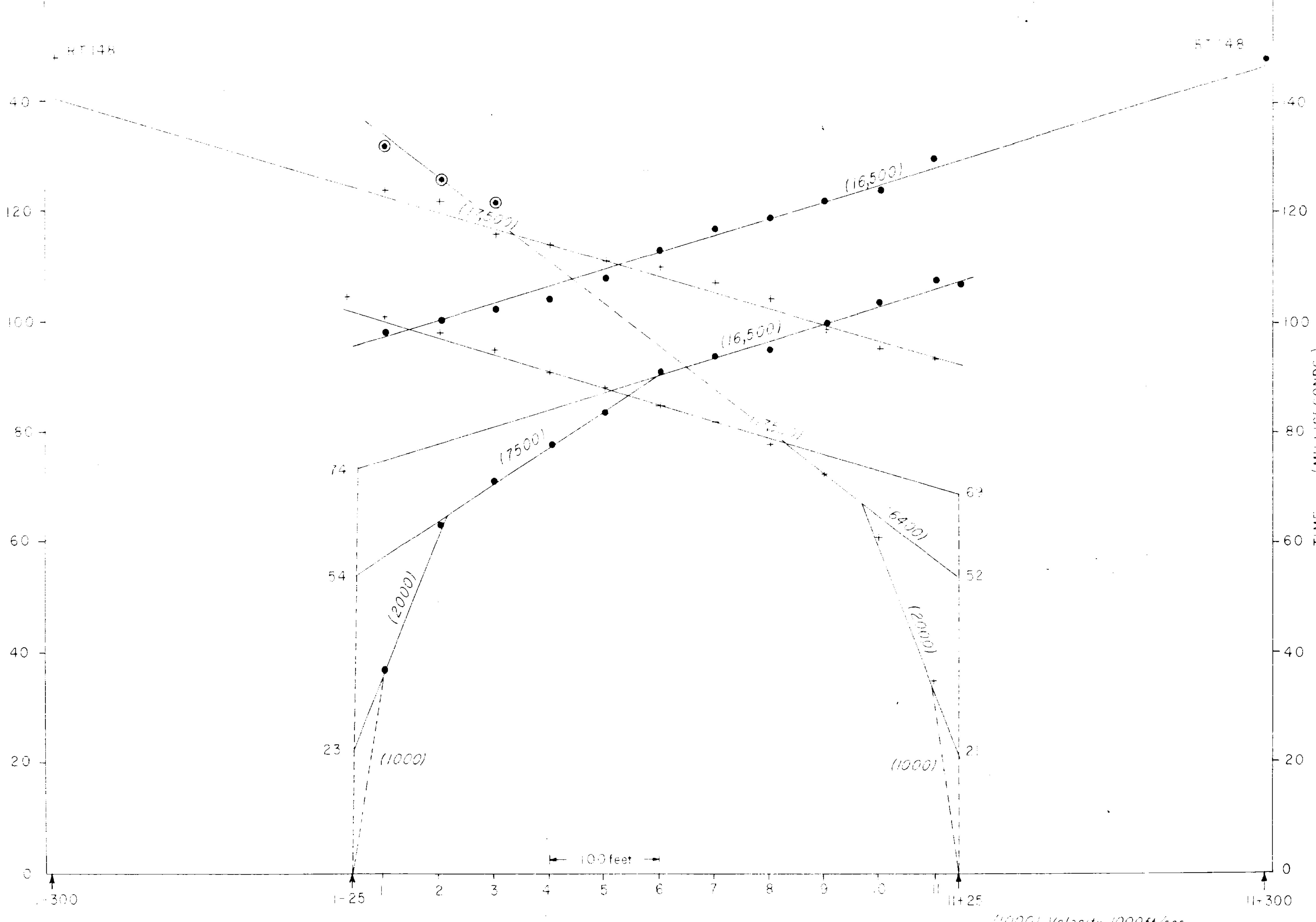



Figure 3 Time-distance curve, spread DE

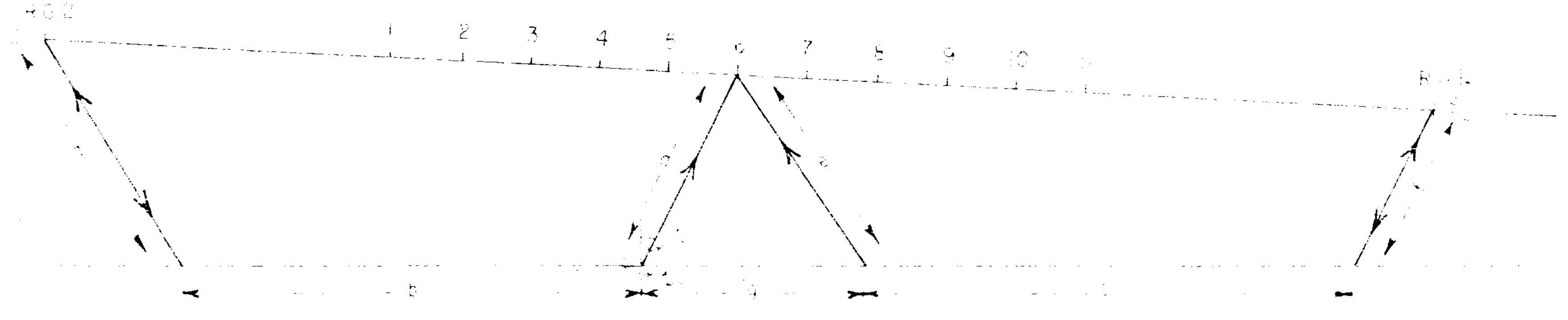


Figure 4 Diagram of reciprocal method

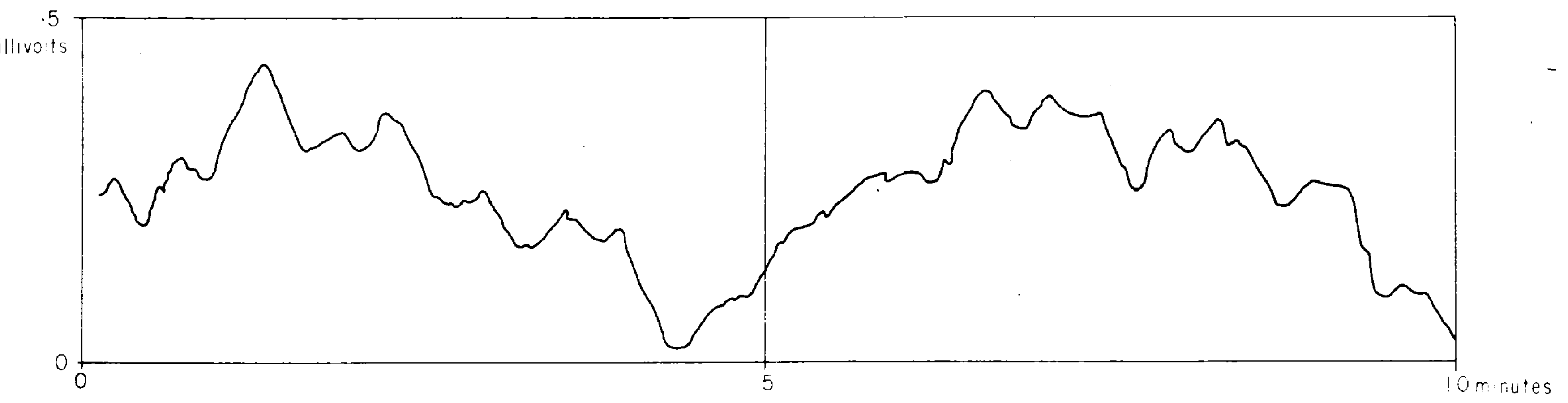



Figure 5 Record of telluric currents from Kunetz, Principles of telluric prospecting, C G G (undated)

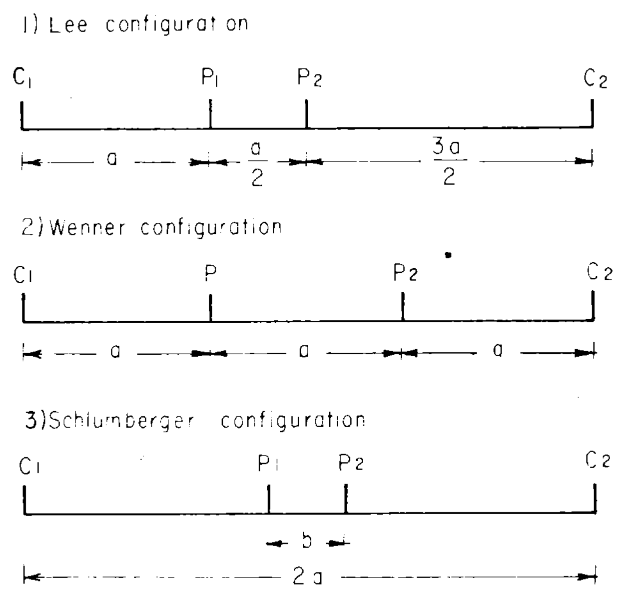



Figure 6 Electrode configurations

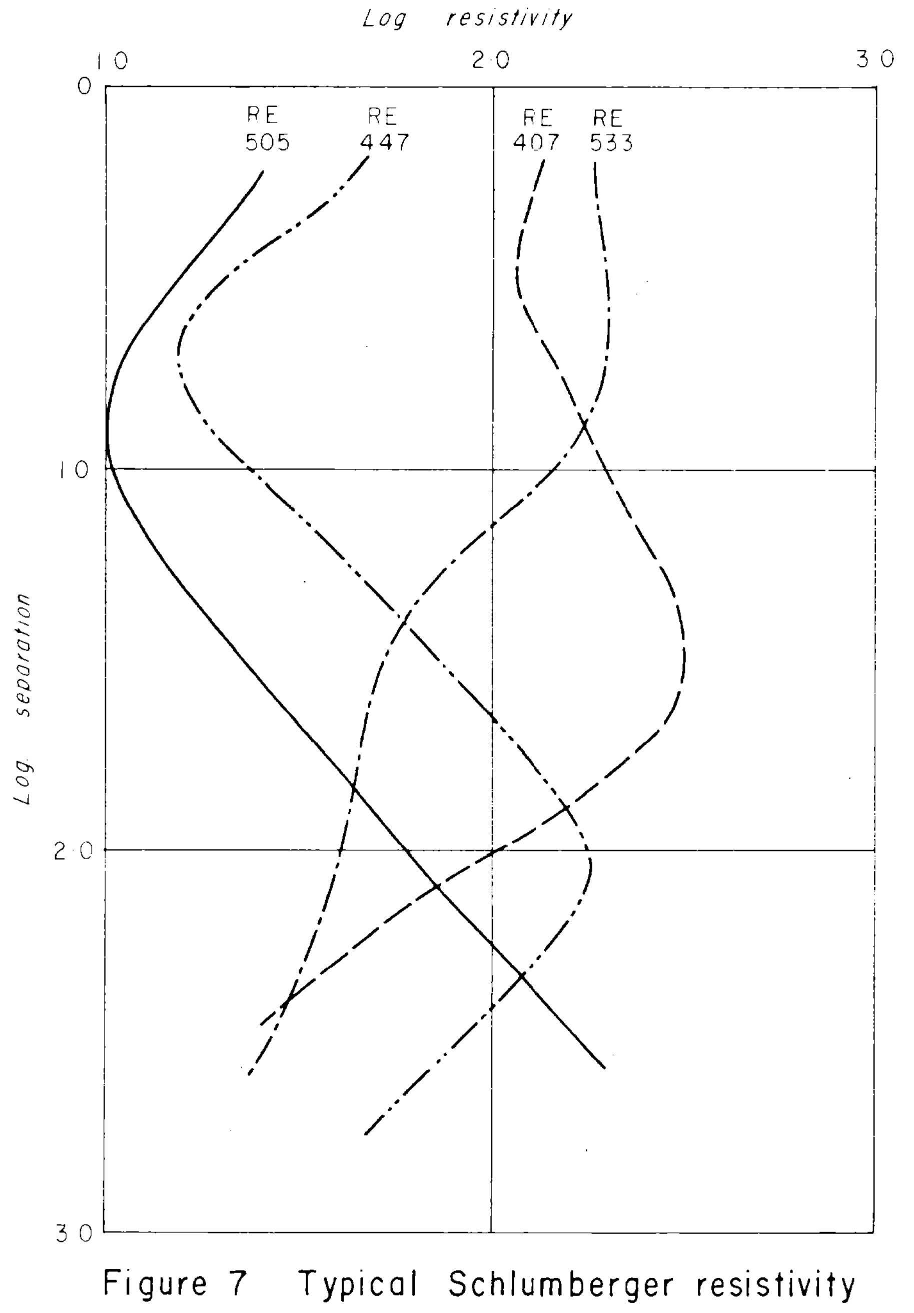



Figure 7 Typical Schlumberger resistivity depth probe curves

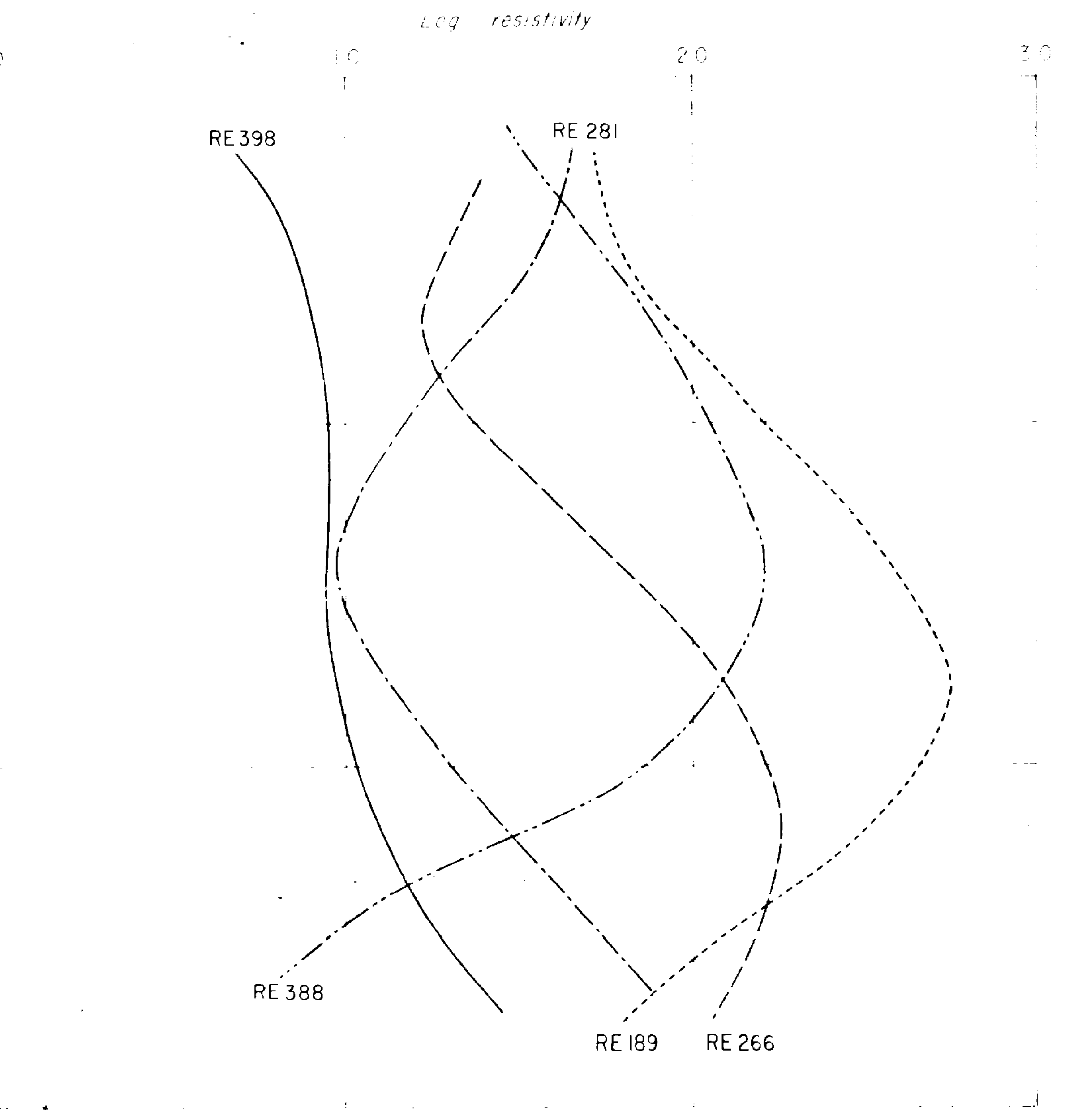



Figure 8 Typical Wenner resistivity depth probe curves

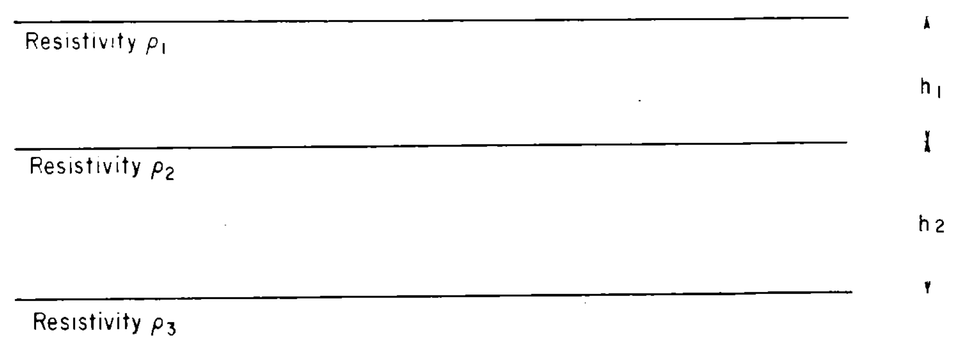



Figure 10 Illustrating Hummels principle $\frac{h_1}{\rho_1} + \frac{h_2}{\rho_2} = \frac{h_1+h_2}{\rho_a}$

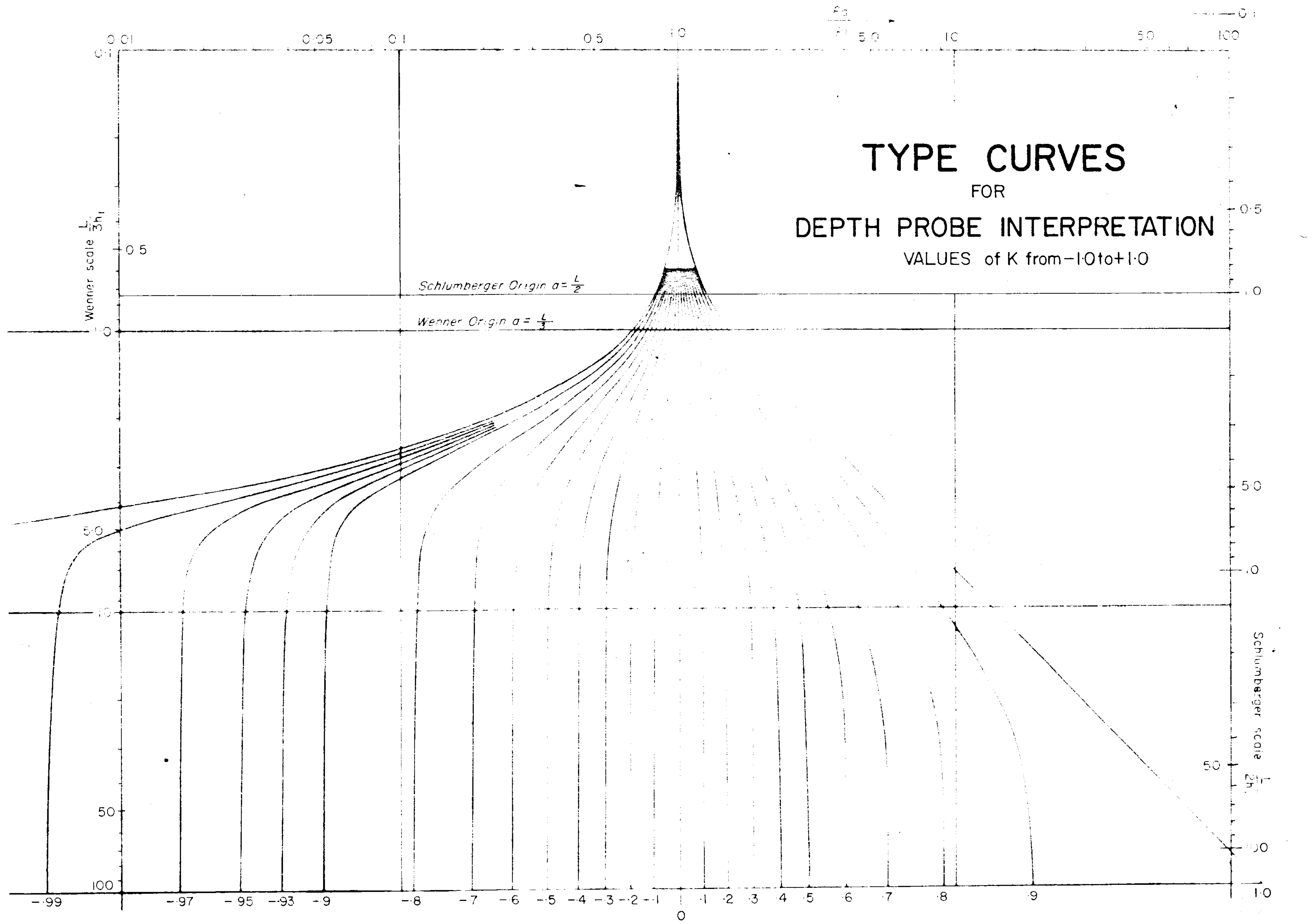



Figure 9 Two-layer Type Curves for resistivity depth probe interpretation Value of k from -1·0 to +1·0

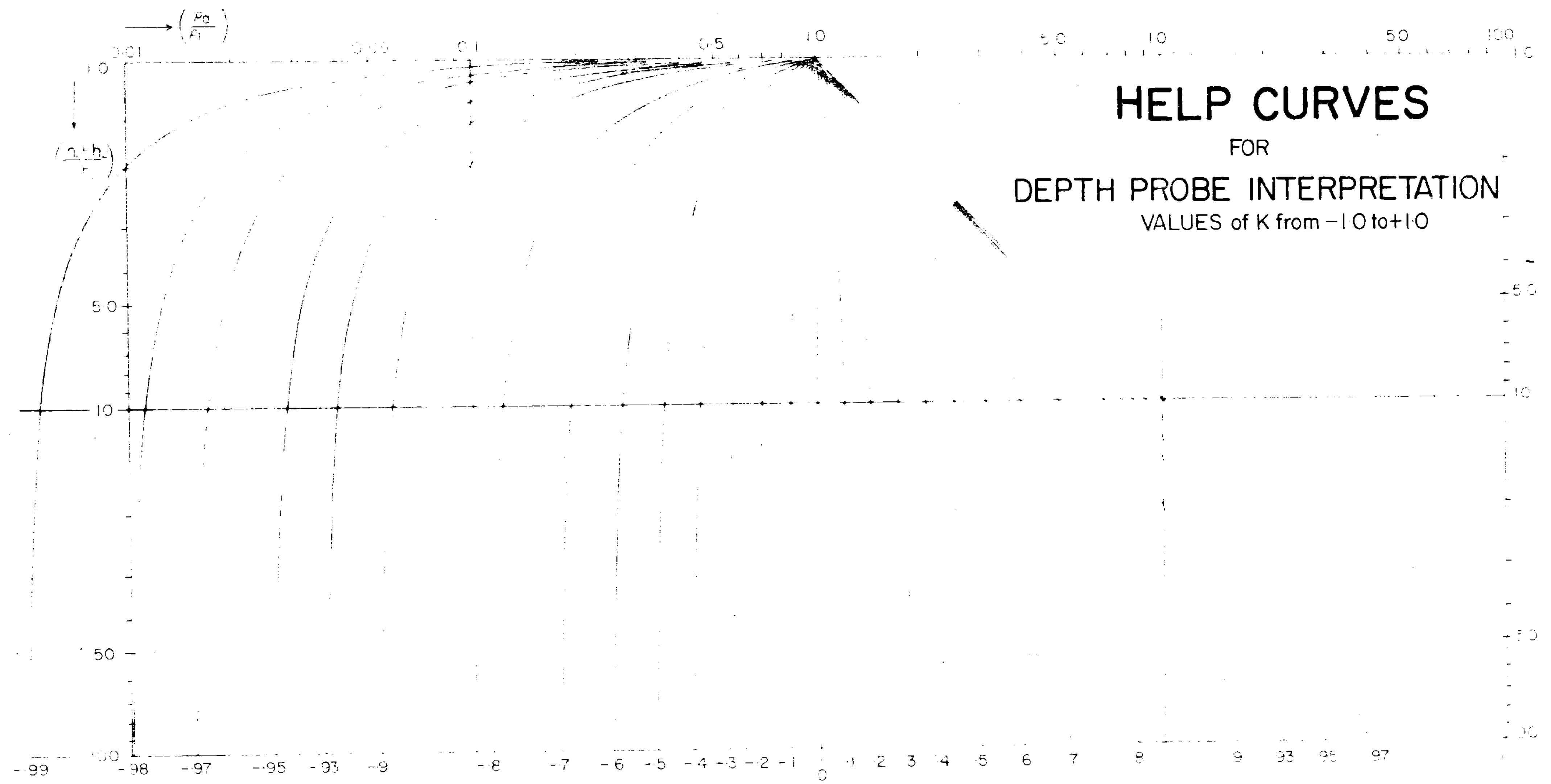



Figure 11
Help curves for resistivity depth probe interpretation based on the Hummel relation $\frac{h_1+h_2}{\rho_a} = \frac{h_1}{\rho_1} + \frac{h_2}{\rho_2}$ for varying $k = \left(\frac{\rho_2-\rho_1}{\rho_2+\rho_1}\right)$

FIG 12-14

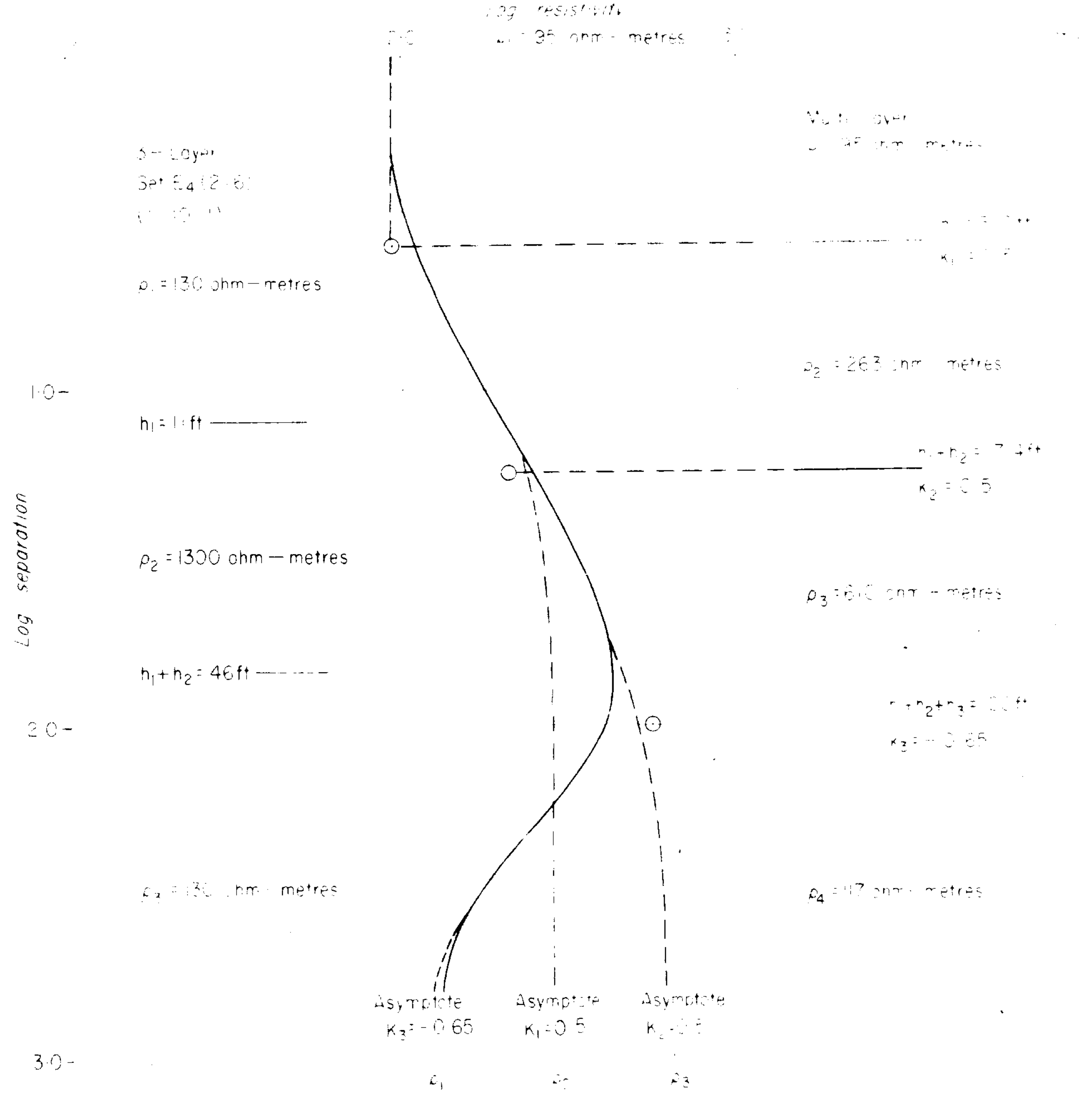
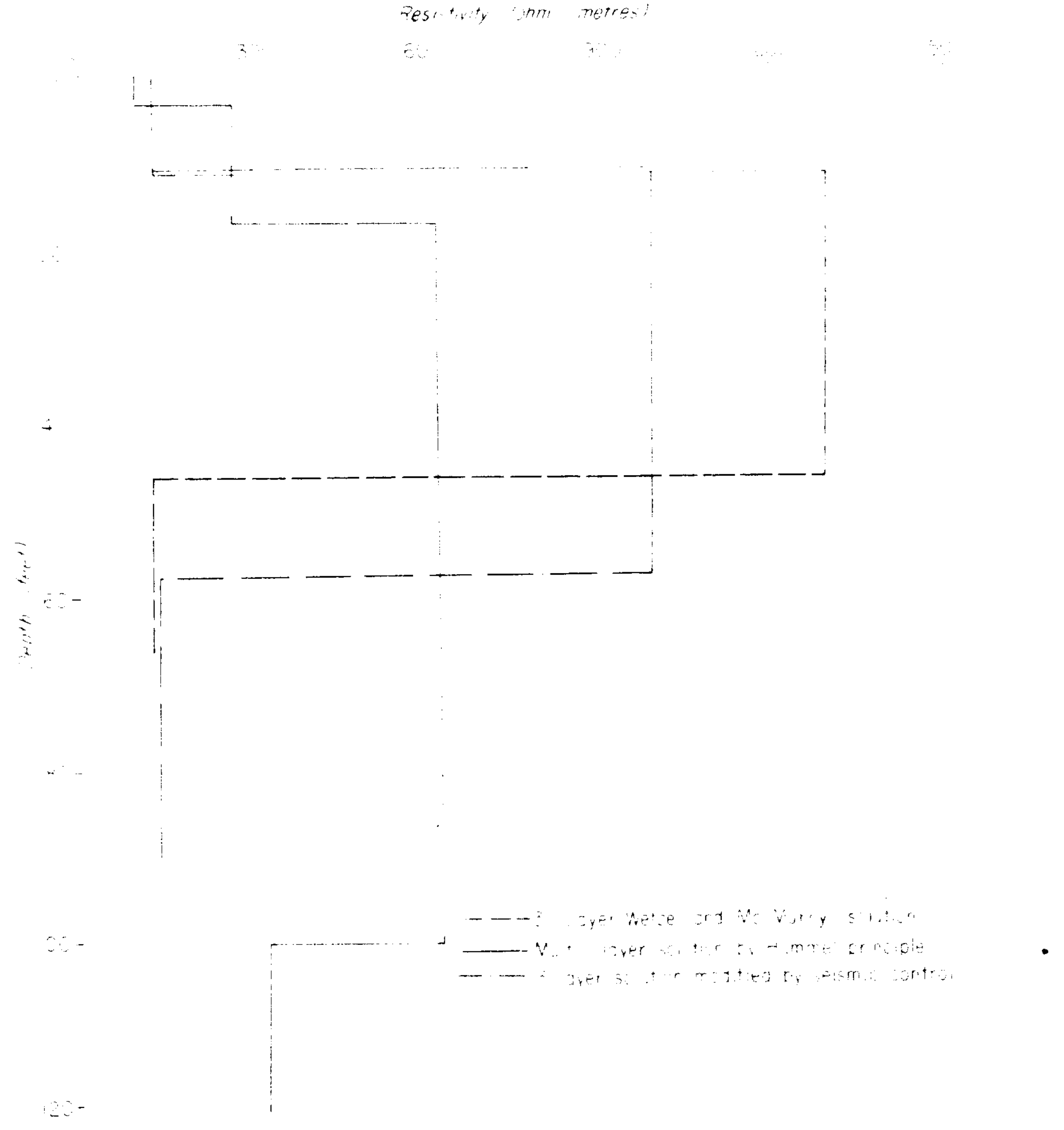


Figure 12

RE 235 Reinterpretation of multi-layer Hummel interpretation by 3 layer method (Wetzel and Mc Murry (1936)



Interpretations of curve

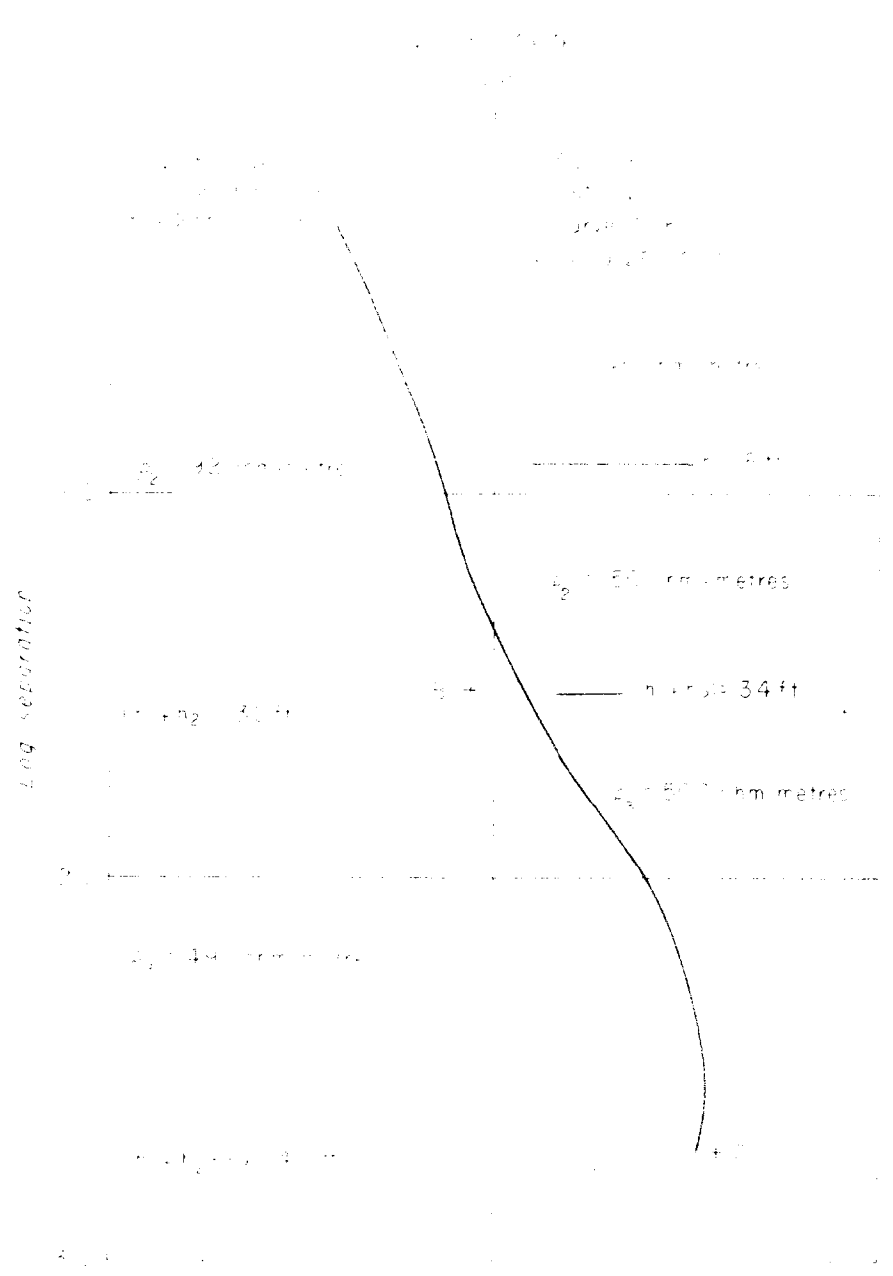
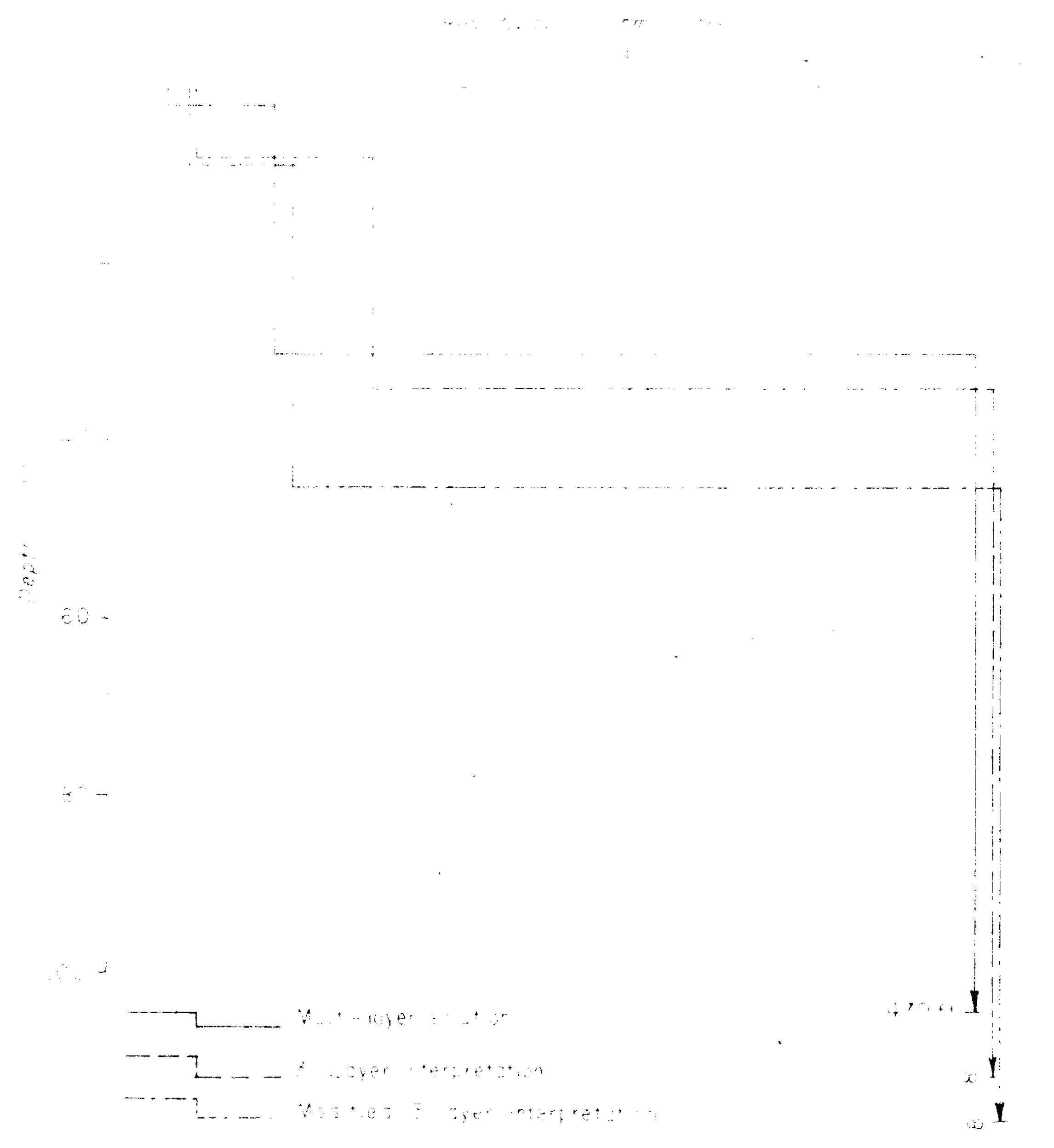


Figure 13 RE ...

Multi-layer and 3 layer interpretations



Interpretations of curve

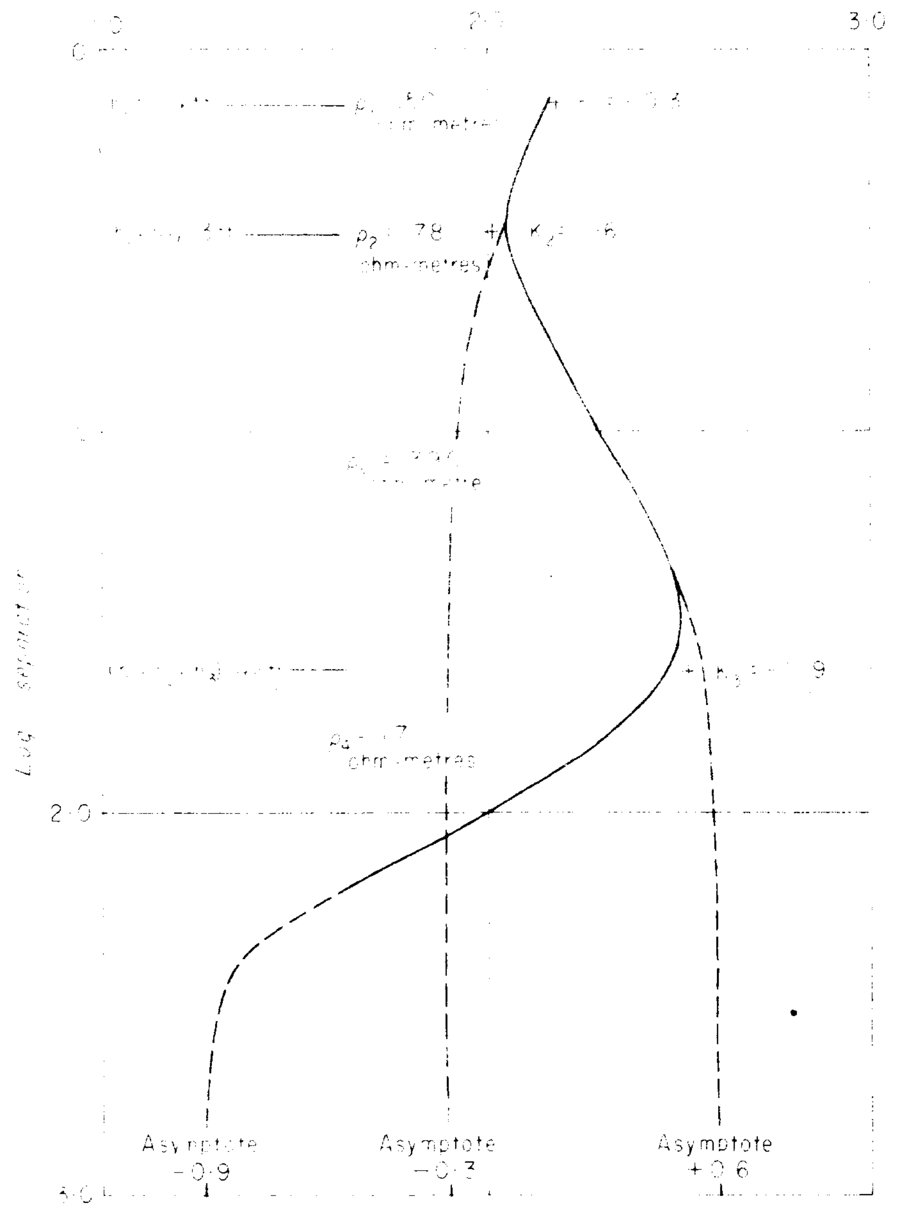
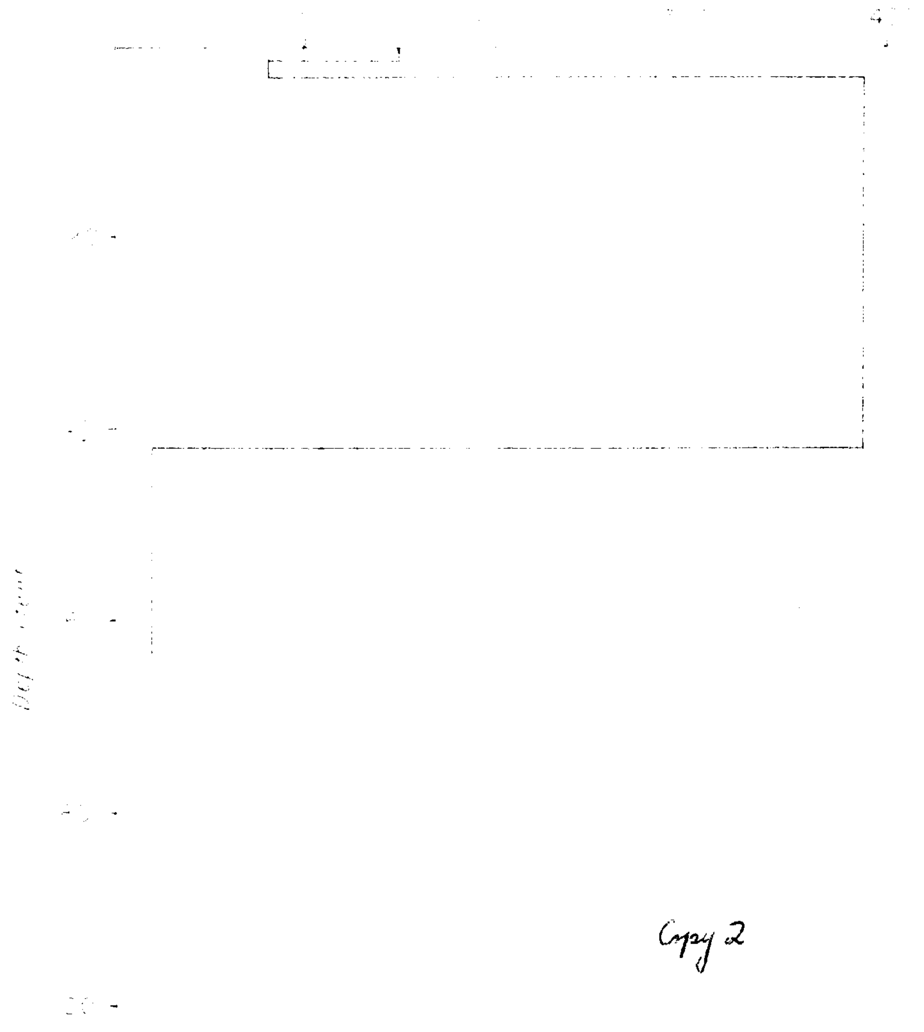


Figure 14 RE 407

Interpretation of Schlumberger curve



Copy 2

Interpretation of curve

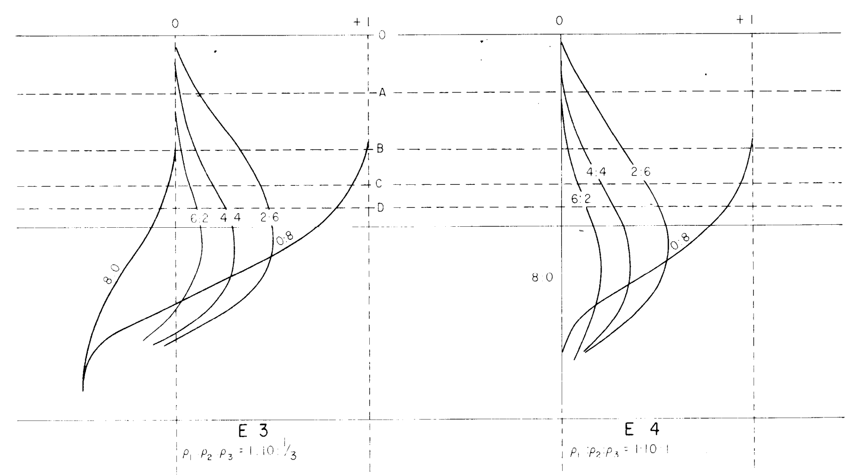



Figure 15  3 layer curves, Wetzel and Mc Murry (1936)

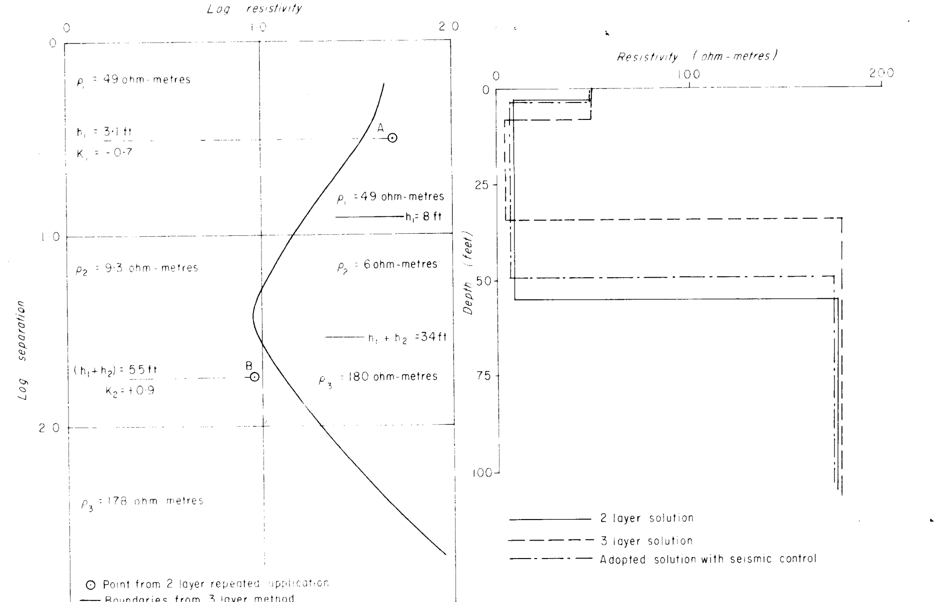


Figure 16, RE 281
Multi-layer and 3 layer interpretation

Interpretations of curve

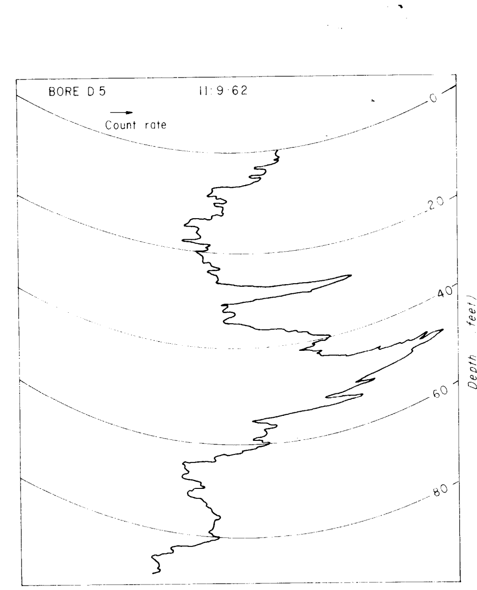


Figure 17  Typical gamma ray log.

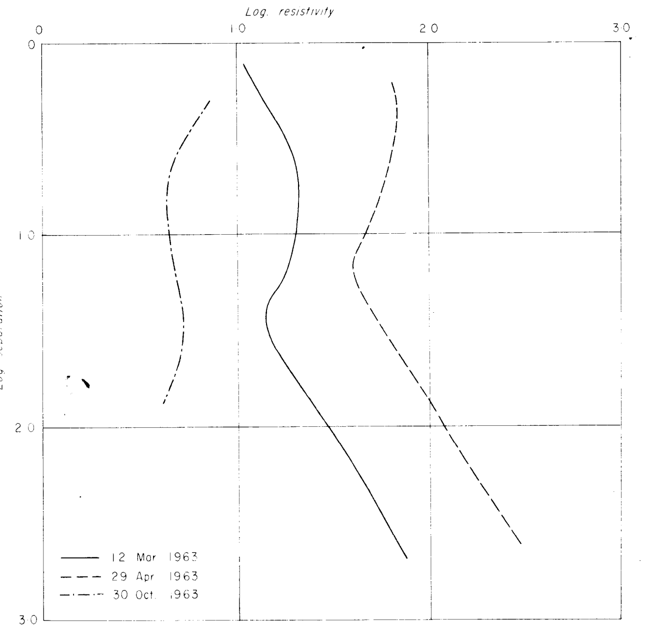


Figure 18  RE 73

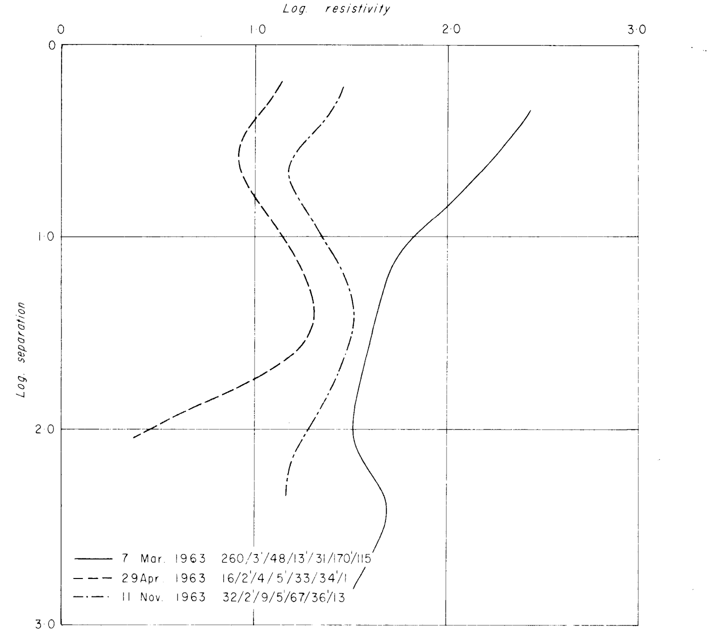


Figure 19  RE 74

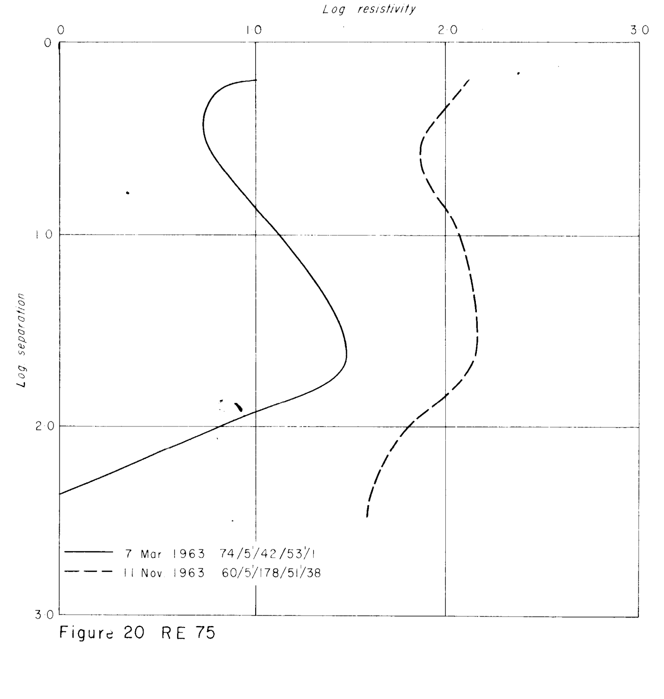


Figure 20  RE 75

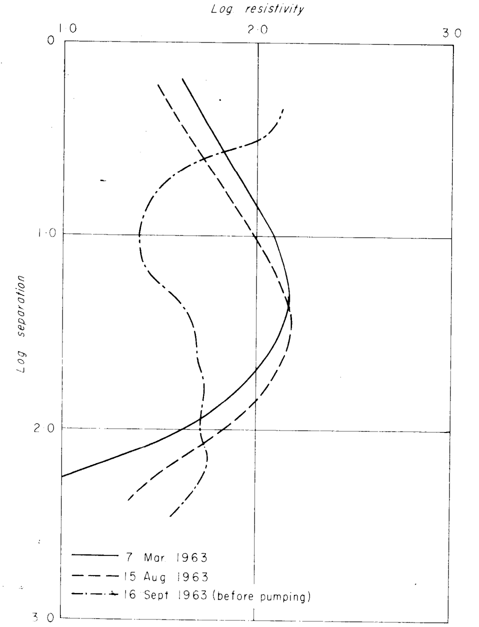


Figure 21  RE 76

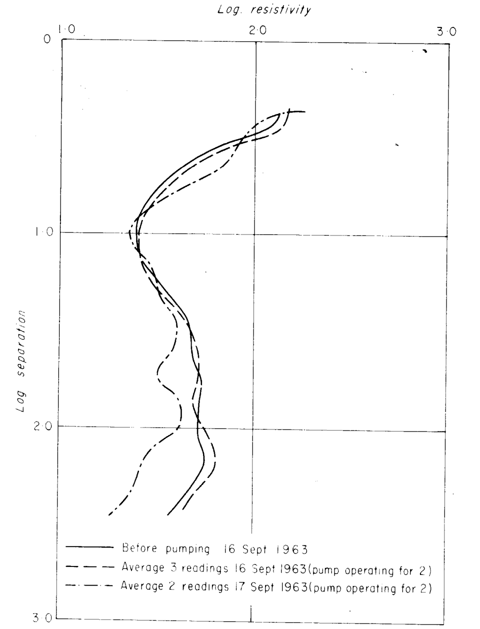


Figure 22  RE 76

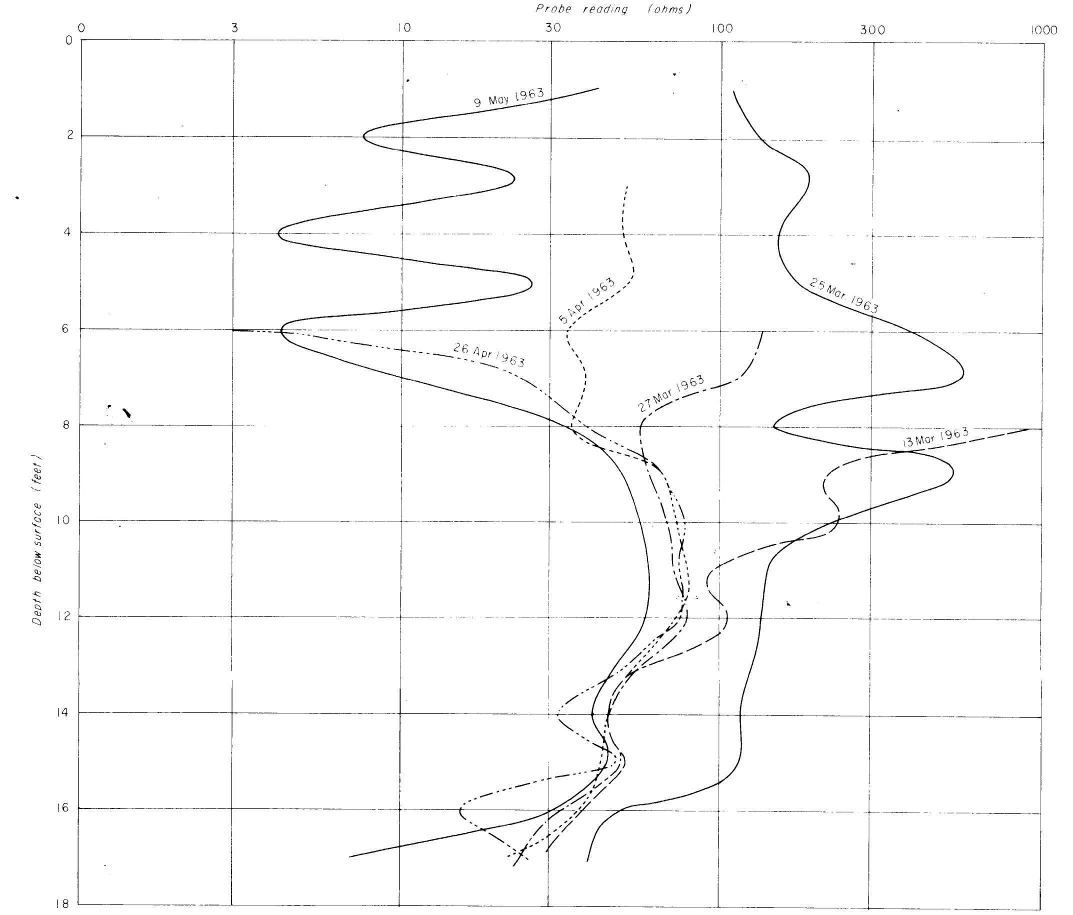


Figure 23  Fixed probe BMR 4 drill hole, opposite Ana-Branch School

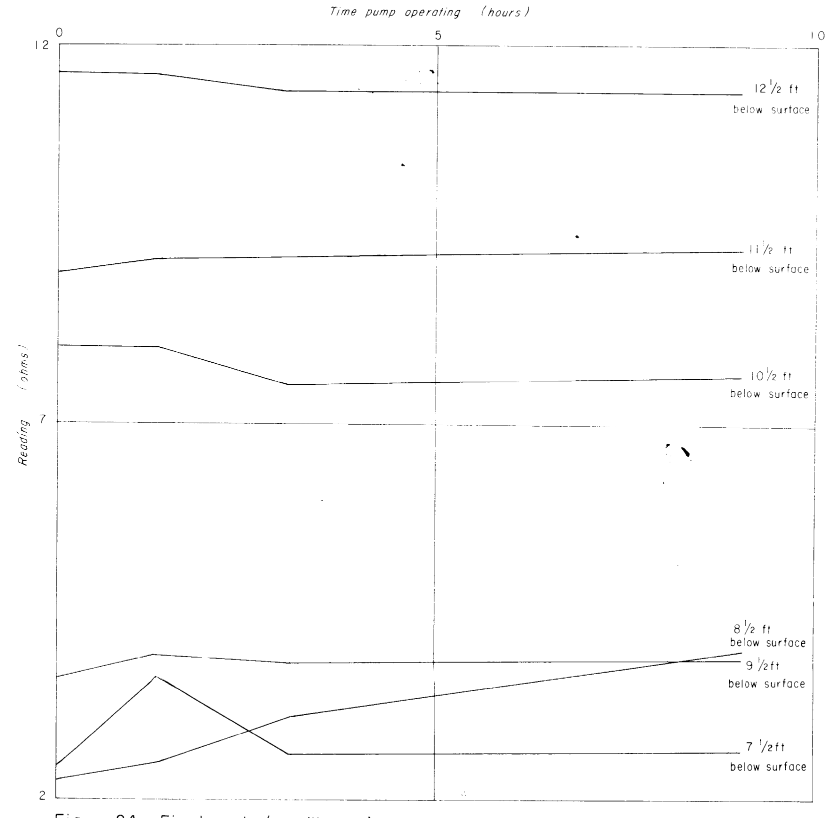


Figure 24  Fixed probe (uncalibrated) adjacent to pump tested near RE 76

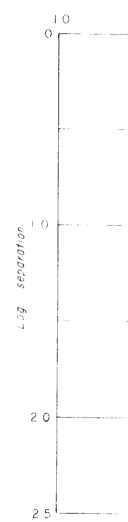


Figure 2

Figure 26  Ide

FIGS 15-26



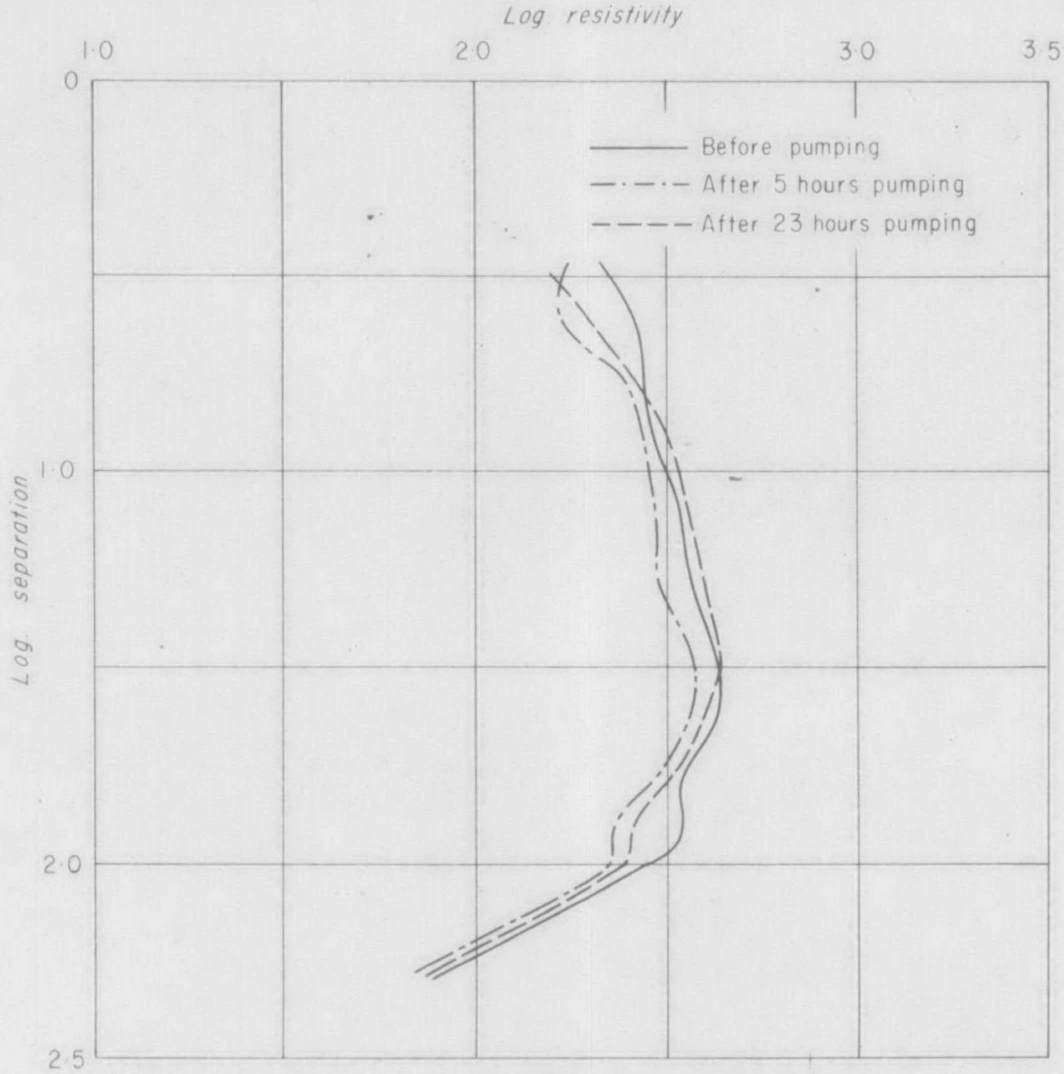



Figure 25 Pegoraro lot 41 Rita Island
19th and 20th Sept. 1963

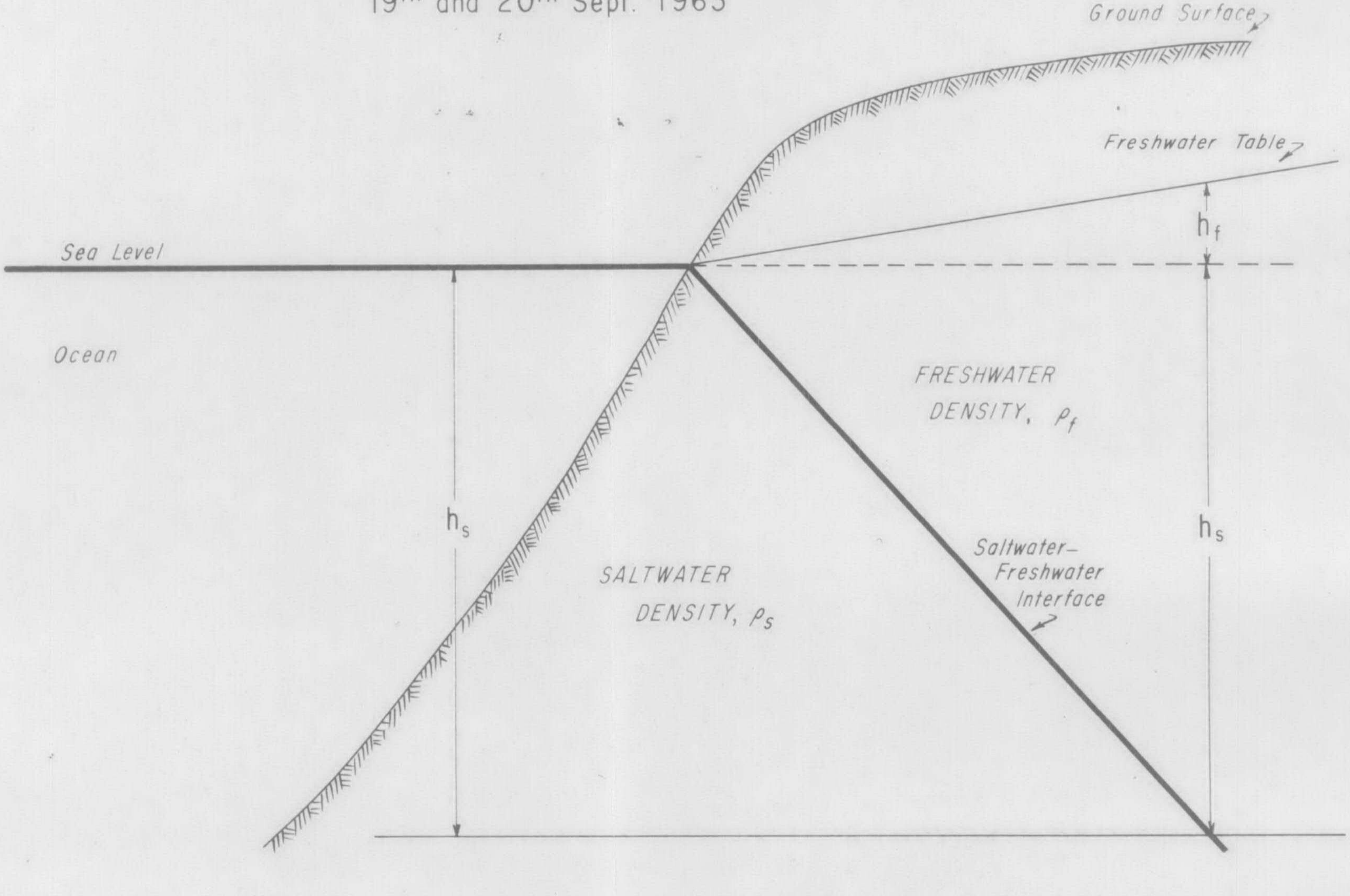
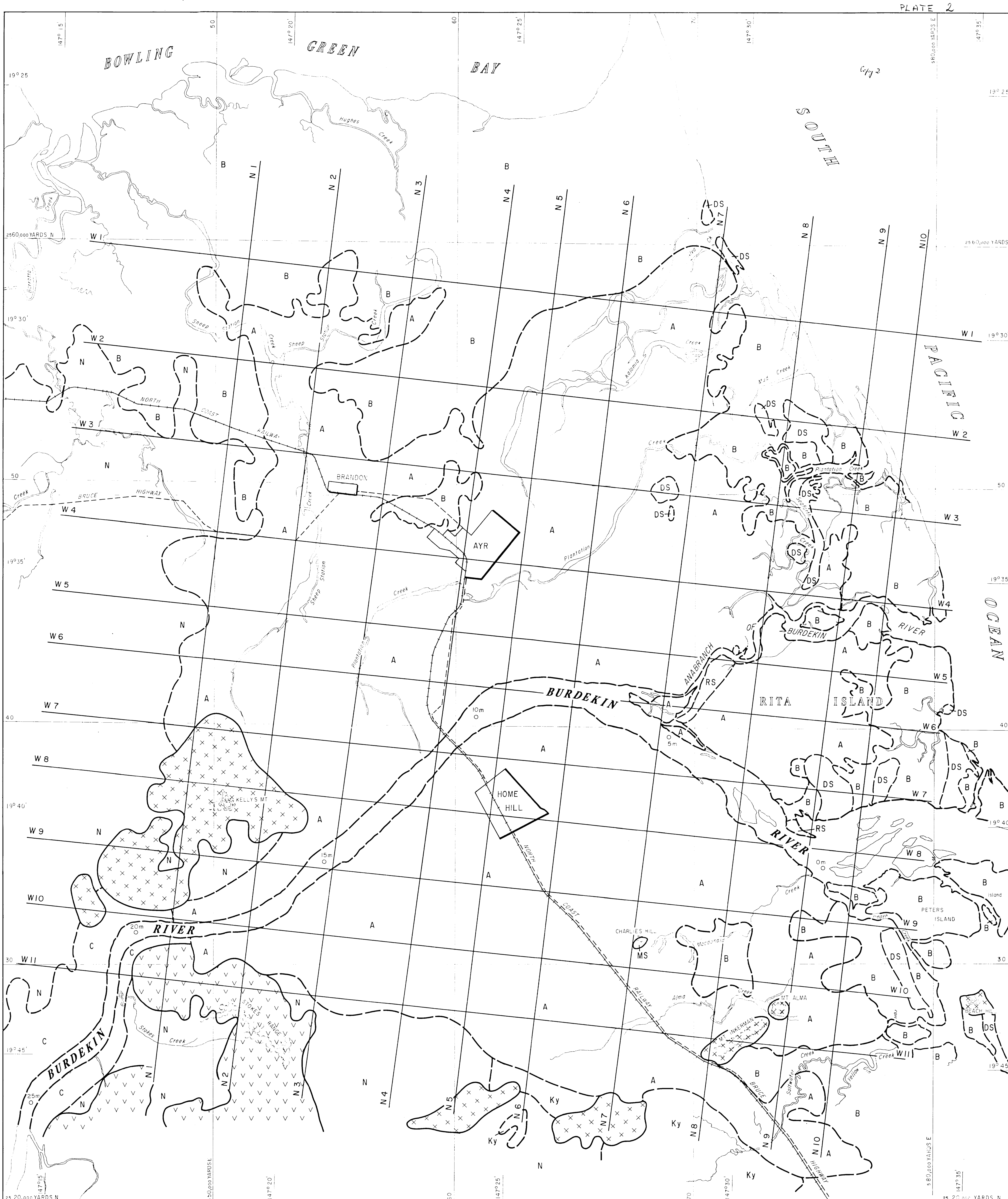



Figure 26 Idealised sketch of Ghyben-Herzberg relation


PLATE 1
BOWLING GREEN BAY
SOUTH PACIFIC OCEAN
BOWLING GREEN
ANTILL
JARVISFIELD
HOWEY
PLANTATION CREEK
MOULD
JORDAN
MORRILL
ISLAND
BURDEKIN RIVER
JOE AHERN
JOHN AHERN
CANNAVAN
FOWLER
NORTH COTE
INKERMAN
UPSTART
LEICHHARDT DOWNS
KILBOGIE
IRRIGATION AND WATER SUPPLY COMMISSION
BURDEKIN RIVER DELTA
• Location of Selected Bores for Tracer Tests
CHAINS 80 40 0
MILES
L 17438
G435-26-1




LEGEND

SUPERFICIAL DEPOSITS

- DS — DUNE SAND
- RS — RIVER SAND
- A — DELTA GROUP, AYR
- B — SALINE LANDS, BOWLING GREEN LITTORAL
- C — CLARE SYSTEM
- Ky — KYBURRA SYSTEM
- N — FLOOD PLAIN GROUP, NORTHCOTE
- W 5 — SECTION
- RAILWAY
- HIGHWAY

SOLID GEOLOGY

- GRANITE, GRANODIORITE, DIORITE
- LIMESTONES, SANDSTONES, AGGLOMERATES, TUFFS
- ANDESITE, SEDIMENTS AND GRANITIC INTRUSIONS
- MS — METASEDIMENTS

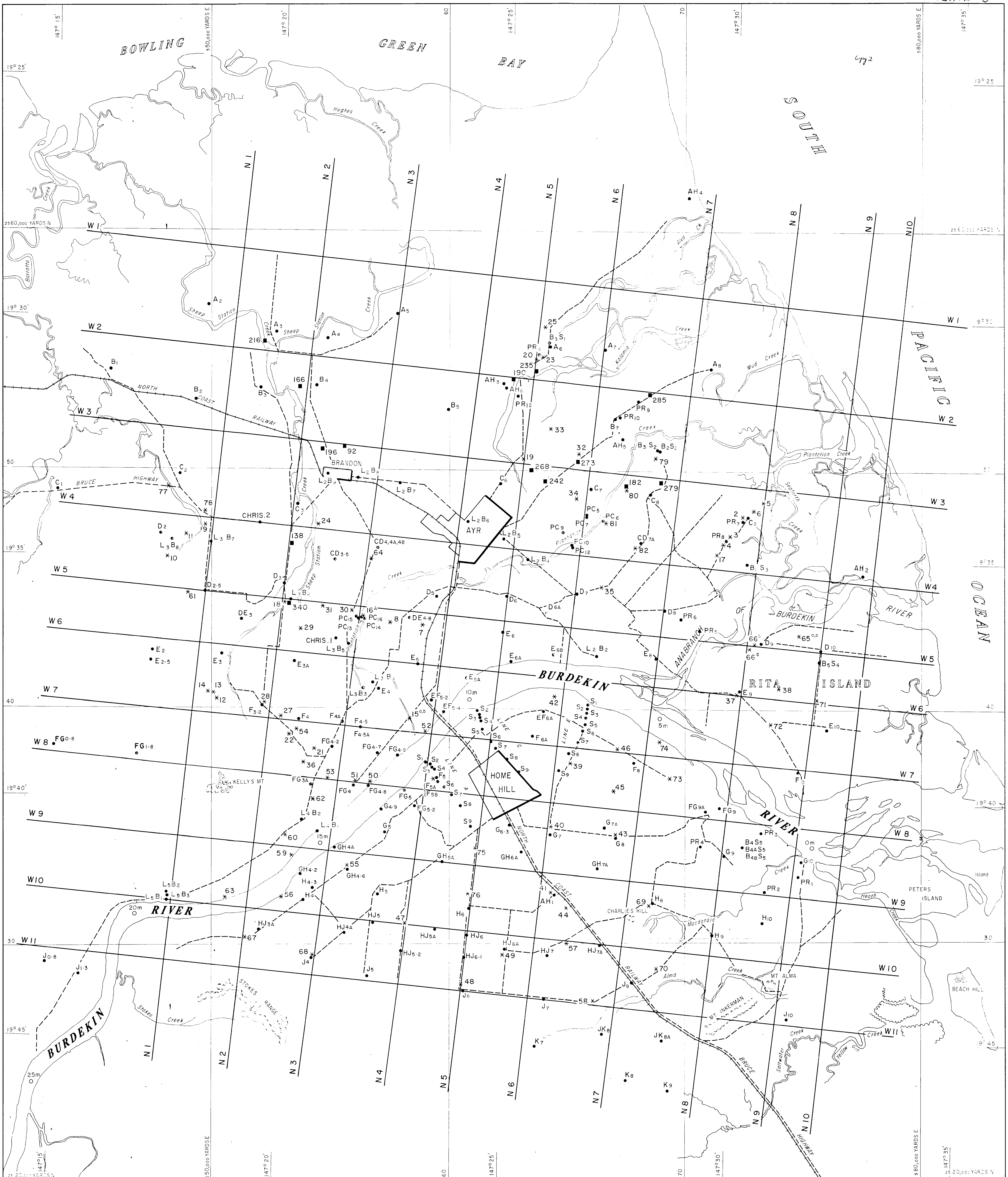
SOLID GEOLOGY: I.W.S.C., PLANS GW-L-690, AND C.S.I.R.O. Q30-3
SUPERFICIAL DEPOSITS: C.S.I.R.O. MAP NM 51/003, AND DEPARTMENT OF DEVELOPMENT AND MINES MAP E 9-4

MILES 1 0 1 2 3

(BASED ON E 55/B5-39)

GEOLOGICAL MAP

GEOPHYSICAL BRANCH, BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS. E55/B5-72




LEGEND

- W3 —— SECTION
- RAILWAY
- ROAD
- ×41 B M R BORE No. 41
- G5 • IWSC WELL OR BORE No. G5
- ■199 PRIVATE WELL OR BORE No. 199
- LINE A S1, S2 IWSC GRID-SITE 1, SITE 2

IWSC BORE DATA TO DECEMBER 1964

MILES 1 0 1 2 3

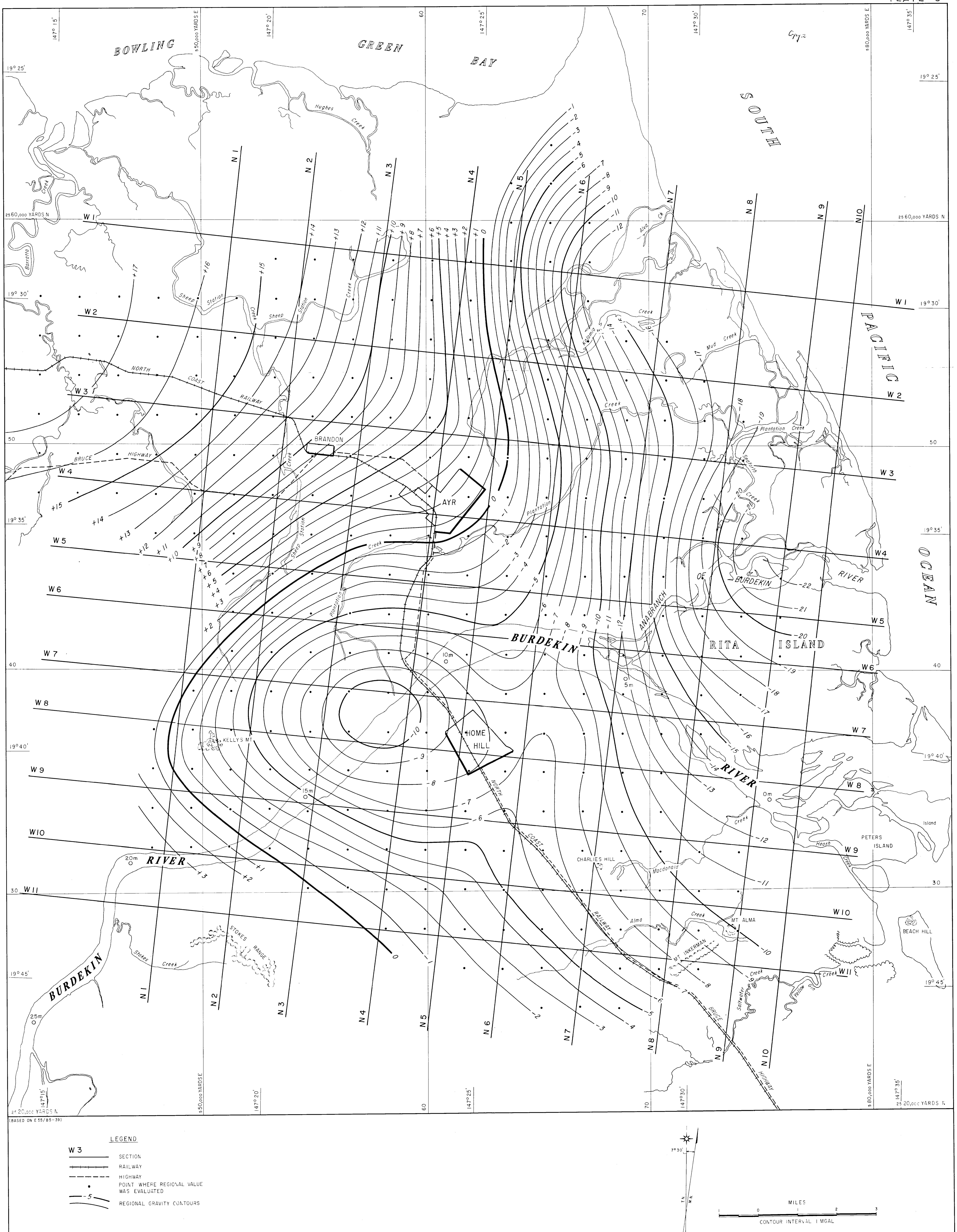
BORE HOLE MAP


BOUGUER ANOMALIES

GEOPHYSICAL BRANCH, BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

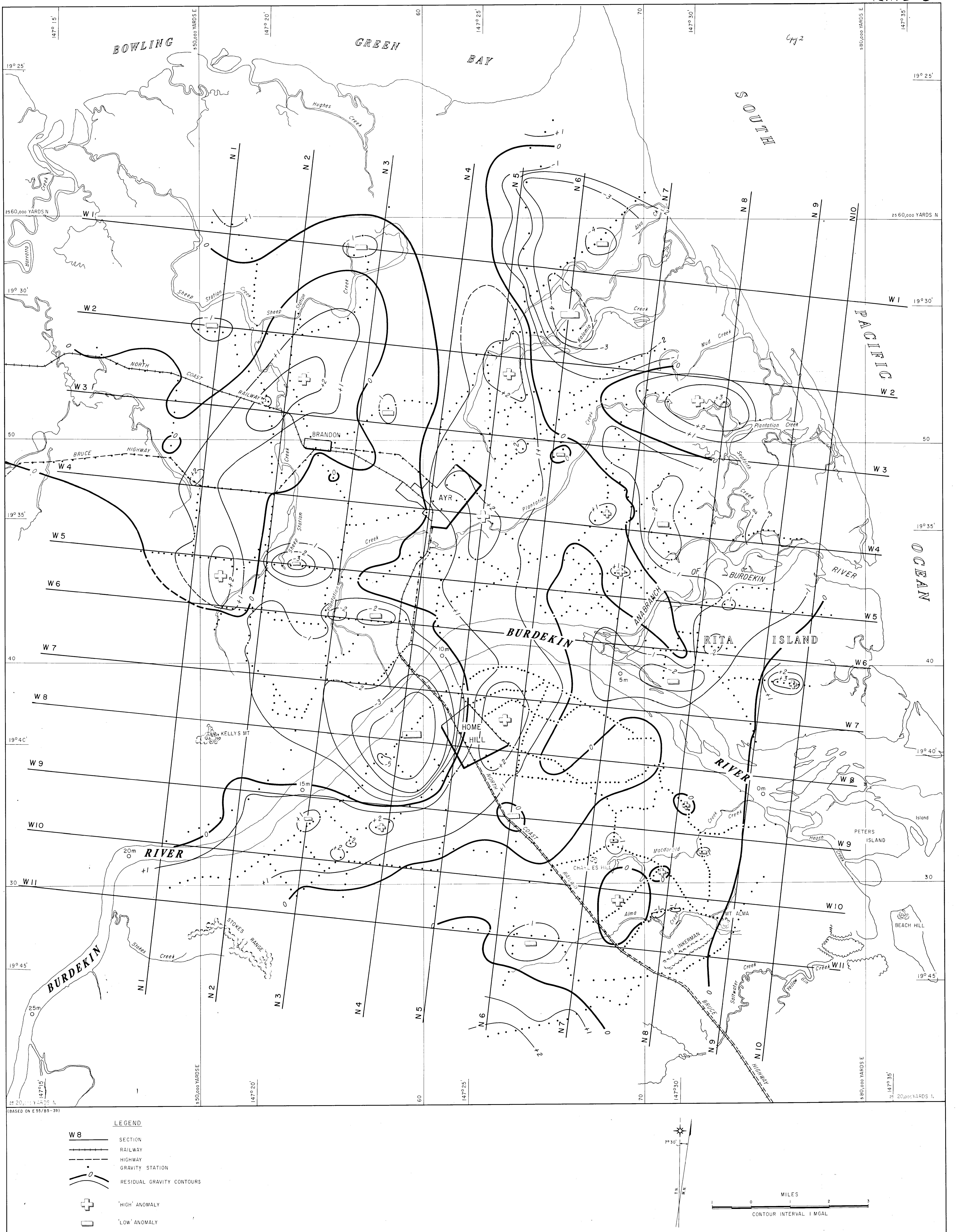
E 55/B5-66

PLATE 5




REGIONAL GRAVITY CONTOURS

GEOPHYSICAL BRANCH, BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS E 55/B5-65

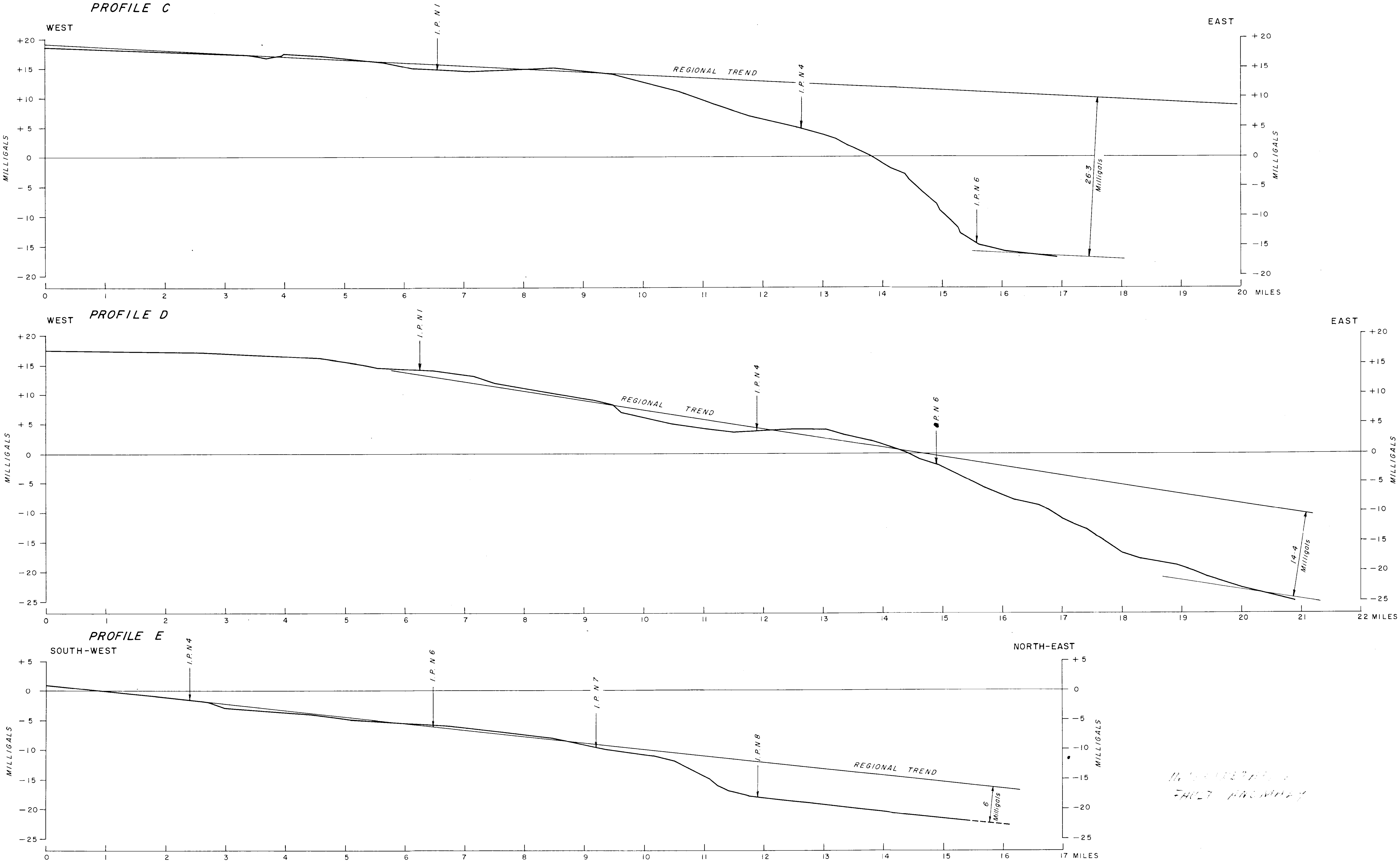



RESIDUAL GRAVITY CONTOURS

GEOPHYSICAL BRANCH, BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

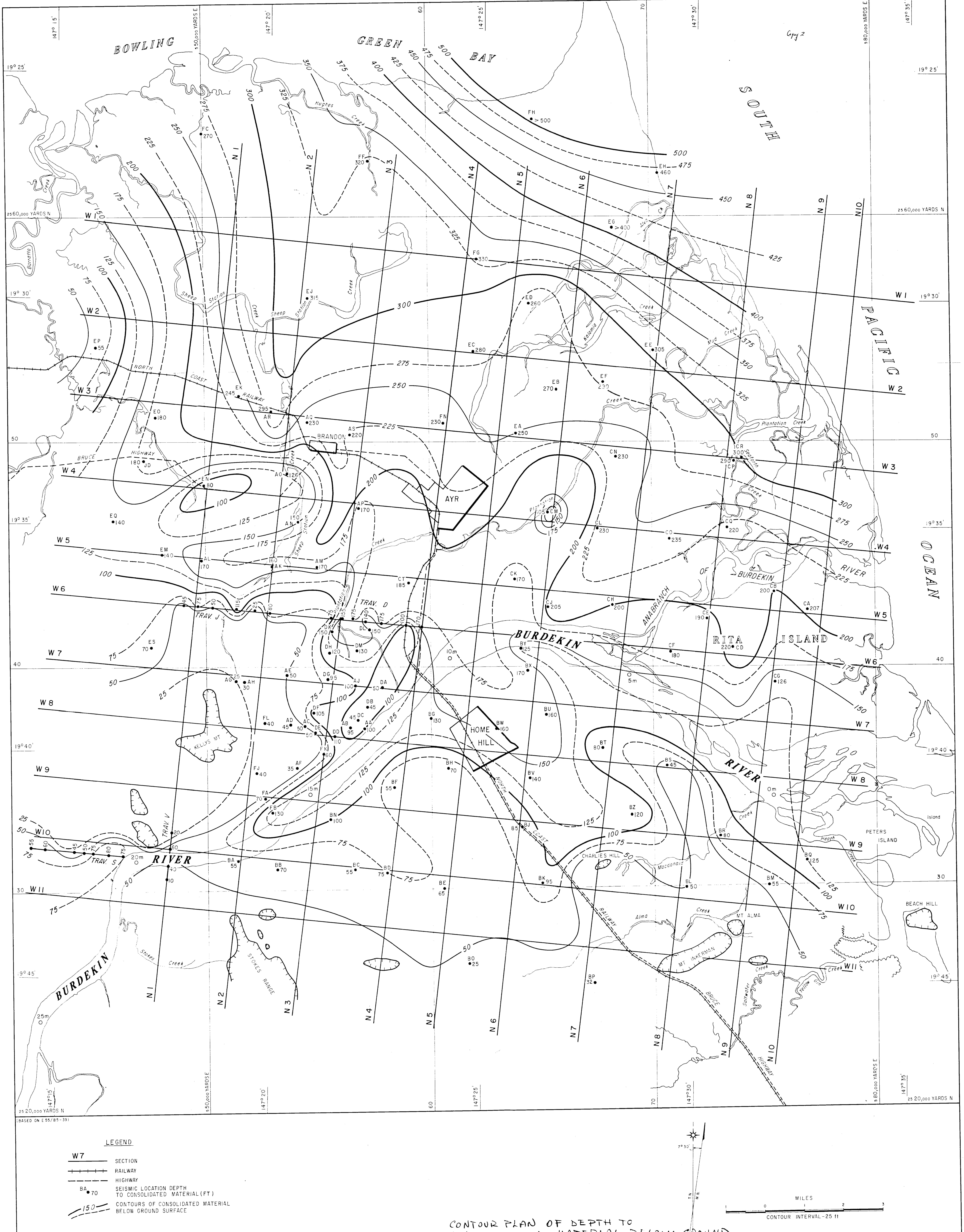
E 55/B5-42


PLATE 7
PROFILE A
NORTH-WEST
SOUTH-EAST
300°
120°
BOUGUER-ANOMALIES PROFILE
REGIONAL TREND
I.P. PROFILE B
MILLIGALS
22 MILES
RESIDUAL GRAVITY PROFILE AND
PROFILE COMPUTED FROM MODEL
SECTION ACROSS MODEL
ALONG PROFILE A
M.S.L. 0
0 M.S.L.
FEET
9 MILES
PROFILE B
SOUTH-WEST
NORTH-EAST
210°
30°
I.P. PROFILE A
13 MILES
SECTION ACROSS MODEL
ALONG PROFILE B
6 MILES
CONTOUR PLAN OF MODEL
N 2
N 3
N 4
N 5
W 6
W 7
W 8
W 9
A
B
RIVER
BURDEKIN
MILES
Density contrast −0·2 milligals
LEGEND
Computed gravity effect by model
Residual gravity profile
Approximate equivalent smooth outline
Depth below sea level
(Value in thousands of feet)
W6
Section
A
Section line for interpretation
Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics
E 55/B 5-87


PROFILE C
WEST
EAST
I.P.N1
I.P.N4
I.P.N6
REGIONAL TREND
26.3 Milligals
MILLIGALS
20 MILES
PROFILE D
WEST
EAST
I.P.N1
I.P.N4
I.P.N6
REGIONAL TREND
14.4 Milligals
MILLIGALS
22 MILES
PROFILE E
SOUTH-WEST
NORTH-EAST
I.P.N4
I.P.N6
I.P.N7
I.P.N8
REGIONAL TREND
6 Milligals
MILLIGALS
17 MILES


BOWLING GREEN BAY
SOUTH PACIFIC OCEAN
BURDEKIN RIVER
RITA ISLAND
ANABRANCH OF BURDEKIN RIVER
AYR
BRANDON
HOME HILL
SHALLOW BEDROCK
PETERS ISLAND
BEACH HILL
MT. ALMA
BRUCE HIGHWAY
NORTH COAST RAILWAY
W1
W2
W3
W4
W5
W6
W7
W8
W9
W10
W11
N1
N2
N3
N4
N5
N6
N7
N8
N9
N10
1964-1
1964-2
1964-3
1964-4
(BASED ON E 55/B5-67)
LEGEND
SECTION
RAILWAY
ROAD
RESISTIVITY DEPTH PROBE LOCATION
DEPTH PROBES 1-59 1962
DEPTH PROBES 60-560 1963
DEPTH PROBES 600-635 1964
SECTION BASED ON 1964 DATA
RESISTIVITY DEPTH PROBE RE 320 INDICATING DRY SUBSURFACE SANDS DURING TIME OF SURVEY
SANDY ZONES BELOW 10 TO 15 ft SUITABLE FOR RECHARGE
CLAYEY ZONES BELOW 10 TO 15 ft
UNCERTAIN INTERPRETATION
AXIS OF SHALLOW BEDROCK
7°30'
TN
MN
MILES
1 0 1 2 3
PERMEABLE SUBSURFACE FORMATIONS
GEOPHYSICAL BRANCH, BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS
E 55/B5-90


BOWLING
GREEN
BAY
SOUTH
PACIFIC
OCEAN
BURDEKIN
RIVER
ANABRANCH OF BURDEKIN RIVER
RITA ISLAND
AYR
BRANDON
HOME HILL
KELLYS MT.
STOKES RANGE
MT. INKERMAN
BEACH HILL
PETERS ISLAND
W1
W2
W3
W4
W5
W6
W7
W8
W9
W10
W11
N1
N2
N3
N4
N5
N6
N7
N8
N9
N10
LEGEND
W3 SECTION
RAILWAY
ROAD
BJ • 19 SEISMIC DEPTH PROBE BEDROCK VELOCITY 19,000 ft/sec
19 19,000 ft/sec. BEDROCK VELOCITY ZONE BOUNDARY
OUTCROP
SEISMIC VELOCITY IN BEDROCK FROM 15,000 TO 17,000 ft/sec
SEISMIC VELOCITY IN BEDROCK FROM 13,000 TO 15,000 ft/sec
GRAVITY MINIMUM INDICATING VOLCANIC PIPE
F F FAULT INDICATED BY GRAVITY
BEDROCK VELOCITY 'HIGH'
BEDROCK VELOCITY 'LOW'
MILES
2
3
MAP
RESOURCES, GEOLOGY AND GEOPHYSICS
E 55/B5-69




CONTOUR PLAN OF DEPTH TO CONSOLIDATED MATERIAL BELOW GROUND SURFACE BASED ON SEISMIC VELOCITIES


(BASED ON E 55/B5-39)

## LEGEND

- W3 — SECTION
- RAILWAY
- HIGHWAY
- −250 — BEDROCK CONTOUR BELOW SEA LEVEL
- APPARENT SUBSURFACE DRAINAGE TREND
- −325 — PROBABLE SEA LEVEL DURING "WURM" GLACIAL PERIOD
- F — F — FAULT BASED ON GRAVITY WORK
- CN. • −210 — SEISMIC DEPTH PROBE-BEDROCK 210 FT BELOW SEA LEVEL
- OUTCROP
- GRAVITY MINIMUM NEAR HOME HILL

NOTE: ROCK IN WHICH SEISMIC VELOCITY ≥ 6700 ft/sec IS DEFINED AS BEDROCK. THIS INCLUDES FRESH BEDROCK, WEATHERED BEDROCK, AND CONSOLIDATED SEDIMENTS

? INTERPRETATION UNCERTAIN

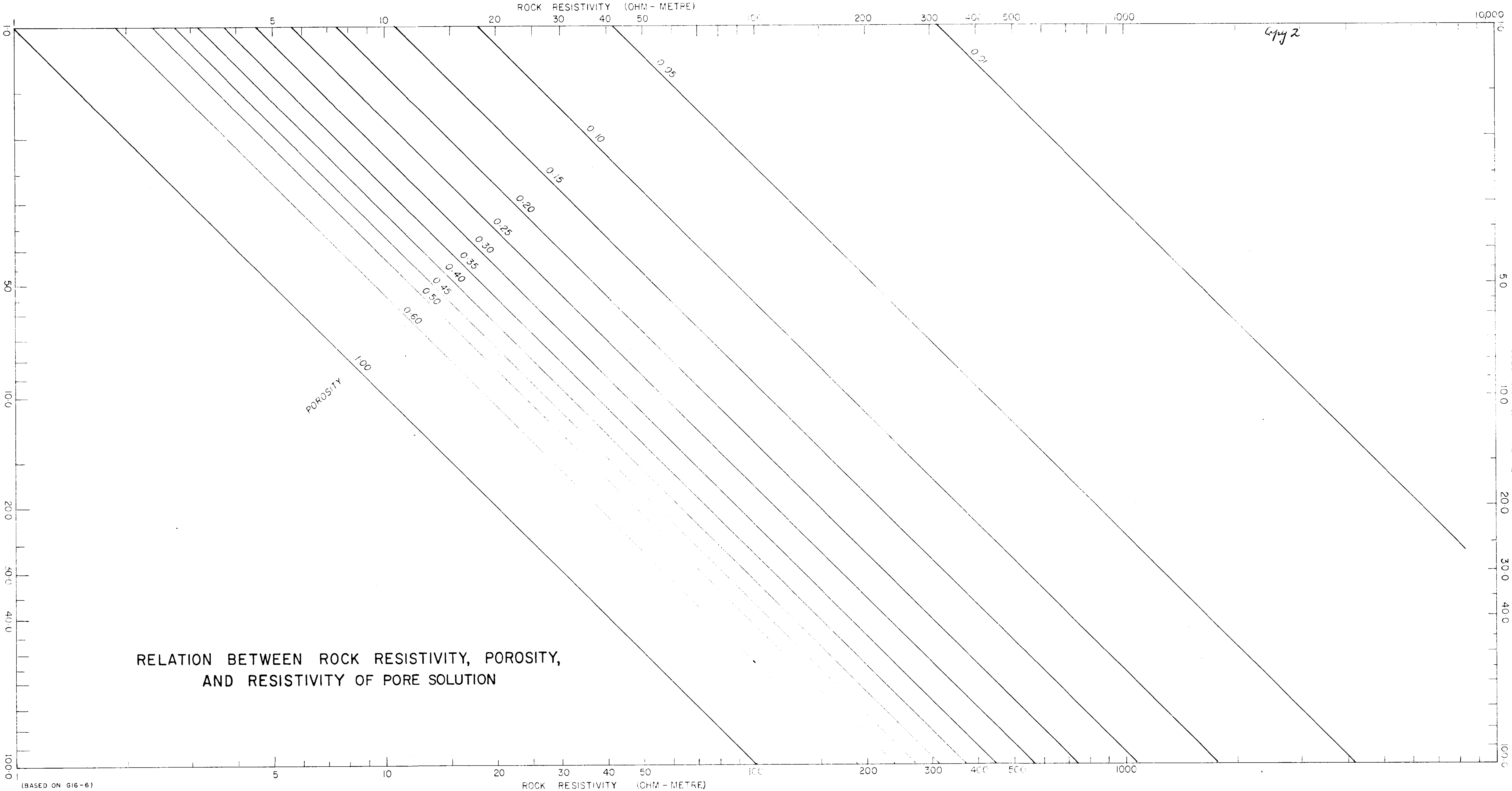
| VELOCITY RANGE (ft/s) | MATERIAL |
|---|---|
| 1000 – 2000 | Sand, clay, sandy clay and soils above water table |
| 2000 – 5700 | Sand, clay, sandy clay and gravels below water table |
| 5700 – 6700 | Semi-consolidated sediments or very weathered bedrock |
| 6700 – 8500 | Consolidated sediments or weathered bedrock |
| 8500 – 14,000 | Slightly weathered bedrock or limestore |
| 14,000 – 20,000 | Fresh bedrock |

MILES

CONTOUR INTERVAL – 25 ft

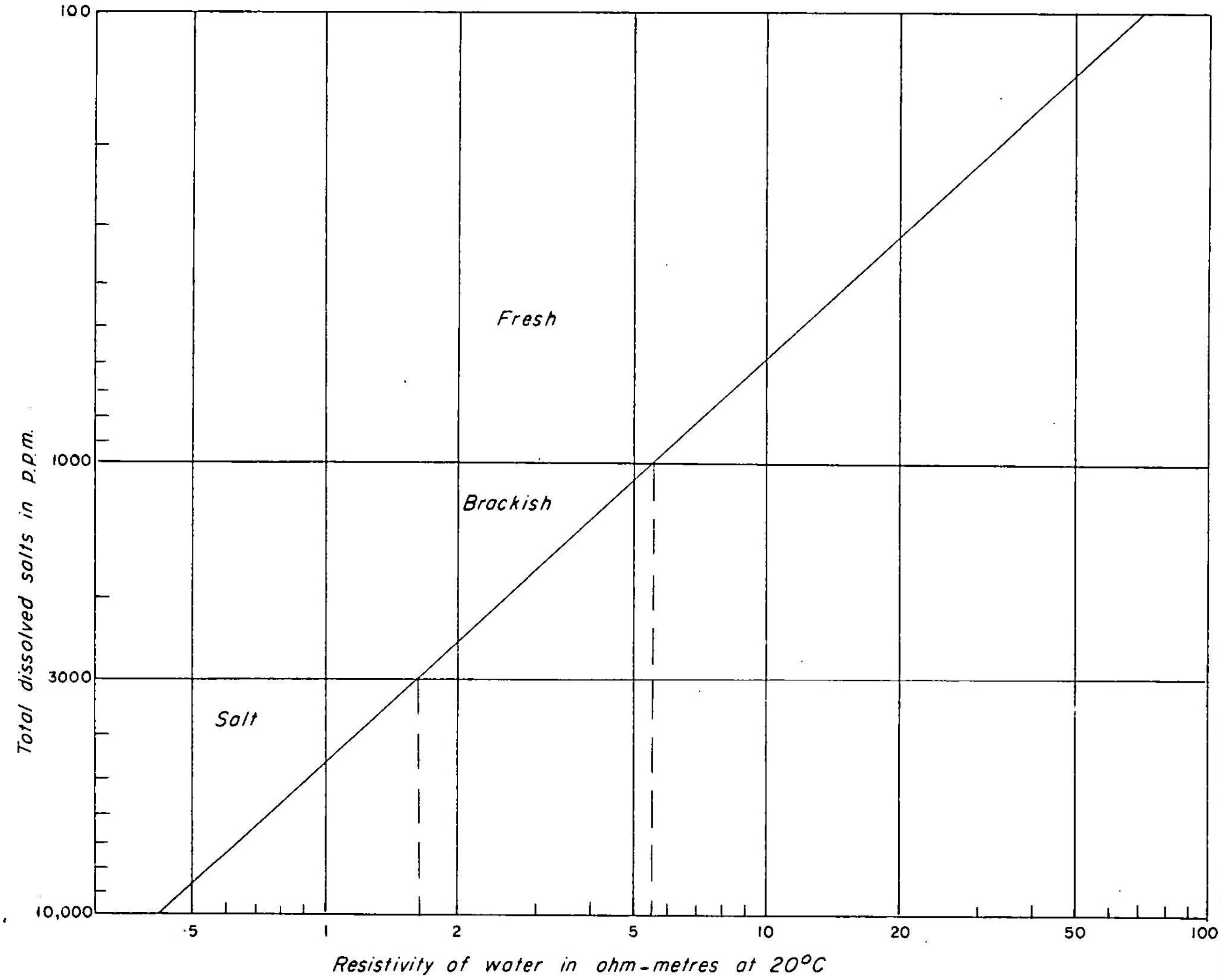
BEDROCK CONTOUR PLAN

GEOPHYSICAL BRANCH, BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS E 55/B5-71

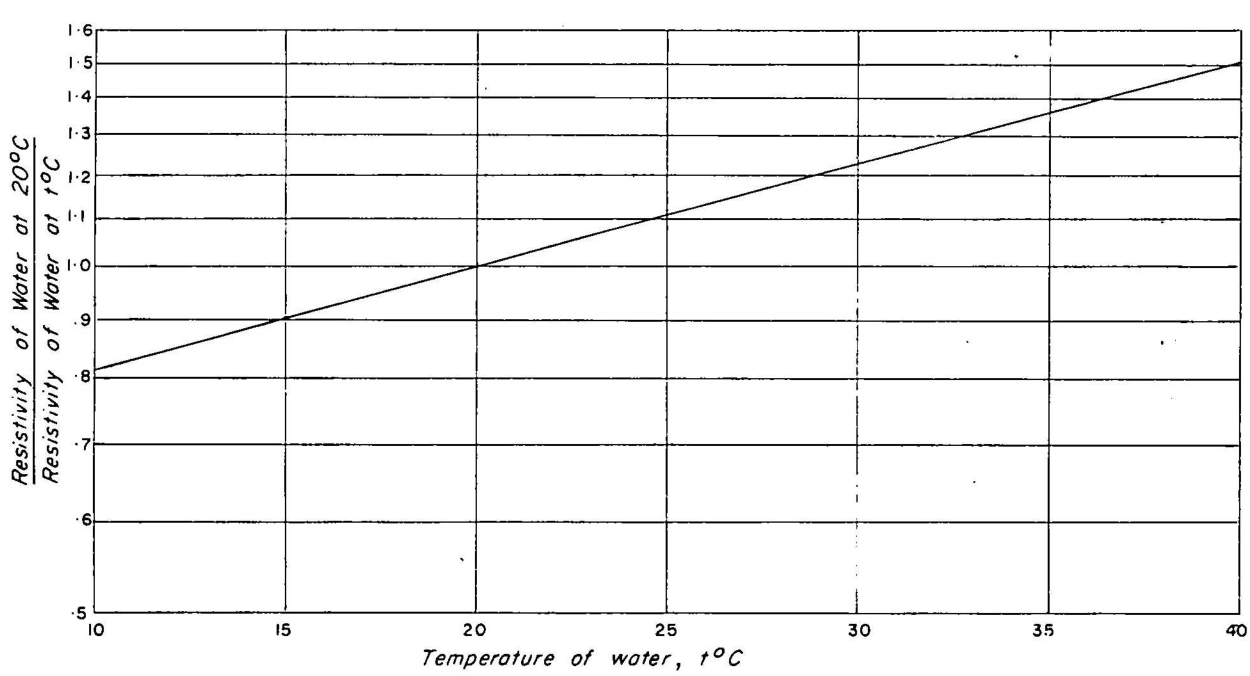



RELATION BETWEEN ROCK RESISTIVITY, POROSITY, AND RESISTIVITY OF PORE SOLUTION

PLATE 14




1. WATER RESISTIVITY TO SALINITY CONVERSION DIAGRAM




2. TEMPERATURE CORRECTION DIAGRAM FOR RESISTIVITY

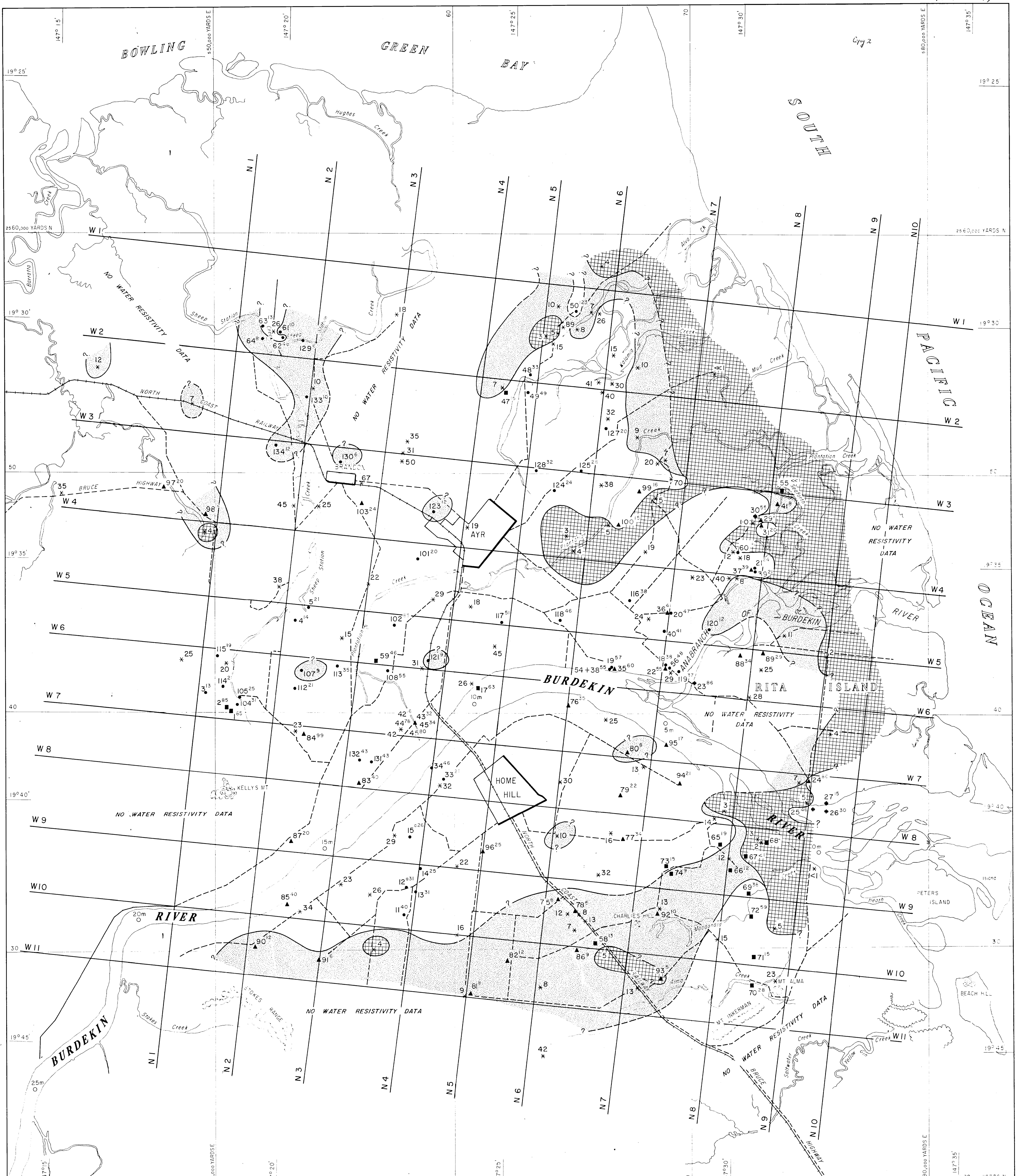
GEOPHYSICAL BRANCH, BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS E55/B5-84

To accompany Record No. 1964/111

G/RU QLD 1963 UNDERGROUND WATER


BOWLING GREEN BAY
SOUTH PACIFIC OCEAN
BURDEKIN RIVER
ANABRANCH OF BURDEKIN RIVER
RITA ISLAND
PETERS ISLAND
AYR
BRANDON
HOME HILL
KELLYS MT
STOKES RANGE
CHARLIES HILL
MT ALMA
MT INKERMAN
BEACH HILL
NORTH COAST RAILWAY
BRUCE HIGHWAY
19° 25'
19° 30'
19° 35'
19° 40'
19° 45'
147° 15'
147° 20'
147° 25'
147° 30'
147° 35'
550,000 YARDS E
580,000 YARDS E
2560,000 YARDS N
2520,000 YARDS N
N1
N2
N3
N4
N5
N6
N7
N8
N9
N10
W1
W2
W3
W4
W5
W6
W7
W8
W9
W10
W11
1964-1
1964-2
1964-3
1964-4
(BASED ON E 55/B5-39)
LEGEND
W8 SECTION
RAILWAY
ROAD
.320 RESISTIVITY DEPTH PROBE LOCATION
DEPTH PROBES 1-59 1962
DEPTH PROBES 60-560 1963
DEPTH PROBES 600-635 1964
SECTION 1964
MILES
1 0 1 2 3
RESISTIVITY DEPTH PROBE LOCATION
GEOPHYSICAL BRANCH, BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS
E 55/B5-67


SALT WATER CONTOURS




## LEGEND

| | |
|---|---|
| W 3 | SECTION |
| | RAILWAY |
| | ROAD |
| 13[31] ● | LOCATION 13. SUBSURFACE SAMPLE MEASURED WITH MUD-CELL, WATER RESISTIVITY 31 OHM-METRES |
| ✱50 | IWSC SAMPLE, WATER RESISTIVITY 50 OHM-METRES |
| 81[8] ▲ | LOCATION 81. SUBSURFACE SAMPLE MEASURED WITH PROBE, WATER RESISTIVITY 8 OHM-METRES |
| ■ 58[13] | LOCATION 58. SURFACE SAMPLE MEASURED WITH MUD-CELL, WATER RESISTIVITY 13 OHM-METRES |
| 26[30] ◆ | LOCATION 26. SURFACE SAMPLE MEASURED WITH PROBE, WATER RESISTIVITY 30 OHM-METRES |

IWSC DATA TAKEN DECEMBER 1963. RESISTIVITY VALUES ADJUSTED TO NEAREST WHOLE NUMBER AT 20° C (OHM-METRES)

| | |
|---|---|
| (cross-hatched) | WATER RESISTIVITY < 6 OHM-METRES |
| (stippled) | WATER RESISTIVITY 6 TO 12 OHM-METRES |
| (blank) | NO WATER RESISTIVITY DATA AVAILABLE |
| --?-- | BOUNDARY UNCERTAIN |

NOTE: WATER RESISTIVITIES LESS THAN 6 OHM-METRES ARE REGARDED AS SALINE OR POTENTIALLY SALINE (TOTAL SALT CONTENT GREATER THAN 1000 p.p.m.)
WATER RESISTIVITIES 6 TO 12 OHM-METRES REPRESENT POORER QUALITY FRESH WATER (TOTAL SALT CONTENT 1000 - 500 p.p.m. APPROX)

MILES 1 0 1 2 3

WATER RESISTIVITY AND LOCATIONS

GEOPHYSICAL BRANCH, BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS E 55/B5-40

# INTERPRETATION OF SEISMIC VELOCITIES

| VELOCITY RANGE (ft/sec) | MATERIALS |
|---|---|
| 1000 – 2000 | SANDS, CLAYS, SANDY CLAY AND SOILS ABOVE WATER TABLE |
| 2000 – 5700 | SANDS, CLAYS, SANDY CLAY AND GRAVELS BELOW WATER TABLE |
| 5700 – 6700 | SEMICONSOLIDATED SEDIMENTS OR VERY WEATHERED BEDROCK |
| 6700 – 8500 | CONSOLIDATED SEDIMENTS OR WEATHERED BEDROCK |
| 8500 – 14,000 | SLIGHTLY WEATHERED BEDROCK OR LIMESTONE |
| 14,000 – 20,000 | FRESH BEDROCK |

## LEGEND

| | |
|---|---|
| RE 106 (3/63) | RESISTIVITY DEPTH – PROBE 106 (MONTH/YEAR) |
| BORE HOLES GH7a * | IWSC |
| BORE HOLES BMR 35 | BMR |
| ← I.P. W4 | INTERSECTION POINT SECTION W 4 |
| (thick line) | BEDROCK (SEISMIC VELOCITY ≥ 6700 ft/s) |
| $\rho_w$ | WATER RESISTIVITY (OHM-METRES) |
| | NOTE: DIRECTION IN BRACKETS, e.g. (NORTH), INDICATES DISPLACEMENT OF FEATURE FROM CROSS-SECTION |
| WATER LEVELS AT INTERSECTION POINTS FEET ABOVE M.S.L. | APRIL 1963 ⊢ |
| | SEPTEMBER 1963 ⊣ |
| | DECEMBER 1963 ◄ |
| | OCTOBER 1964 ● |
| FORMATION RESISTIVITY VALUES | FRESH > 20 OHM-METRES (50) |
| | BRACKISH 6 TO 20 OHM-METRES (14) |
| | SALINE < 6 OHM-METRES (3) |
| LITHOLOGY | SAND |
| | CLAY, MUD, SILT |
| | SANDY CLAY, SANDY LOAM |
| | GRAVEL |
| | GRAVEL AND SAND |
| | GRAVEL AND CLAY |
| | BEDROCK, AS DEFINED ABOVE |

## LEGEND

| | |
|---|---|
| RE 62 (3/63) | RESISTIVITY DEPTH – PROBE 62 (MONTH/YEAR) |
| B D | SEISMIC DEPTH – PROBE STATION |
| (18,000) | SEISMIC VELOCITY IN ft/s |
| ← I.P. N9 | INTERSECTION POINT SECTION N 9 |
| BORE HOLES AH3 * | IWSC |
| BORE HOLES BMR47 | BMR |
| BORE HOLES BH101 | PRIVATE BORE |
| (line) | SEISMIC INTERFACE |
| —?— | UNCONFIRMED SEISMIC INTERFACE |
| (thick line) | UPPER SURFACE OF DECOMPOSED BEDROCK OR CONSOLIDATED SEDIMENTS |
| (dashed line) | TOP OF POSSIBLE AQUIFER BODIES |
| $\rho_w$ | WATER RESISTIVITY (ohm-metres) |
| CD / CE | PROFILE INTERMEDIATE BETWEEN SEISMIC PROBES (CD TO NORTH) |
| | NOTE: DIRECTION IN BRACKETS, e.g. (EAST), INDICATES DISPLACEMENT OF FEATURE FROM CROSS-SECTION |
| ↕ | DEPTH OF INTERFACE DOUBTFUL |
| WATER LEVELS AT INTERSECTION POINTS FEET ABOVE M.S.L. | JANUARY 1963 ► |
| | APRIL 1963 ⊢ |
| | SEPTEMBER 1963 ⊣ |
| | DECEMBER 1963 ◄ |
| | OCTOBER 1964 ● |
| FORMATION RESISTIVITY VALUES | FRESH > 20 OHM-METRES (50) |
| | BRACKISH 6 TO 20 OHM-METRES (14) |
| | SALINE < 6 OHM-METRES (3) |
| LITHOLOGY | SAND |
| | CLAY, MUD, SILT |
| | SANDY CLAY, SANDY LOAM |
| | GRAVEL |
| | GRAVEL AND SAND |
| | GRAVEL AND CLAY |
| | BEDROCK OR DECOMPOSED BEDROCK |


RESIDUAL GRAVITY PROFILE
MILLIGALS
NO INFORMATION AVAILABLE
KELLYS MOUNTAIN AREA
BURDEKIN RIVER
SOUTH
N I
Possible line of Burdekin Fault weathered to greater depth in sheared material
ELEVATION IN FEET
0 M.S.L.
RE 187 (4/63)
RE 282 (5/63)
I.P.W 10
I.P.W 11
Dry


RESIDUAL GRAVITY PROFILE AND CROSS-SECTION N2
SHOWING SEISMIC RESISTIVITY AND BORE HOLE DATA
(SCALE 4" = 1M)

E55/85-44


RESIDUAL GRAVITY PROFILE AND CROSS-SECTION N3
SHOWING SEISMIC RESISTIVITY AND BORE HOLE DATA
(SCALE 1"=1M)

RESIDUAL GRAVITY PROFILE
MILLIGALS
N 4
NORTH
N 4
SOUTH
ELEVATION IN FEET
M.S.L.
PLANTATION CREEK
BURDEKIN RIVER
Saline clays or
salt water encroachment
along surface
Brackish
Fresh
Saline
Clay
Dry
Sand
Decomposed
granite
scale 4" to 1M


RESIDUAL GRAVITY PROFILE AND CROSS-SECTION N5
SHOWING SEISMIC RESISTIVITY AND BORE HOLE DATA
(SCALE 4"=1 M)

E55/B5/47

PLATE 23


RESIDUAL GRAVITY PROFILE AND CROSS-SECTION N6
SHOWING SEISMIC RESISTIVITY AND BORE HOLE DATA
(SCALE 4" = 1M)

E55/85-48


RESIDUAL GRAVITY PROFILE
MILLIGALS
PLANTATION CREEK
BURDEKIN RIVER
CHARLIES HILL
(BANDED CALC-SILICATE HORNFELS)
ROCK OUTCROP AT SURFACE EAST OF CROSS-SECTION N7
N 7
SOUTH
M.S.L.
ELEVATION IN FEET
Saline
Fresh
Clay
Dry
Limestone

118


(SCALE 4"=1M)


CROSS-SECTION N9 SHOWING SEISMIC/RESISTIVITY AND BORE HOLE DATA

SCALE 4" = 1 M

ESS/BS-51


RESIDUAL GRAVITY PROFILE AND CROSS-SECTION W2
SHOWING [illegible] AND [illegible]
(Scale 4" = 1M)

E55/85-5A

W 3
WEST
W 3
EAST
RESIDUAL GRAVITY PROFILE
MILLIGALS
ELEVATION IN FEET
SHEEP STATION CREEK
PLANTATION CREEK
Saline
Clay
Brackish
Moist
Dry
M.S.L.


RESIDUAL GRAVITY PROFILE AND CROSS SECTION W4
SHOWING SEISMIC RESISTIVITY AND BORE HOLE DATA
SCALE 1 MILE TO 4 IN.

E55/B5-56

PLATE 30


RESIDUAL GRAVITY PROFILE
MILLIGALS
W 5
WEST
M.S.L.
ELEVATION IN FEET
Dry
Moist or Dry
FLORIZATION CREEK
ANABRANCH
RITA ISLAND
Brackish
Saline
W 5
EAST


RESIDUAL GRAVITY PROFILE AND CROSS-SECTION W6
SHOWING SEISMIC RESISTIVITY [illegible]

(Scale [illegible])

E55/35-58


PROFILE AND CROSS-SECTION W7 ... RESISTIVITY AND BORE HOLE DATA

(SCALE 4" TO 1 M)

E55/B5-59


RESIDUAL GRAVITY PROFILE
MILLIGALS
BURDEKIN RIVER
W8 WEST
W8 EAST
ELEVATION IN FEET
M.S.L.
Dry
Moist
Brackish
Clay
I.P. N2
I.P. N3
I.P. N4
I.P. N5
I.P. N6
I.P. N7
I.P. N8
I.P. N9


RESIDUAL GRAVITY PROFILE AND CROSS-SECTION W9
SHOWING SEISMIC [illegible] AND [illegible] DATA
Scale 1 MILE = 0·4 IN
E55 [illegible]


RESIDUAL GRAVITY PROFILE
BURDEKIN RIVER
Fresh Water
Brackish or Saline Clay
Saline Clay
M.S.L.
ELEVATION IN FEET
W 10
EAST


RESIDUAL GRAVITY PROFILE AND CROSS-SECTION W11
SHOWING SEISMIC RESISTIVITY AND BORE HOLE DATA
(SCALE 4" TO 1 M)

E55/B5-63

PLATE 37

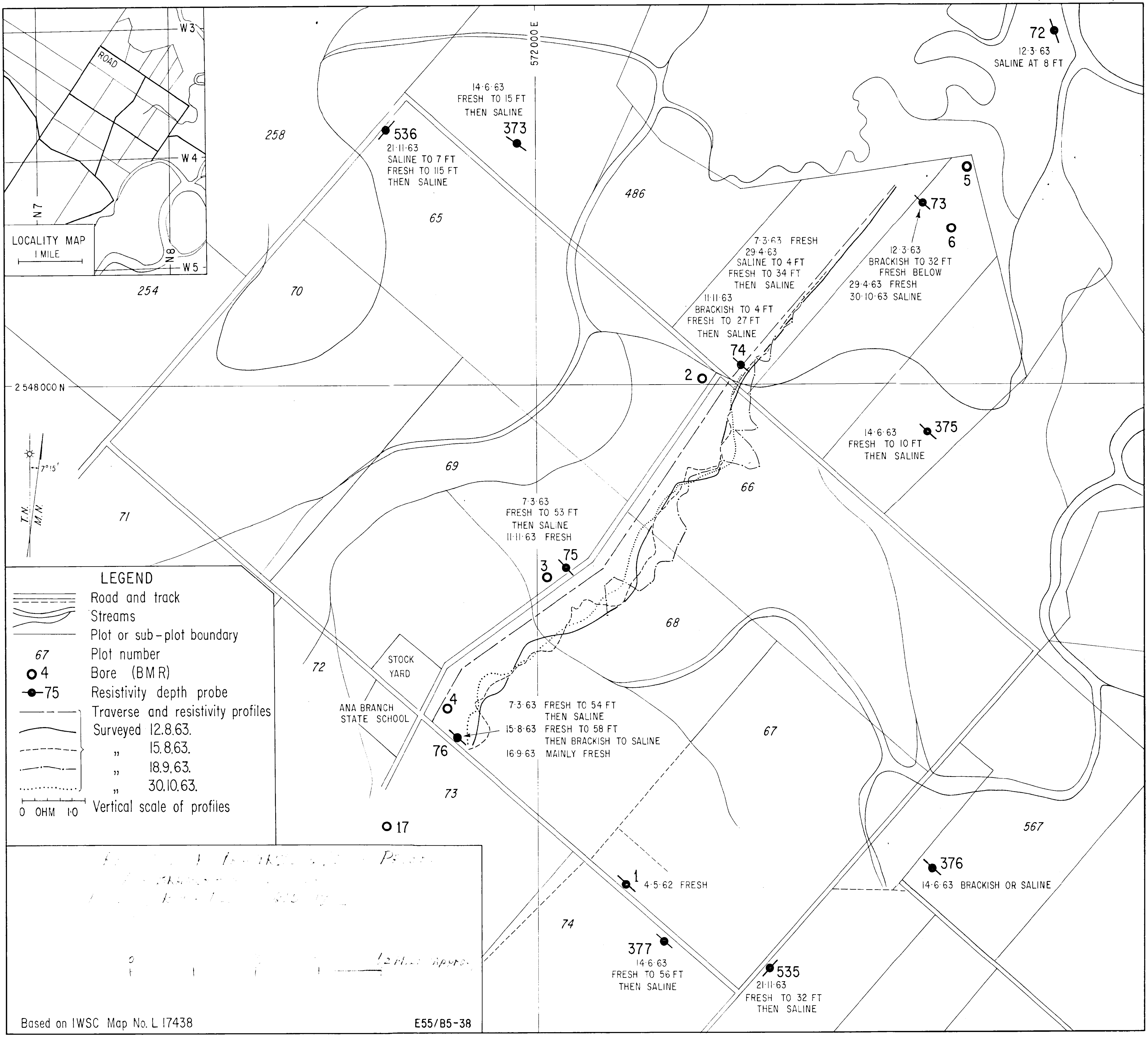
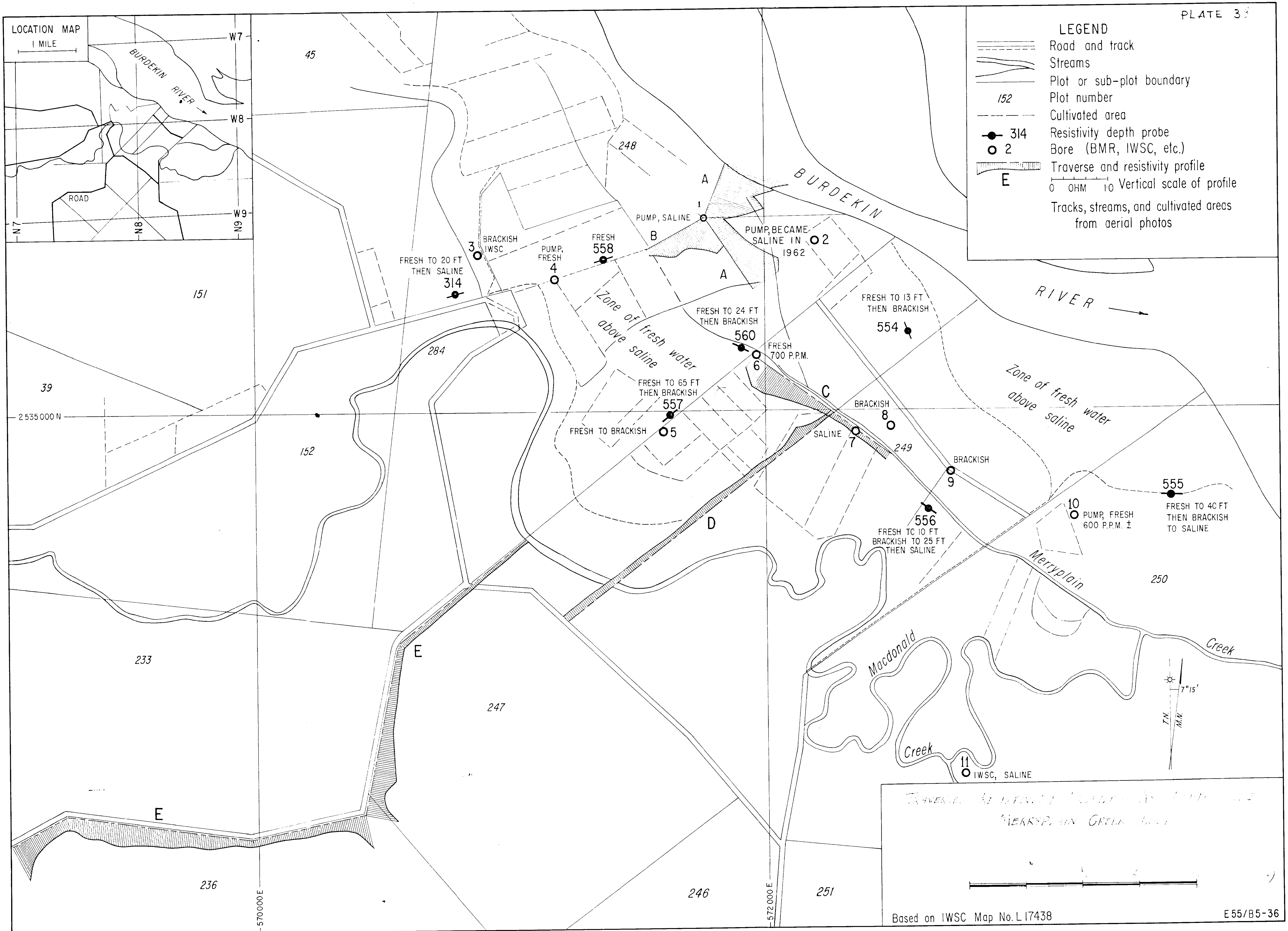
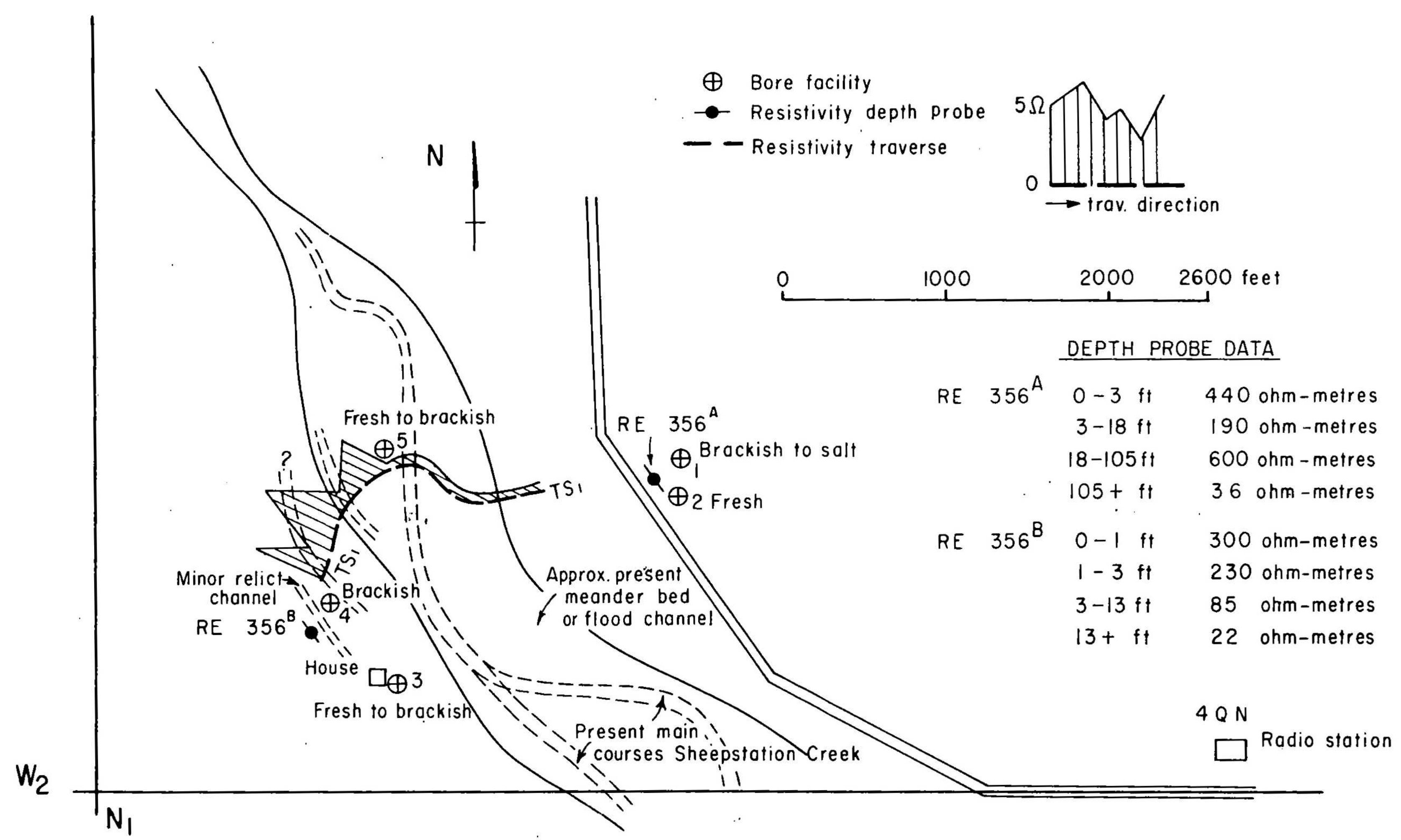

LOCALITY MAP
1 MILE
ROAD
W3
W4
W5
N7
N8
572000 E
2548000 N
T.N.
M.N.
7°15'
LEGEND
Road and track
Streams
Plot or sub-plot boundary
67 Plot number
4 Bore (BMR)
75 Resistivity depth probe
Traverse and resistivity profiles
Surveyed 12.8.63.
" 15.8.63.
" 18.9.63.
" 30.10.63.
0 OHM 1·0 Vertical scale of profiles
258
254
70
65
69
71
72
73
74
486
66
68
67
567
536
21·11·63
SALINE TO 7 FT
FRESH TO 115 FT
THEN SALINE
14·6·63
FRESH TO 15 FT
THEN SALINE
373
72
12·3·63
SALINE AT 8 FT
5
73
6
12·3·63
BRACKISH TO 32 FT
FRESH BELOW
29·4·63 FRESH
30·10·63 SALINE
7·3·63 FRESH
29·4·63
SALINE TO 4 FT
FRESH TO 34 FT
THEN SALINE
11·11·63
BRACKISH TO 4 FT
FRESH TO 27 FT
THEN SALINE
74
2
375
14·6·63
FRESH TO 10 FT
THEN SALINE
7·3·63
FRESH TO 53 FT
THEN SALINE
11·11·63 FRESH
3
75
STOCK
YARD
ANA BRANCH
STATE SCHOOL
4
76
7·3·63 FRESH TO 54 FT
THEN SALINE
15·8·63 FRESH TO 58 FT
THEN BRACKISH TO SALINE
16·9·63 MAINLY FRESH
17
1
4·5·62 FRESH
376
14·6·63 BRACKISH OR SALINE
377
14·6·63
FRESH TO 56 FT
THEN SALINE
535
21·11·63
FRESH TO 32 FT
THEN SALINE
Based on IWSC Map No. L 17438
E55/B5-38

PLATE 3

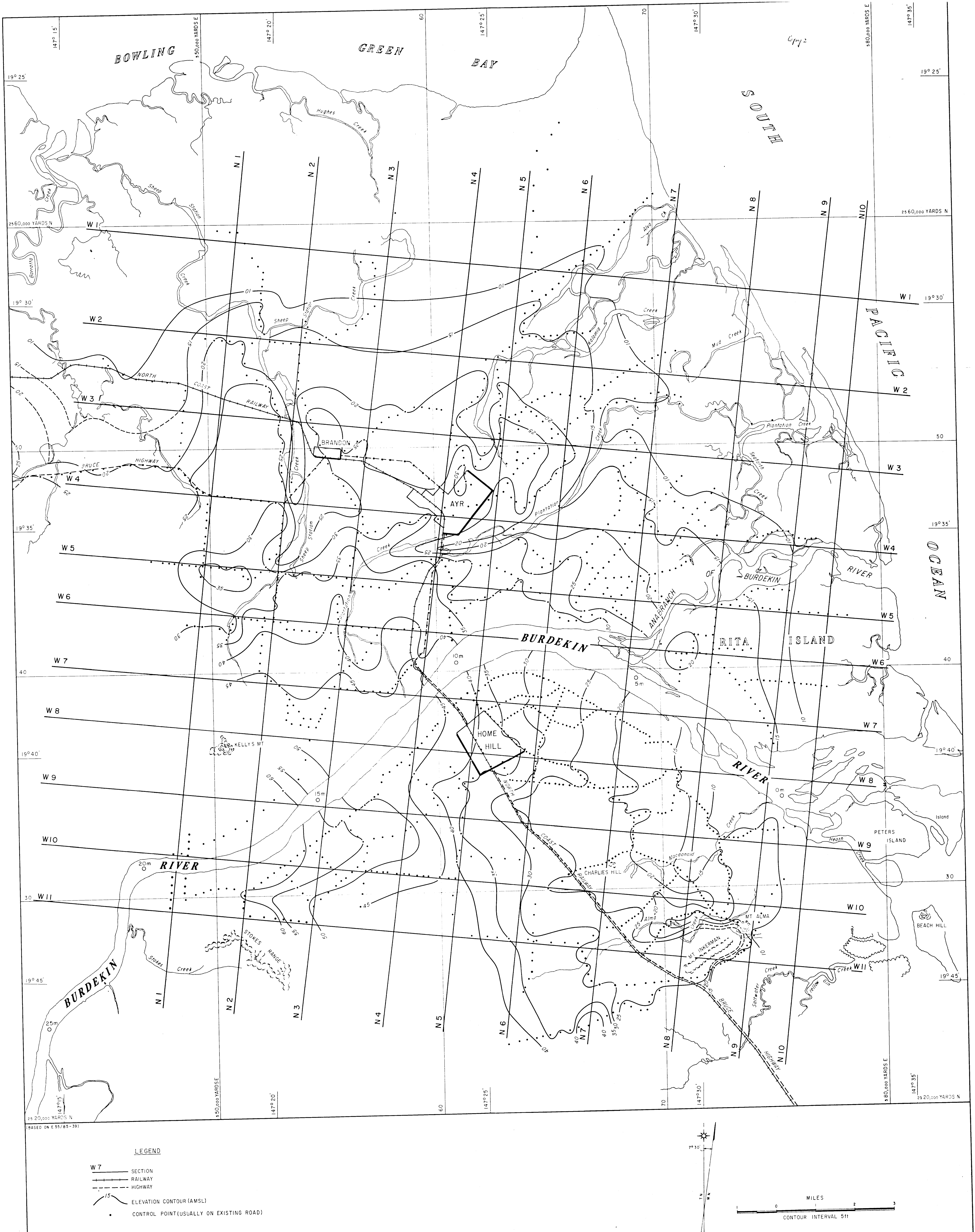


LOCATION MAP
1 MILE
BURDEKIN RIVER
ROAD
W7
W8
W9
N7
N8
N9
LEGEND
Road and track
Streams
Plot or sub-plot boundary
152 Plot number
Cultivated area
314 Resistivity depth probe
2 Bore (BMR, IWSC, etc.)
E Traverse and resistivity profile
0 OHM 10 Vertical scale of profile
Tracks, streams, and cultivated areas from aerial photos
BURDEKIN
RIVER
45
248
151
39
152
284
233
247
236
246
251
249
250
2535000 N
570000 E
572000 E
A
B
C
D
E
PUMP, SALINE
PUMP, BECAME SALINE IN 1962
BRACKISH IWSC
PUMP, FRESH
FRESH 558
FRESH TO 20 FT THEN SALINE 314
FRESH TO 24 FT THEN BRACKISH 560
FRESH 700 P.P.M.
FRESH TO 13 FT THEN BRACKISH 554
Zone of fresh water above saline
FRESH TO 65 FT THEN BRACKISH 557
FRESH TO BRACKISH
SALINE
BRACKISH
FRESH TO 10 FT BRACKISH TO 25 FT THEN SALINE 556
PUMP, FRESH 600 P.P.M. ±
555 FRESH TO 40 FT THEN BRACKISH TO SALINE
Merryplain Creek
Macdonald Creek
IWSC, SALINE
7°15'
T.N.
M.N.
Based on IWSC Map No. L 17438
E55/B5-36




Traverse TS1 Sheepstation Creek North Jarvisfield

Copy 2




ELEVATION CONTOURS

GEOPHYSICAL BRANCH, BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS E 55/B5-64

PLATES 41-42


PLATE 42

PLATE 41

CROSS-SECTIONS 1964/1 & 1964/2
SHOWING SEISMIC RESISTIVITY AND
HOLE DATA (SCALE 4" = 1M)
E55/B5-88

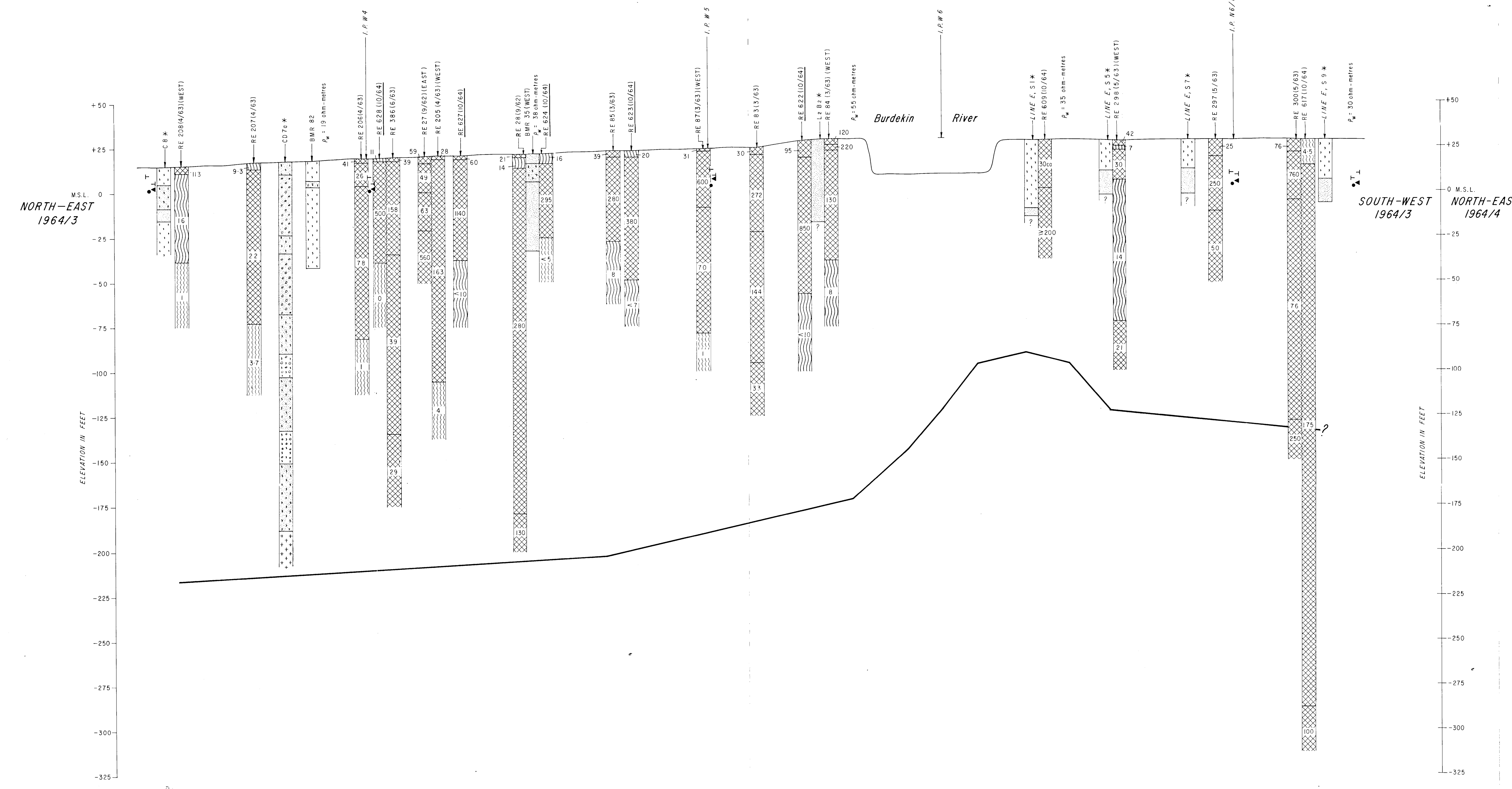



PLATE 43

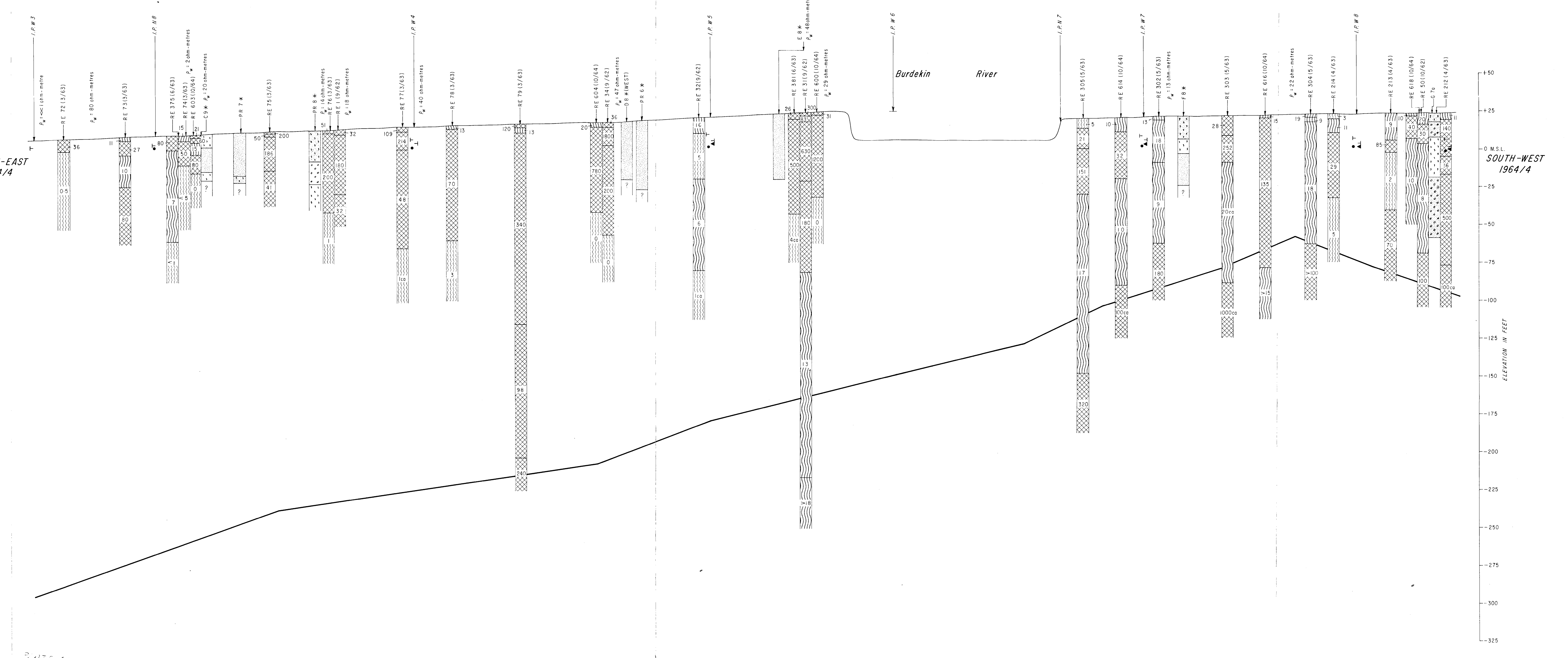



PLATE 44

| Tens \ Units | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | N \ W | 8/4 | 4/6 | 3/6 | 3/4 | 3/4 | 3/5 | 3/5 | 3/5 | 3/4 |
| 1 | 3/4 | ? | 2/6 | 3/6 | 1/7 | 2/5 | 3/8 | 4/4 | 3/8 | 1/7 |
| 2 | 3/8 | 1/6 | 3/10 | 3/10 | 3/10 | | | 7/4 | 7/4 | 5/5 |
| 3 | 6/5 | 7/5 | 7/5 | 7/5 | 7/5 | 4/4 | 5/3 | 6/3 | 6/3 | 6/2 |
| 4 | 5/3 | 5/3 | 3/3 | 2/2 | 2/3 | 1/11 | 3/9 | 4/8 | 5/8 | 6/8 |
| 5 | 7/8 | 3/7 | 3/7 | 2/2 | 2/2 | 2/4 | 2/3 | 4/7 | 5/6 | |
| 6 | 4/10 | 4/11 | 4/11 | 4/11 | 4/9 | 4/9 | 4/9 | 4/8 | 4/8 | 4/8 |
| 7 | 5/9 | 4/10 | 8/3 | 8/3 | 8/3 | 8/4 | 8/4 | 7/4 | 7/4 | 7/4 |
| 8 | 7/5 | 7/5 | 7/5 | 7/5 | 6/5 | 6/5 | 6/4 | 6/5 | 6/5 | 5/5 |
| 9 | 5/5 | 4/5 | 4/5 | 4/5 | 3/5 | 3/5 | 3/5 | 2/5 | 2/5 | 2/5 |
| 10 | 2/5 | 1/5 | 1/5 | 1/4 | 1/4 | 1/4 | 2/4 | 2/4 | 2/4 | 1/7 |
| 11 | 2/7 | 2/7 | 2/7 | 3/7 | 3/8 | 3/8 | 4/7 | 4/7 | 4/7 | 4/7 |
| 12 | 4/7 | 4/7 | 4/6 | 4/6 | 3/8 | 3/7 | 3/7 | 3/7 | 3/8 | 4/4 |
| 13 | 3/4 | 3/4 | 2/4 | 3/4 | 3/4 | 4/6 | 3/6 | 3/6 | 3/8 | 3/9 |
| 14 | 2/9 | 4/4 | 4/4 | 4/4 | 6/8 | 6/8 | 6/8 | 6/7 | 6/7 | 6/7 |
| 15 | 6/8 | 6/8 | 6/8 | 6/9 | 4/6 | 5/5 | 5/5 | 5/5 | 5/3 | 5/3 |
| 16 | 5/3 | 5/2 | 5/2 | 5/2 | 5/2 | 5/1 | 5/1 | 5/3 | 5/3 | 6/3 |
| 17 | 6/3 | 6/3 | 6/3 | 6/3 | 6/3 | 5/4 | 5/4 | 6/4 | 6/3 | 6/3 |
| 18 | 5/3 | 5/3 | 5/3 | 6/2 | 6/2 | 2/9 | 1/10 | 1/10 | 1/10 | 4/5 |
| 19 | 5/5 | 5/5 | 6/5 | 6/5 | 6/5 | 6/5 | 2/8 | 2/8 | 2/7 | 2/7 |
| 20 | 3/7 | 3/8 | 2/9 | 6/5 | 6/4 | 6/4 | 7/4 | 7/4 | 7/3 | 7/3 |
| 21 | 6/8 | 6/8 | 7/8 | 7/8 | 7/8 | 6/9 | 6/9 | 6/9 | 6/9 | 7/10 |
| 22 | 7/10 | 7/10 | 6/9 | 6/10 | 6/10 | 5/10 | 5/9 | 5/9 | 5/9 | 2/7 |

| Tens \ Units | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|
| 23 | 2/4 | 2/5 | 2/5 | 2/6 | 3/8 | 2/7 | 5/10 | 5/10 | 5/10 | 5/11 |
| 24 | 6/10 | 5/11 | 6/11 | 6/8 | 6/8 | 6/11 | 6/11 | 6/11 | 7/11 | 8/5 |
| 25 | 9/5 | 9/5 | 9/5 | 7/5 | 10/5 | 8/5 | 8/5 | 8/6 | 8/6 | 9/6 |
| 26 | 9/6 | 9/6 | 8/6 | 8/6 | 8/6 | 4/8 | 3/9 | 3/9 | 3/9 | 2/10 |
| 27 | 3/10 | 3/10 | 3/10 | 3/11 | 3/10 | 2/11 | 2/10 | 4/10 | 2/10 | 2/11 |
| 28 | 2/10 | 1/11 | 1/11 | 1/10 | 5/8 | 5/9 | 5/10 | 4/10 | 4/10 | 3/10 |
| 29 | 4/8 | 4/9 | 4/9 | 4/7 | 5/7 | 5/7 | 5/7 | 6/7 | 6/7 | 6/6 |
| 30 | 6/7 | 7/7 | 7/7 | 7/7 | 7/8 | 7/7 | 7/7 | 8/7 | 2/5 | 1/5 |
| 31 | 6/8 | 7/7 | 7/8 | 8/8 | 8/8 | 8/8 | 6/9 | 6/10 | 7/11 | 8/11 |
| 32 | 7/10 | 6/10 | 7/10 | 3/3 | 2/3 | 3/3 | 3/4 | 4/4 | 4/4 | 4/4 |
| 33 | 3/5 | 3/6 | 3/3 | 2/3 | 2/4 | 2/3 | 2/3 | 2/2 | 2/2 | 3/8 |
| 34 | 4/7 | 4/7 | 4/7 | 6/4 | 6/4 | 6/4 | 3/8 | 3/8 | 3/9 | 2/10 |
| 35 | 3/6 | 3/7 | 3/5 | 2/3 | 1/3 | 2/3 | 1/2 | 2/2 | 2/2 | 7/10 |
| 36 | 7/9 | 7/9 | 8/10 | 8/10 | 6/2 | 7/2 | 6/2 | 7/3 | 7/3 | 7/3 |
| 37 | 7/3 | 7/3 | 6/4 | 8/3 | 7/3 | 8/3 | 8/4 | 8/4 | 7/4 | 8/4 |
| 38 | 7/5 | 7/5 | 4/3 | 4/5 | 6/4 | 6/6 | 7/4 | 7/4 | 7/4 | 5/5 |
| 39 | 5/6 | 8/6 | 8/6 | 9/5 | 9/7 | 5/8 | 7/8 | 7/9 | 8/9 | 8/9 |
| 40 | 8/10 | 8/10 | 7/11 | 8/11 | 8/11 | 8/11 | 3/2 | 3/2 | 2/3 | 4/3 |
| 41 | 9/5 | 8/5 | 8/8 | 8/9 | 7/11 | 6/10 | 6/10 | 6/9 | 7/9 | 6/9 |
| 42 | 7/9 | 8/9 | 7/9 | 5/9 | 5/8 | 7/11 | 7/11 | 5/10 | 8/10 | 4/11 |
| 43 | 4/11 | 2/3 | 3/3 | 4/4 | 3/4 | 3/11 | 3/11 | 3/11 | 2/11 | 2/11 |
| 44 | 4/5 | 4/4 | 4/3 | 4/3 | 5/3 | 5/11 | 5/11 | 6/11 | 6/11 | 6/11 |
| 45 | | | | | | | | | | |

| Tens \ Units | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|
| 46 | | | | | | | | | | |
| 47 | | | | | | | | | | |
| 48 | | | | | | | | | | |
| 49 | | | | | | | | | | |
| 50 | 1/3 | | | | | | | | | 1/3 |
| 51 | | | | | | | | | | |
| 52 | | | | | | | | | | |
| 53 | 9/7 | 8/7 | 5/4 | 6/4 | 7/4 | 8/4 | 8/3 | 7/3 | 7/3 | 8/5 |
| 54 | 7/5 | 3/2 | 3/2 | 3/2 | 4/2 | 8/8 | 7/10 | 6/9 | 9/11 | |
| 55 | 8/10 | 9/10 | 9/9 | | 9/8 | 9/8 | 9/8 | 8/8 | 8/8 | |
| 56 | 8/8 | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| 60 | 7/6 | 8/5 | 8/6 | 8/3 | 7/5 | 8/8 | 6/6 | 5/7 | 5/6 | 6/6 |
| 61 | 2/2 | 2/2 | 2/1 | 6/2 | 7/7 | 8/7 | 7/7 | 6/7 | 7/8 | 8/8 |
| 62 | 8/8 | 5/6 | 6/5 | 7/5 | 7/4 | 6/4 | 6/4 | 7/4 | 7/4 | 9/7 |
| 63 | 9/6 | 2/4 | 2/3 | 1/4 | 1/5 | 2/4 | | | | |
| 64 | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
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*SAMPLE WITH HEAVY LINES SHOWS THAT PROBE RE284 IS NEAR INTERSECTION POINT N5/W8*

# GUIDE TO LOCATION OF RESISTIVITY DEPTH PROBES

*GEOPHYSICAL BRANCH, BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS* E55/B5-92