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DEPARTMENT OF MINES
SOUTH AUSTRALIA

REPORT ON FIELD PERMEABILITY TESTING OF THE MURRAY BASIN LIMESTONE AQUIFER - WANBI EXPERIMENTAL STATION, SOUTH AUSTRALIA

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and

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ABSTRACT

At Wanbi in South Australia the laterally extensiv limestone aquifer of the Murray Basin is over two hundred feet thick, and in this locality contains non-pressure wate Pump tests on a $16\frac{1}{2}$ inch diameter open bore hole showed the specific yield of the bore to be about 450 gallons per hour per foot of drawdown, and gave a value of 25 feet per day for ~~k~~ the hydraulic conductivity. Individual bores are capable of yielding volumes of water in excess of 20,000 g.p.hour, but because of the great distance to the intake area and the flat hydraulic gradient, there appears to be insufficient water for extensive development of irrigation.

LOCATION

Wanbi Experimental Station, administered by the South Australian Department of Agriculture, lies in the Hd. Mindarie in the main part of the Murray Basin at a point about three miles southwest from Wanbi township. It is approximately 35 miles west of the Victorian - South Australian border, and 45 miles south of the Murray River at Overland Corner, near the southeastern corner of County Albert. The land surface is approximately 200 feet above sea level, and the static level of the groundwater about 50 feet above sealevel.

PREVIOUS HISTORY

For many years landholders have been drilling bores for stock water supply, water being readily obtainable at a depth varying with topography, but generally about 200 feet or less. Barnes (1951) recorded a considerable number of such bores, but at that time no irrigation from groundwater sources had been undertaken. As a result of his recommendations two attempts were made to interest landholders in conducting some experimental irrigation using groundwater, and pumping equipment was supplied to one property, but for various reasons the projects lapsed.

During the last three years or so, possibly because more money was available to them after several good seasons, some landholders in surrounding areas drilled rather deeper bores expressly for the purpose of obtaining irrigation water, and supplies of the order of 12,000 - 15,000 gallons per hour were reported.

INTEREST IN INVESTIGATION OF RESERVES

The obtaining of such supplies immediately emphasized the importance of finding answers to several problems. Work was currently in hand by Ludbrook (1960) who established the stratigraphic succession in the Murray Basin, and O'Driscoll

(1960) who investigated the hydrology of the area. As a result, it was known that two potential aquifers existed, the upper one a limestone sequence (Murray Group & Glenelg Group) and the lower a sand (Knight Group). Both these beds originally contained saline water which was gradually being replaced by low salinity water from a distant southeastern intake in Victoria, the connate water being pushed northwestward to outlets along the bed of the Murray River. The process of replacement was apparently very slow, and O'Driscoll (op. cit.) had calculated the rate of groundwater movement as being about one foot in two hundred days under existing hydraulic conditions. Replacement [illegible] the connate water is only partially complete, but irrigation [illegible]ater occurs beneath a substantial area of the Main Basin [illegible]uifer being drilled, and the one to which opera[illegible]inly be confined in the foreseeable future, was the uppe[illegible]oup - Glenelg Group limestone sequence. These beds, althou[illegible] appearance a fairly soft and generally rather marly and sandy coquinite, will stand unsupported in an uncased hole, and are capable of yielding quite large volumes of water without the insertion of a screen. The deeper Knight Group sand aquifer, on the other hand, is loosely consolidated and can only be developed as a source of water by the use of screens in bores.

As regards the main limestone sequence, little was known of the aquifer's capacity to provide large volumes over a long period; the considerable static lift meant high pumping costs; and the water quality deteriorated with distance from the intake. This last consideration not only would affect landholder living in the transition zone from known good water to poor quality water, but also involved the problem of what would happen if prolonged and heavy pumping in contiguous areas caused a reversal of flow, and consequent encroachment of saline waters from the north.

If groundwater was to be developed for irrigation, it appeared desirable to investigate the permeability and general hydraulic characteristics of the upper limestone aquifer, determi the probable specific yield of future bores and the hydrostatic lift, and the general farm economics of water use under the prevailing conditions of soil, climate and productivity. It was doubted whether individual landholders would be in a position to carry out experimental irrigation work and keep a detailed and satisfactory account of costs involved as well as would the Department of Agriculture, which very fortunately had an already established experimental centre in the Wanbi district. This centre had another attraction, in that it was near the edge of the zone of good quality water, and experiments could be made using water of a rather less favourable salinity than would be available to many others. The Department of Agriculture was therefore approached, and agreed to field permeability experiments being conducted on its property, and subsequently to utilise the main bore for its own experimental irrigation work.

Testing of the upper or limestone aquifer only was planned, as it was reasoned that landholders were unlikely, in the foreseeable future, to drill through this known source of water into the underlying Knight Group sands in which development was only possible at considerable extra expense.

STRATIGRAPHIC SUCCESSION

The stratigraphic succession was known from several rather widely scattered deep bores from which logs and samples were available (Ludbrook - op. cit.).

Locally the upper beds of Recent age vary considerably in character, and their thickness is partly a reflection of the topography. They comprise red to yellow and yellow grey sandy marls, sands and sandstones, which overlie the Loxton Sands, represented by white, cream, yellow and often strongly ironstained sands, sandstones and gritty limestones, usually micaceous and frequently fossiliferous in the lower section. The total thickness of Recent beds and Loxton sands was expected to be eighty to one hundred feet, below which a thin clay stratum, the Bookpurnong Beds, was known to occur in the adjoining Hd. Allen to the eastward, thinning out to the west. Drilling subsequently proved this stratum not to occur at Wanbi, the drill passing directly into the uppermost Murray Group limestone.

The Murray Group, which includes the sequence locally known as "cliff rock" and the upper part of the underlying Glenelg Group, are rather similar types of highly bryozoal limestone, usually cream to white in color, which in the main part of the Murray Basin grade downward into a greenish or grey glauconitic marl. This is a gradual lithologic change, and it was not possible to predict the thickness of limestones which would be an effective aquifer, although from the evidence of distant bores, and the known thinning of the sediments in a westerly direction, a total thickness of four to five hundred feet was anticipated. Below this the drill would enter first the greyblack carbonaceous silty clays of the upper Knight Group, and then the waterbearing sands of the same Group, although it was not intended to drill into these latter.

CHOICE OF SITE

Three considerations controlled the choice of site, one being proximity to an area having a suitable soil type for the conducting of irrigation experiments, as not all soils on the Research Station would lend themselves to this purpose. Since accurate observation of water levels during pumping was necessary, the bore had to be outside the anticipated radius of influence of any other bores in use nearby, and there had to be an adjacent area where the volumes of water pumped during the experiments could be discharged without danger either of flooding the borehead surround or of the pumped water making its way quickly downwards into the aquifer and being re-circulated. The site ultimately chosen was on a gentle slope where runoff could spread over the floor of a small adjacent flatbottomed valley some hundreds of yards away. Since there was a thickness of well over one hundred feet of dry sandy marls and sandstones beneath the floor of this flat, and the area of spread was quite considerable, the danger of re-circulation was considered to be negligible over the short period of operation of the tests.

DIAMETER OF BORE

The bore had to be of sufficient diameter to permit use of a large turbine pump if a high discharge was to be maintained. Furthermore, it has in the past been found unwise to pump water from similar limestones in such a manner as to induce a very high velocity of entry, as erosion and collapse of the bore walls may occur when the drawdown is considerable, and the area of entry of the water is restricted. The material is rarely homogeneous, and the water probably gains entry to the bore through restricted channels of high permeability. Another hazard was that the lower section of the Loxton Sand, expected somewhere between the depths of 80 and 120 feet below natural surface in this area, had elsewhere contained irregular beds of a dense hard sandy limestone which often hindered or prevented the insertion of the first string of casing to greater depth.

It was therefore decided to commence drilling for 24 inch diameter casing, and to continue with this to the waterbearing bed if possible. Two further strings of 18-inch and 16-inch casing were available in case of trouble. During subsequent construction 24-inch casing was seated on a coarse sandstone at 70'6"; and the 18-inch casing was inserted to 132 feet where it was seated in a rather marly limestone, the hole below that depth and all through the aquifer being of approximately 16½ inches diameter, and uncased.

DEPTH

It was proposed to continue drilling right through the bryozoal limestones of the Murray and Glenelg Groups, and since these sometimes have marly lenses in them, to penetrate some fifty feet or so into the lower part of the Glenelg Group sequence, a grey or greenish grey marl, to ensure that the whole of that part of the sequence acting as an effective aquifer was available for pump testing. The depth was expected to be 500-550 feet, and drilling was in fact discontinued at 495 feet.

HYDRAULIC SURFACE

Current investigations (O'Driscoll op. cit.) had established that the hydraulic surface showed a gradual decline in a westerly and northwesterly direction from the distant Victorian intakes, and at Wanbi was at a level of about ~~one hundred~~ fifty feet above sea level. Although confined by the clayey Bookpurnong Beds and under slight pressure in the Hd. Allen not far eastward, the water occurred free in Hd. Mindarie, the uppermost few feet of the limestone aquifer being dry.

Whether the water level remained constant or was subject to fluctuations, either natural or induced by pumping from distant bores, was not known. All local bores were in continual use, and none could be used for observing the behaviour of the water surface, so it was decided to use one of the observation bores to be drilled as part of the experiment. This was done, and records of the water surface level in the bore taken over a period of some six weeks prior to commencement of the pump tests, using an Electro-flo meter**. Initially a light nylon cord was used to suspend the float in the water, but proved unsatisfactory because of stretch, and it was replaced by a stainless steel wire. Results were not altogether satisfactory because of the tendency of the float to stick against the walls of the hole, and the large scale of the graph obtained, although it was apparent that only very small short-term fluctuations occurred. Subsequent to the

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** Manufactured by the E.M. Co. Ltd. London, and having a 9½ inch dia. rotating face, eight day clock mechanism, and a 10 ft. range.

completion of the pump tests, observations were continued over a five-month period using a water stage recorder*. Some trouble was experienced with this instrument also, as it was found difficult to prevent clogging of the mechanism with fine dust which caused sticking and occasional sudden dislocations of the recording track, but the general pattern was clear enough.

Two separate movements of the groundwater surface were observed, one a long-term, presumably seasonal fluctuation, and the other with a shorter period of eight to ten days. This latter effect is considered to be closely associated with pumping in the same area, some distance away, notably from a bore on Sec. 37, Hd. Mindarie which was at the time being developed, pump tested, and periodically pumped for a few hours at a time at several thousand gallons per hour. The drawdown and subsequent recovery caused by this pumping is considered to have caused rises and falls in the groundwater surface rather in excess of that which would normally be anticipated.

As the three bores used in these tests were only each some 50 feet apart, and the external pumping took place some 2 miles from them, it may reasonably be assumed that the groundwater surface in all bores would be equally affected. Since the calculations depend primarily on differences in drawdown between each of the bores at specific times, the errors induced in the final results by any such fluctuation would be of the order of, at most 0.2%, even if pumping were commenced on Sec. 37 at a crucial stage in the tests.

DRILLING

Observation Bores

Drilling commenced on 17/11/58 and after some interruptions finished on 6/5/59. Three bores were drilled in a straight line at fifty feet centres, the two observation bores being located in a direction southeastward of the main bore, or up slope hydraulically. These were cased with six-inch casing and continued

* Type C. Water Stage Recorder, marketed by E. Esdaile & Sons Ltd., and having an eight-day clockwork mechanism and a 24 inch range.

to a depth of 220 feet, well into but not through the aquifer. Casing was suspended in one to a depth of 157½ feet, and the other to 163¼ feet.

Test Bore

As anticipated, some difficulty was experienced in drilling through some of the dense and hard calcareous sandstone bars, and further trouble was occasioned by the welded tubing used as casing, which was found to be not perfectly round. Details of the bore are set out hereunder.

Hundred: Mindarie   Section: 32

Depth in feet below surface			Strata Description
0	to	3	Brown sand
3	-	5	light brown sandy marl
5	-	30	light creamy buff very marly sand
30	-	60	light yellow brown very sandy marl
60	-	68	light greenish brown dirty rather gritty marl
68	-	70	light grey buff hard calcareous sandstone
70	-	79	light greenish brown marly coarse sandstone
79	-	84	light greenish brown marly coarse sandstone and grit
84	-	90	yellow buff marly sandstone and grit.
90	-	95	yellow buff marly hard sandstone and grit
95	-	103	yellow buff hard calcareous sandstone, some grit grains.
103	-	113	light greyish cream fossiliferous limestone
113	-	120	creamy white slightly sandy limestone
120	-	145	off-white rather marly limestone
145	-	160	white bryozoal limestone
160	-	165	white slightly marly limestone
165	-	180	white slightly marly limestone with occasional grit grains.
180	-	185	creamy white bryozoal limestone
185	-	190	cream bryozoal limestone
190	-	195	very pale brown bryozoal limestone
195	-	205	very light grey bryozoal limestone
205	-	210	off-white bryozoal limestone, with a hard sandy band.

Depth in feet below surface			Strata Description
210	to	225	off-white slightly bryozoal limestone
225	-	255	off-white bryozoal limestone
255	-	280	creamy white bryozoal limestone
280	-	305	cream bryozoal limestone, a hard bar between 295' and 300'
305	-	310	pale creamy grey bryozoal limestone.
310	-	350	pale grey bryozoal limestone, a hard bar between 320' and 325'
350	-	365	light grey slightly marly limestone
365	-	370	light grey marly limestone
370	-	375	light grey very marly limestone
375	-	380	light grey marly limestone
380	-	405	light grey very marly glauconitic limestone, probably fairly impermeable
405	-	410	light grey very marly bryozoal glauconitic limestone
410	-	415	light grey glauconitic fossiliferous marl
415	-	425	light grey glauconitic very marly fossiliferous limestone
425	-	430	light grey glauconitic very marly limestone
430	-	440	light grey glauconitic fossiliferous marl
440	-	470	light grey glauconitic sandy marl
470	-	475	light green fossiliferous sandy marl
475	-	480	light greenish grey glauconitic fossiliferous slightly sandy marl
480	-	485	light green glauconitic slightly sandy marl
485	-	495	light greyish green fossiliferous sandy marl

Water cut, 157 ft.

Static water level, 157 ft.

Salinity 105.2 grains per gallon, total dissolved salts

Cased to 70'6" with 24" diameter steel tubing, and to 132' with 18" diam. tubing, open $16\frac{1}{2}$ inch dia. hole below.

Sludges of the strata intersected were collected at intervals of five feet for geological examination, from which, in conjunction with the driller's report, the geological log was compiled.

SALINITY

A facsimile of the analyst's report is shown below. This was of a sample collected for analysis prior to pumping, and subsequent samples showed no salinity variation.

~~FIGURE~~......

GEOLOGICAL SURVEY OF SOUTH AUSTRALIA

WATER ANALYSIS

Sample No. W 1071/59

Name and Address: Dept. of Agriculture, Wanbi Research Station

Location of Sample: Hundred Mindarie Section: 32

Sample collected by: D.R. Phillips Date: 6/5/59

Analysis made by: T.R. Frost and dated 1/7/1959.

	Grains per Gallon	ASSUMED COMPOSITION OF SALTS	Grains per Gallon
Chlorine, Cl	37.6	Calcium carbonate	6.2
Sulphuric acid (radicle), SO_4	12.8	Calcium sulphate	-
Carbonic acid (radicle), CO_3	16.1	Calcium chloride	-
Nitric acid (radicle), NO_3	nil	Magnesium carbonate	14.6
Sodium, Na	32.0	Magnesium sulphate	-
Potassium, K	-	Magnesium chloride	-
Calcium, Ca	2.5	Sodium carbonate	3.5
Magnesium, Mg	4.2	Sodium sulphate	18.9
Silica, SiO_2	-	Sodium chloride	62.0
		Sodium nitrate	Nil
		Potassium chloride	

Total saline matter, Grains per gallon	105.2
Total saline matter, Ounces per gallon	0.24
Suspended matter	-
Organic matter	-

HARDNESS

	English Degrees
Total	23.5
Temporary	23.5
Permanent	-
Due to calcium	6.2
Due to magnesium	17.3

Bore No.	1
Depth	495'
Water Level	157'
Water Cut	157'
Supply G.P.H.	Not yet tested

REMARKS

T.A. BARNES
Government Geologist

EFFECTIVE THICKNESS OF AQUIFER

From an inspection of the sludge samples it was not possible accurately to determine the lower limit of the strata which could be regarded as effectively permitting the passage of water. However it was obvious that at a depth of about 380 feet the material was fairly impermeable and the bottom of the aquifer was therefore arbitrarily chosen as 377 feet, or 220 feet below the static water level. This figure of 220 feet was used in subsequent calculations, but is admittedly an approximation.

INFORMATION TO BE OBTAINED

The initial intention was to utilise both non-equilibrium and equilibrium conditions of pumping in calculating the aquifer characteristics, and compare the two methods under local conditions Specifically, it was desired to obtain a value for the coefficient of permeability in gallons per hour per square foot of cross-sectional area, and from this to calculate the specific yield of the bore, i.e. the quantity available in gallons per hour per foot of drawdown.

Certain basic assumptions common to both the Theis (non-equilibrium) and Theim (equilibrium) methods of calculation had to be made, these being (i) that the aquifer is uniform in character and permeability both horizontally and vertically. Quite obviously this is unlikely to be true in a vertical sense, as a glance at the geological log will show, but it was felt that the variations which might occur would not significantly affect the validity of the calculations. Horizontally, any permeability variations, in a local sense, could be regarded also as small. (ii) that the aquifer is of uniform thickness and indefinite extent. No aquifer has indefinite extent, but this one was felt to be a reasonable approximation for calculation purposes, as it is known to extend for many miles in all directions. Since it gradually thins to the westward and thickens in the opposite direction it is not uniform, and moreover since the lower part of the sequence becomes very marly and obviously incapable of transmitting much, or any, water, some depth had to be arbitrarily selected as the base. However the existing conditions are believed to be a reasonable approximation for calculation purposes, although it became apparent during the course of the tests that the aquifer was more permeable in its upper section.

It had also to be assumed that no unanticipated short-term water level fluctuations occurred.

WATER LEVEL MEASUREMENTS

An air line was installed in the main bore, and the water levels in this and the two observation bores were also measured with two 200 ft. steel tapes. Because of the depth and consequent air pressure involved, the original plastic tubing failed, and was subsequently replaced by heavy rubber tubing. However it was found that the airline and pressure gauge were not sufficiently accurate to do more than serve as a check on the steel tape readings, which were therefore used throughout on all three bores.

Initially, the tapes were smeared with a water sensitive paste, but this was found to be unsatisfactory for rapid use, and very messy to handle, so it was discarded. Excellent results were obtained by rubbing the surface of the tape with white chalk, and readings were possible to the nearest 1/200 of a foot.

Because of the depth to water, measurements were rather laborious even with two men handling the steel tape, and it was found that each reading took 7 to 8 minutes, or approximately 20-25 minutes for the three bores, unless more than one team was employed. Using two teams of observers eliminated much of the time lost in winding up the measuring tapes, and transferring from one bore to another.

PORosity OF AQUIFER

No undisturbed samples were available for laboratory tests on porosity of the material comprising the aquifer. This type of limestone however is commonly known in outcrop in many places, and G. Crawford had already conducted a number of porosity tests on samples of these, obtaining an average value, in round figures, of 45%. As some of the aquifer material appeared slightly marly, a slightly lower value of 40% was adopted in the calculations.

PUMPING EQUIPMENT - (Preliminary)

Initially, a five-inch, five-stage M.C. turbine pump was installed at a depth of 300 feet - i.e. 143 feet below static water level - and coupled to a 25 H.P. Wisconsin engine with an H_4B head. The unit did not perform to expectations, as on a short test on 21/5/59 the maximum delivery rate was only 1490 gallons per hour, and pumping was accompanied by strong surging of the water level, rendering it difficult to measure the drawdown. After four and a half hours, pumping was stopped and the unit removed.

MEASUREMENT OF DISCHARGE

During this first run, measurement of the discharge was attempted by means of a long pipe with a circular $1\frac{1}{2}$ inch orifice plate. It soon became obvious that this was not satisfactory, for three reasons. The pipe was subject to accidental disturbance, and difficult to keep perfectly horizontal. Short term and quite strong fluctuations in pressure made it almost impossible to read the manometer tube accurately; and variations in the pumping rate prevented accurate recording of the progressive and total volumes pumped.

The orifice tube was therefore replaced by a previously calibrated flow meter connected in the middle of a long discharge pipe. This was then used throughout the main tests made four months later, a delay occasioned by the necessity of obtaining suitable pumping equipment, but which had the additional advantage of allowing time for the aquifer to recover completely from the effects of removal of the small volume of water pumped during the preliminary tests.

Despite hourly checks on pump revolutions and the maintenance of constant throttle once equilibrium was approached, fluctuations in pumping rates still occurred with a resultant effect on drawdown levels. Since both the equilibrium and non-equilibrium methods rely on constant discharge, it is considered that for all future tests of this type the engine should be equipped with a fine throttle control and that discharge readings should be taken at 15 or 30 minute intervals. Diurnal temperature variations or some similar factor appear to affect the efficiency of the engine, which results in these fluctuations which should be eliminated rather than allowed for in later calculations.

PUMPING EQUIPMENT - (Main Tests)

For the main tests a ten-inch, ten-stage L.C. turbine pump with H_4L geared head was set at a depth of 306 feet from the surface, or approximately 149 feet below static water level, and coupled to a Perkins 6 Diesel engine of nominal 80 H.P. at 1800 R.P.M. This was successfully operated at a maximum discharge rate of about 22,000 gallons per hour.

TEST PROCEDURE

Initial Pumping - Duration 0540 hours. On 14th September 1959 at 1034 hours the pump was started, and operated at a rate of approximately 21,000 gallons per hour, in a preliminary test to determine an optimum pumping rate for the tests to follow. The water level in the main bore declined until at 1353 hours it exceeded 43 feet, and was then over 200 feet below surface, beyond the range of the measuring tapes, although roughly determinable by airline.

After several hours pumping, some discoloration was evident in the discharge, but this disappeared in about another hour and a quarter. The pump was stopped at 1614 hours, after 121,200 gallons of water had been removed, at an almost but not perfectly steady rate.

As a result of the information obtained, it was decided to set the pump at the approximate rates of 10,000 and 15,000 gallons per hour for the two main pump tests. Fig. 6 shows a cross section through the three bores, and the general shape of the drawdown curve.

Test No. 1

Pumping at a rate of 11,400 gallons per hour commenced at 0900 hours on 15th September, and continued for fifty hours. The extent of the static water level recovery following the previous day's pumping 18 hours earlier is shown by the following:

	14/9/59 S.W.L.(ft.)	15/9/59 S.W.L.(ft.)	Difference (ft.)
Bore No. 1	43.08	42.86	- 0.22
Bore No. 2	42.93	42.60	- 0.33
Bore No. 3	43.30	42.86	- 0.44

Drawdown levels during the operation were taken in No. 1 Bore at four minute intervals, and in Nos. 2 & 3 Bores at five minute intervals.for a further 1½ hours. This required two men reading No. 1 Bore water levels, two others for Nos. 2 and 3, and one man attending the pump and reading discharges at ten minute intervals.

After three hours continuous pumping, drawdown readings were taken at hourly intervals for the remainder of the fifty hour period, the pump being stopped for servicing at 1201 hours on 17/9/59. Equilibrium appeared to have been obtained in No. 1 Bore after forty-eight hours, with a drawdown of some 25⅓ feet, and results were used in the calculation contained in Appendix No. 1.

Test No. 2

Pumping recommenced at 1215 hours on 17/5/59, after a short interval for servicing the engine. The delivery rate was increased to 16,500 gallons per hour, and hourly readings continued until equilibrium was again established after 45 hours with a drawdown level of approximately 37½ feet in No. 1 Bore.

Results of this second pump test are shown in Appendix No. 2.

RECOVERY

The pump was stopped at 1400 hours on 19/9/59, and recovery readings taken of the water levels. These readings were at two minute intervals for No. 1 Bore and four minute intervals for Bores No. 2 and 3 for the first hour, then at ten minute intervals until 2000 hours (a period of six hours duration), when observations were discontinued.

Even after the removal of over 1½ million gallons of water, the water level during this short recovery period returned to within two feet of the original static water level, indicating quite a high permeability within the aquifer. Recovery levels are plotted in Fig. 10.

COMPARISON OF FORMULAE USED

(1) Non-Equilibrium Conditions

The Theis (non-equilibrium) formula assumes both immediate response of the water level to pressure changes, and parallel flow lines into the bore, i.e. a small drawdown and full penetration of the aquifer. Although full penetration was obtained, the maximum drawdown of approximately 18% of the total thickness of the aquifer appears, from the results, to be greater than the permissible limit for this particular stratum.

(2) Equilibrium Conditions

Use of the Thiem formula, which has been developed for pumping under equilibrium conditions, has given good agreement between the values obtained for k_p, k, and the Specific Yield from the two tests made, pumping at the rates of 11,400 gallons per hour and 16,500 gallons per hour respectively. The conclusion drawn is that this formula is more applicable to conditions existing in an unconfined aquifer, a finding in agreement with Jacob (1938) and others for sedimentary basins having many features in common with the Murray Basin.

SUMMARY OF RESULTS

(1) The lower boundary of the aquifer is difficult to demarcate accurately, but the total effective thickness at Wanbi was assumed to be 220 feet.

(2) The permeability is not constant throughout the whole vertical range of this depth, being higher in the upper section than lower down.

(3) The local conditions are not altogether favourable to the use of non-equilibrium pumping conditions as a basis for calculating the aquifer characteristics.

(4) In any future pump tests, pumping should be continued till equilibrium conditions are established, when the Thiem formula should be applicable.

(5) The values obtained in the pump tests for Thiem's factor kp, the coefficient of permeability, were 2.60 and 2.68 gallons per hour per square foot; and for the hydraulic conductivity k (Darcy's Law) were 25.0 and 25.8 feet per day.

(6) The specific yield of the bore was 440 - 450 gallons per hour per foot of drawdown. This was for a bore of approximately 16 inches diameter. Since reduction to 8-inch diameter may be expected to reduce the output by about one-tenth, a normal 8-inch bore drilled under comparable conditions should be capable of yielding 400 gallons per foot of drawdown.

It is interesting to note that in an 8-inch bore pumping from 200 feet of producing aquifer at a rate of 20,000 gallons per hour, the entry velocity of the water through the walls of the bore would be only about 0.006 feet per second if the water bearing stratum were homogeneous.

(7) The hydraulic gradient between Wanbi and the distant Victorian intake area is known to be approximately one foot per

mile. The value of the hydraulic conductivity K has been determined as 25 feet per day, which was the figure adopted by O'Driscoll, (1956, op. cit.) in calculating the amount of water available for irrigation in the area, under existing conditions, without depleting the storage.

That writer suggested that there was only sufficient water to irrigate a tiny area on each property, and the recent pumping operations have confirmed the value of Kp adopted by him in his calculations.

The conclusion to be drawn from the work so far done is that individual bores can be expected to yield large volumes of water, probably well in excess of 20,000 gallons per hour, but that any extensive future development will result in depletion of available reserves. The great distance to the intake, and the flat gradient on the hydraulic surface are factors which put severe restrictions on the overall volume of groundwater available in that the movement of recharge water is extremely slow. This question has been dealt with by E.P. O'Driscoll (Bulletin 35) in which it is suggested that only a comparatively limited volume of water may be available for irrigation. Overpumping will probably not only deplete the available reserves, but also induce lateral movement of more saline water from the northward into the aquifer, causing a gradual deterioration in quality which will first affect bores in the marginal areas.

G.J. Crawford
Geologist

GJC& EPO'D:AGK
29/7/60

E.P.D. O'Driscoll
Senior Geologist

APPENDIX NO. 1

WANBI PUMP TESTS

Equilibrium Test at 11,410 gallons per hour:

Applying the Dupuit-Theim Equation for an unconfined aquifer where equilibrium has been attained:-

$$k_p = \frac{Q \log_e {}^{r_1}/_{r_2}}{\pi(h_1^2 - h_2^2)}$$

where k_p = coefficient of permeability

Q = rate of discharge

and h = height of the water table above the base of the aquifer at a distance r from the pumping bore.

k = hydraulic conductivity (Darcy's Law)

Q = 11,410 gallons per hour,

${}^{r_1}/_{r_2} = \frac{101.67}{51.87}$ i.e. $\log_e \frac{r^1}{r_2} \approx 2.303 \log_{10} 2$,

m = thickness of aquifer = 220 ft.

h_1 = 220' - drawdown in Bore 3 at equilibrium (= 8.60 feet),

and h_2 = 220' - drawdown in Bore 2 at equilibrium (= 10.90 feet).

$$\therefore k_p = \frac{11,410 \times 2.303 \times 0.3010}{\pi\{(220-8.60)^2 - (220-10.90)^2\}}$$

$$= \frac{11,410 \times 2.303 \times 0.3010}{\pi \times 420.5 \times 2.30}$$

= 2.60 gallons per hour per square foot

The porosity of the aquifer is assumed as 40%,

$$\therefore k \text{ in Darcy's Law} = \frac{k_p}{\text{porosity}} = \frac{2.60 \times 100}{40} = 6.5 \text{ galls/hr./ft.}^2$$

$$= \frac{6.5}{6.23} \text{ feet/hour}$$

$$\frac{6.5}{6.23} \times 24 = \underline{25.0 \text{ feet per day}}$$

$$\text{Specific Yield} = \frac{\text{discharge}}{\text{drawdown in main bore}} = \frac{11,410}{25\frac{1}{3}} = 450 \text{ galls/hr./ft.}$$

APPENDIX NO. 2

WANBI PUMP TESTS

Equilibrium Test at 16,500 g.p.h.

$$k_p = \frac{Q \times 2.303 \log_{10} {}^{r_1}/_{r_2}}{\pi(h_1^2 - h_2^2)}$$ when equilibrium has been attained

$Q = 16{,}500$ gallons per hour $\quad \log_{10} {}^{r_1}/_{r_2} = 0.3010$

$h_1 = 220 - 12.6$ feet (Bore 3)

$h_2 = 220 - 15.9$ feet (Bore 2)

$$k_p = \frac{16{,}500 \times 2.303 \times .3010}{\pi\{(220-12.6)^2 - (220-15.9)^2\}}$$

$$= \frac{16{,}500 \times 2.303 \times .3010}{\pi \times 411.5 \times 3.30}$$

$$= 2.68 \text{ galls./hr./ft.}^2$$

$\therefore$ k in Darcy's Law $\left(= \frac{k_p}{\text{porosity}}\right) = \frac{2.68 \times 100}{40}$

$= 6.7$ galls./hr./ft.^{2}

$= 1.08$ ft./hour.

$= \underline{\underline{25.8 \text{ ft./day.}}}$

Specific yield $= \frac{16{,}500}{37'6''} = 440$ gallons/hr./ft. of drawdown

APPENDIX NO. 3

WANBI PUMP TESTS

Recovery Test from 16,500 g.p.h.

Applying this Formula in terms of transmissibility:-

$$T = \frac{2.303 \times Q \times \log_{10}}{4 \pi \ (S_2 - S_1)} \ {}^{t_2}/_{t_1}$$

where S_2 and S_1 are drawdowns at times t_2 and t_1, and Q = discharge = 16,500 g.p.h.

Choosing t_2 and t_1 to be one log cycle apart (e.g. 20 & 200)

$$T = \frac{2.303 \times 16,500}{4 \pi \times 4.04}$$

$$= 748.4 \text{ galls./hr./ft.}$$

Thickness of aquifer = 220 feet

i.e. $k_p = \frac{748.4}{220} = 3.40$ gallons per hour per square foot.

$\therefore$ k (in Darcy's Law) $= \frac{3.40}{40} \times 100 = 8.5$ galls./hr./ft.^{2}

$= 1.36$ ft./hr. or 32.7 ft./day.

APPENDIX 4

WANBI PUMP TESTS

OBSERVATION RECORDS

Assumed Datum	- Main No. 1 Bore Head	200.00 ft.
	No. 2 (Observation Bore)	199.38
	No. 3 (" ")	200.65

Date	Time (hrs.)	Main Bore(1) Draw-down	Main Bore(1) Water Level	Obs.Bore(2) Draw-down	Obs.Bore(2) Water Level	Obs.Bore(3) Draw-down	Obs.Bore(3) Water Level	Pumping Rate (g.p.h.)	Volume pumped-progressive (gallons)
				Preliminary Pumping					
14/9/59	1000	-	43.08	-	42.93	-	43.30		nil
"	1034 Pump Started								
"	1353		below 00					21,500	70,400
"	1614 Pump Stopped							21,400	121,200
				First Test Pumping					
15/9/59	0830		42.86		42.60		42.86		
"	0900 Pump started							11,400	nil
"	0906	30.83	12.03	7.10	35.50	4.21	38.65	21,000	2,046
"	0913	34.62	8.24	8.93	33.67	5.83	37.03	12,000	2,726
"	0925	22.24	20.62	7.22	35.38	5.02	37.84	17,000	7,240
"	0930	23.36	19.50	7.27	35.33	5.10	37.76	16,200	8,460
"	0937	22.60	20.26	7.42	35.18	5.21	37.65	11,400	9,720
"	0941	22.60	20.26	7.49	35.11	5.30	37.56	11,400	10,470
"	0948	22.85	20.01	7.60	35.00	5.42	37.44	11,400	11,280
"	0952	22.63	20.23	7.69	34.91	5.49	37.37	11,400	12,060
"	1000	22.84	20.02	7.85	34.75	5.56	37.30	11,400	13,540
"	1010	23.06	19.80	7.93	34.67	5.70	37.16	12,700	15,660
"	1015	22.64	20.18	7.96	34.64	5.75	37.11	10,800	16,560
"	1020	22.91	19.95	8.01	34.59	5.78	37.08	10,800	17,460
"	1030	23.66	19.80	8.12	34.48	5.91	36.95	11,400	19,360
"	1040	23.66	19.80	8.22	34.38	6.02	36.84	12,000	21,360
"	1050	23.26	19.60	8.32	34.28	6.11	36.75	12,000	23,360
"	1100	23.38	19.48	8.42	34.18	6.18	36.68	11,400	25,260
"	1120	23.31	19.55	8.52	34.08	6.43	36.53	11,400	29,060
"	1140	23.53	19.33	8.64	33.96	6.41	36.45	11,500	32,900
"	1200	23.21	19.65	8.57	33.83	6.51	36.35	11,100	36,600
"	1300	23.46	19.40	8.94	33.66	6.76	36.10	11,200	47,800
"	1400	23.88	18.98	9.19	33.41	6.99	35.87	11,300	59,100
"	1500	23.86	19.00	9.31	33.29	7.09	35.77	11,200	70,300
"	1600	23.99	18.87	9.41	33.19	7.21	35.65	11,300	81,600
"	1700	24.19	18.67	9.56	33.04	7.34	35.52	11,100	92,700
"	1800	24.61	18.25	9.78	32.82	7.55	35.31	11,300	104,000
"	1900	25.36	17.50	10.11	32.49	7.80	35.06	11,500	115,500
"	2000	25.49	17.37	10.25	32.35	7.95	34.91	11,700	127,200
"	2100	25.55	17.31	10.32	32.28	8.03	34.83	11,600	138,800
"	2200	25.63	17.23	10.42	32.18	8.12	34.74	11,900	150,700
"	2300	25.88	16.98	10.52	32.08	8.23	34.63	11,700	162,400
"	2400	25.84	17.02	10.53	32.07	8.26	34.60	11,800	174,200
16/9/59	0100	25.99	16.87	10.60	32.00	8.32	34.54	11,700	185,900
"	0200	26.09	16.77	10.63	31.97	8.34	34.52	11,600	197,500
"	0300	25.88	16.98	10.64	31.96	8.33	34.53	11,500	209,000
"	0400	25.90	16.96	10.64	31.96	8.35	34.51	11,500	220,500
"	0500	25.94	16.92	10.66	31.94	8.38	34.48	11,900	232,400
"	0600	25.96	16.90	10.67	31.93	8.35	34.51	11,700	244,100
"	0700	26.21	16.65	10.62	31.98	8.44	34.42	12,000	256,100

		Main Bore(1)		Obs.Bore(2)		Obs.Bore(3)			
Date	Time (hrs.)	Draw-down	Water Level	Draw-down	Water Level	Draw-down	Water Level	Pumping Rate (g.p.h.)	Volume pumped-progressive (gallons)
16/9/59	0800	25.40	17.46	10.57	32.03	8.35	34.51	11,300	267,400
"	0900	25.40	17.46	10.58	32.02	8.35	34.53	11,400	278,800
"	1000	25.71	17.15	10.61	31.99	8.38	34.48	11,500	290,300
"	1100	25.57	17.29	10.58	32.02	8.32	34.54	11,500	301,800
"	1200	25.65	17.21	10.60	32.00	8.35	34.51	11,200	313,000
"	1300	25.32	17.54	10.56	32.04	8.30	34.56	11,700	324,700
"	1400	25.23	17.63	10.57	32.03	8.30	34.56	11,200	335,900
"	1500	25.53	17.33	10.57	32.03	8.32	34.54	11,500	347,400
"	1600	25.53	17.33	10.75	31.95	8.40	34.46	11,500	358,900
"	1700	25.53	17.33	10.72	31.98	8.39	34.47	11,500	370,400
"	1800	25.82	17.04	10.85	31.85	8.48	34.38	11,500	381,900
"	1900	26.05	16.81	10.79	31.81	8.52	34.34	11,500	393,400
"	2000	26.28	16.58	10.93	31.67	8.61	34.25	11,700	405,100
"	2100	26.19	16.67	10.94	31.66	8.64	34.22	11,700	416,800
"	2200	26.28	16.58	11.00	31.60	8.68	34.18	11,700	428,500
"	2300	26.11	16.75	10.94	31.66	8.66	34.20	11,500	440,000
"	2400	25.94	16.92	10.90	31.70	8.62	34.24	11,600	451,600
17/9/59	0100	25.88	16.98	10.84	31.76	8.63	34.23	11,500	463,100
"	0200	25.94	16.92	10.87	31.73	8.63	34.23	11,400	474,500
"	0300	26.07	16.79	10.87	31.73	8.62	34.24	11,500	486,000
"	0400	25.88	16.98	10.83	31.77	8.59	34.27	11,600	497,600
"	0500	25.82	17.04	10.84	31.76	8.60	34.26	11,500	509,100
"	0600	25.63	17.23	10.81	31.79	8.59	34.27	11,500	520,600
"	0700	26.25	16.61	11.03	31.57	8.74	34.12	11,500	532,100
"	0800	25.69	17.17	10.83	31.77	8.60	34.26	11,400	543,500
"	0900	25.42	17.44	10.75	31.85	8.59	34.27	11,300	554,800
"	1000	25.40	17.46	10.83	31.77	8.54	34.32	11,300	566,100
"	1100	25.15	17.71	10.64	31.96	8.46	34.40	11,200	577,300
"	1200	25.09	17.77	No Reading		No Reading		11,200	588,500
"	1201	PUMP STOPPED							

SECOND TEST PUMPING

17/9/59	1215	PUMP STARTED						16,500	
"	1300	34.23	8.63	13.70	28.90	10.65	32.21	18,100	602,200
"	1400	35.17	7.69	14.17	28.43	11.10	31.76	15,900	618,100
"	1500	35.86	7.00	14.64	27.96	11.40	31.46	16,000	634,100
"	1600	36.59	6.27	14.86	27.74	11.63	31.23	17,250	651,350
"	1700	34.23	8.63	14.22	28.38	11.21	31.65	14,250	665,600
"	1800	34.99	7.87	14.46	28.14	11.39	31.47	15,300	680,900
"	1900	35.71	7.15	14.79	27.81	11.66	31.20	15,700	696,600
"	2000	35.86	7.00	14.87	27.73	11.74	31.12	16,000	712,600
"	2100	35.90	6.96	14.97	27.63	11.83	31.03	16,000	728,600
"	2200	Rain-No reading		15.02	27.58	11.81	31.05	16,000	744,600
"	2300	36.36	6.50	15.18	27.42	11.97	30.89	16,000	760,600
"	2400	36.44	6.42	14.72	27.88	12.01	30.85	16,100	776,700
18/9/59	0100	36.76	6.10	15.30	27.30	12.07	30.79	15,900	792,600
"	0200	36.49	6.37	15.19	27.41	12.05	30.81	16,200	808,800
"	0300	36.34	6.52	15.23	27.37	12.05	30.81	16,000	824,800
"	0400	36.38	6.48	15.26	27.34	12.11	30.75	16,200	841,000
"	0500	36.53	6.23	15.32	27.28	12.17	30.69	16,300	857,300
"	0600	36.74	6.12	15.47	27.13	12.23	30.63	16,400	873,700
"	0700	36.30	6.56	15.29	27.31	12.15	30.71	16,200	889,900
"	0800	35.80	7.06	15.11	27.49	12.03	30.83	15,900	905,800
"	0900	35.86	7.00	15.21	27.39	12.05	30.81	16,000	921,800
"	1000	36.07	6.79	14.98	27.62	12.05	30.81	15,900	937,700
"	1100	36.21	6.65	14.39	28.21	12.17	30.69	15,900	953,600
"	1120 to 1122	PUMP STOPPED FOR SERVICING							
"	1200	36.67	6.19	15.38	27.22	12.14	30.72	15,700	969,300
"	1300	36.82	6.04	15.43	27.17	12.13	30.73	16,200	985,500

		Main Bore(1)		Obs.Bore(2)		Obs.Bore(3)			
Date	Time (hrs.)	Draw-down	Water Level	Draw-down	Water Level	Draw-down	Water Level	Pumping Rate (g.p.h.)	Volume pumped-progressive (gallons)
18/9/59	1400	36.44	6.42	15.22	27.38	12.13	30.73	16,300	1,001,800
"	1500	36.61	6.25	15.52	27.08	12.03	30.83	15,800	1,017,600
"	1600	Rain-No reading		Rain-No reading		Rain-no reading		16,600	1,034,200
"	1700	38.36	4.50	16.12	26.48	12.11	30.75	16,600	1,050,800
"	1800	38.36	4.50	16.01	26.59	12.63	30.23	17,200	1,068,000
"	1900	39.15	3.71	16.25	26.35	12.81	30.05	16,900	1,084,900
"	2000	38.45	4.41	16.22	26.38	12.90	29.96	17,100	1,102,000
"	2100	Rain-No reading		16.40	26.20	12.93	29.93	17,100	1,119,100
"	2200	38	5 (Airline)	16.35	26.25	12.93	29.93	17,400	1,136,500
"	2300	Rain-No reading		Rain-No Reading		Rain-No Reading		16,800	1,153,300
"	2400	"	"	16.27	26.33	12.87	29.99	17,100	1,170,400
19/9/59	0100	36.15	6.71	16.25	26.35	12.90	29.96	17,200	1,187,600
"	0200	38.36	4.50	16.16	26.44	12.82	30.04	16,700	1,204,300
"	0300	Rain-No reading		16.15	26.45	12.80	30.06	16,900	1,221,200
"	0400	38.57	4.29	16.28	26.32	12.78	30.08	16,900	1,238,100
"	0500	39.53	3.23	16.54	26.06	13.12	29.74	17,400	1,255,500
"	0600	39.42	3.44	15.30	27.30	12.27	30.59	16,200	1,271,700
"	0700	Rain-No reading		15.40	27.20	12.29	30.57	15,400	1,287,100
"	0800	"	"	15.64	26.96	12.51	30.35	16,300	1,303,400
"	0900	"	"	15.67	26.93	12.47	30.39	16,400	1,319,800
"	1000	"	"	Rain-No Reading		Rain-No Reading		16,400	1,336,200
"	1100	37.36	5.50	15.93	26.67	12.66	30.20	16,300	1,352,500
"	1200	37.59	5.27	15.86	26.74	12.68	30.18	16,500	1,369,000
"	1300	37.32	5.54	15.85	26.75	12.64	30.22	16,700	1,485,700
"	1330	No reading		15.91	26.69	12.63	30.23	-	-
"	1400	PUMP STOPPED						16,500	1,502,200
		RECOVERY TEST COMMENCED							
"	1402			12.15	30.45				
"	1404	12.07	30.79						
"	1405					9.51	33.35		
"	1406	11.30	31.56						
"	1407			9.51	33.09				
"	1408	11.38	31.48						
"	1409					8.39	34.47		
"	1410	11.55	31.31						
"	1411			8.25	34.35				
"	1412	9.05	33.81						
"	1413					7.53	35.33		
"	1414	8.59	34.27						
"	1415			7.57	35.03				
"	1416	8.28	34.58						
"	1417					6.95	35.91		
"	1418	8.01	34.85						
"	1420	7.80	35.06	6.85	35.75				
"	1422	7.59	35.27						
"	1423					6.46	36.40		
"	1424	7.36	35.50	6.50	36.10				
"	1426	7.17	35.69			6.10	36.76		
"	1428	7.03	35.83						
"	1429			6.23	36.37				
"	1430	6.82	36.04						
"	1434	6.55	36.31						
"	1436	6.40	36.46			5.58	37.28		
"	1438	6.32	36.54	5.69	36.91				
"	1442	6.19	36.67						
"	1445					5.21	37.65		

Date	Time (hrs.)	Main Bore(1) Draw-down	Main Bore(1) Water Level	Obs.Bore(2) Draw-down	Obs.Bore(2) Water Level	Obs.Bore(3) Draw-down	Obs.Bore(3) Water Level	Pumping Rate (G.p.h.)	Volume pumped-progressive (gallons)
19/9/59	1446	5.84	37.02						
"	1447			5.29	37.31				
"	1450	5.67	37.19						
"	1454	5.55	37.31						
"	1455					4.85	38.01		
"	1457			4.96	37.64				
"	1500	5.34	37.52	4.90	37.70	4.72	38.14		
"	1510	4.88	37.98	4.59	38.01	4.49	38.37		
"	1520	4.77	38.09	4.34	38.26				
"	1530	4.51	38.35	4.12	38.48				
"	1545			3.94	38.66	3.83	39.03		
"	1600	3.97	38.89	3.64	38.96	3.61	39.25		
"	1625	3.69	39.17	3.36	39.24	3.30	39.56		
"	1645	3.45	39.41	3.17	39.43	3.16	39.70		
"	1720	3.13	39.73	2.92	39.68	2.85	40.01		
"	1745			2.72	39.88	2.68	40.18		
"	1830	2.69	40.17	2.50	40.10	2.54	40.32		
"	1850	2.61	40.25	2.37	40.23	2.38	40.48		
"	1920	2.40	40.46	2.24	40.36	2.24	40.62		
"	1950	~~[illegible]~~.28 2	40.58	2.15	40.45	2.17	40.69		
20/9/59	0845			1.94	41.66				

APPENDIX 4

Non-equilibrium Test at 11,410 gallons/hour:-

Applying the Theis Formula in terms of transmissibility:-

$$T = \frac{2.303 \times Q \times (\log_{10} \frac{t_2}{t_1})}{4\pi \times (S_2 - S_1)}$$

Where S_2 and S_1 are drawdowns at times t_2 and t_1, and Q = discharge = 11,410 gallons per hour.

Choosing t_1 and t_2 to be one log cycle apart (e.g. 20 minutes and 200 minutes) :-

$$T = \frac{2.303 \times 11,410}{4\pi \times 2.29}$$

= 912.0 gallons per hour per foot.

For an aquifer 200 feet thick.

Coefficient of Permeability = $K_p = \frac{T}{\text{Thickness}}$

$= \frac{910}{220} =$ 4.1 gallons per hour per square foot.

$\therefore K_v = \frac{K_p}{\text{porosity}} = \frac{4.1}{40} \times 100 =$ 10.0 galls/hr/ft.

= 1.6 feet per hour or **38.5** feet/day

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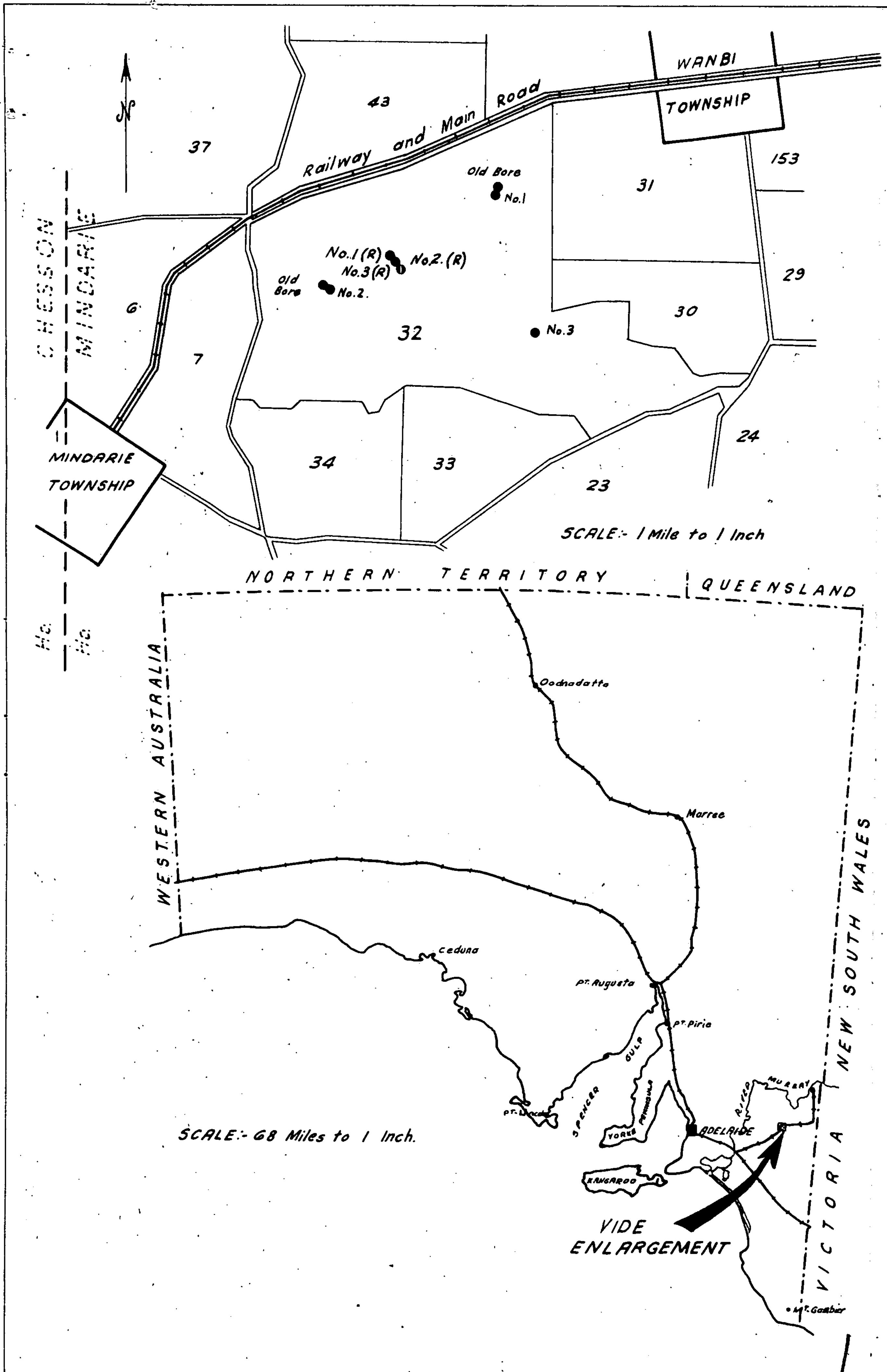
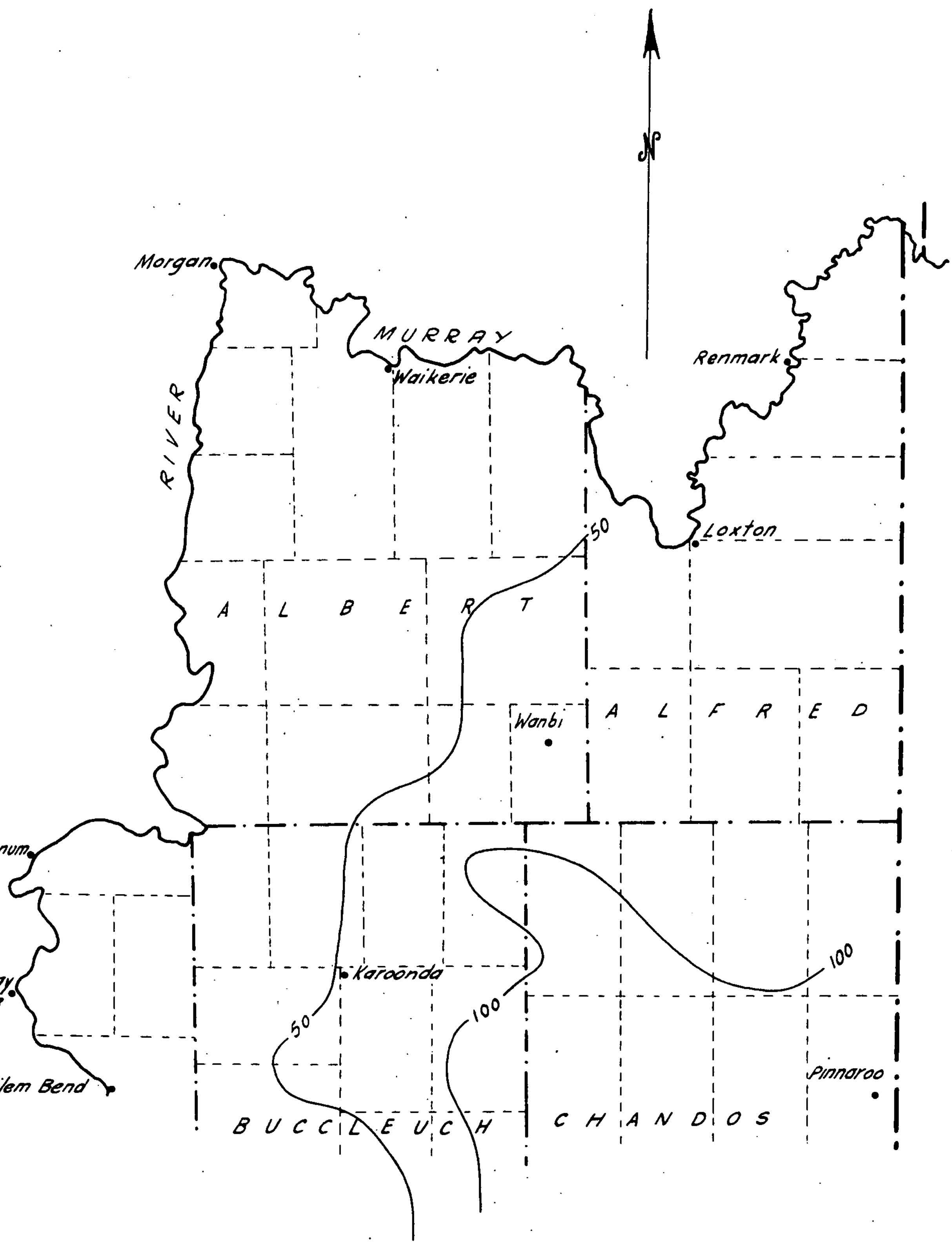


To accompany report by G. Crawford & E.P. O'Driscoll

S.A. DEPARTMENT OF MINES

Approved	Passed	Drn.	WANBI PERMEABILITY TEST BORES LOCALITY PLAN	D.M.	Scale As Shown
		Tcd. A.W.		Req.	S2493 Ja 13
		Ckd. M.B.L.			
Director		Exd.			Date 22-6-60

200—8.59 2776



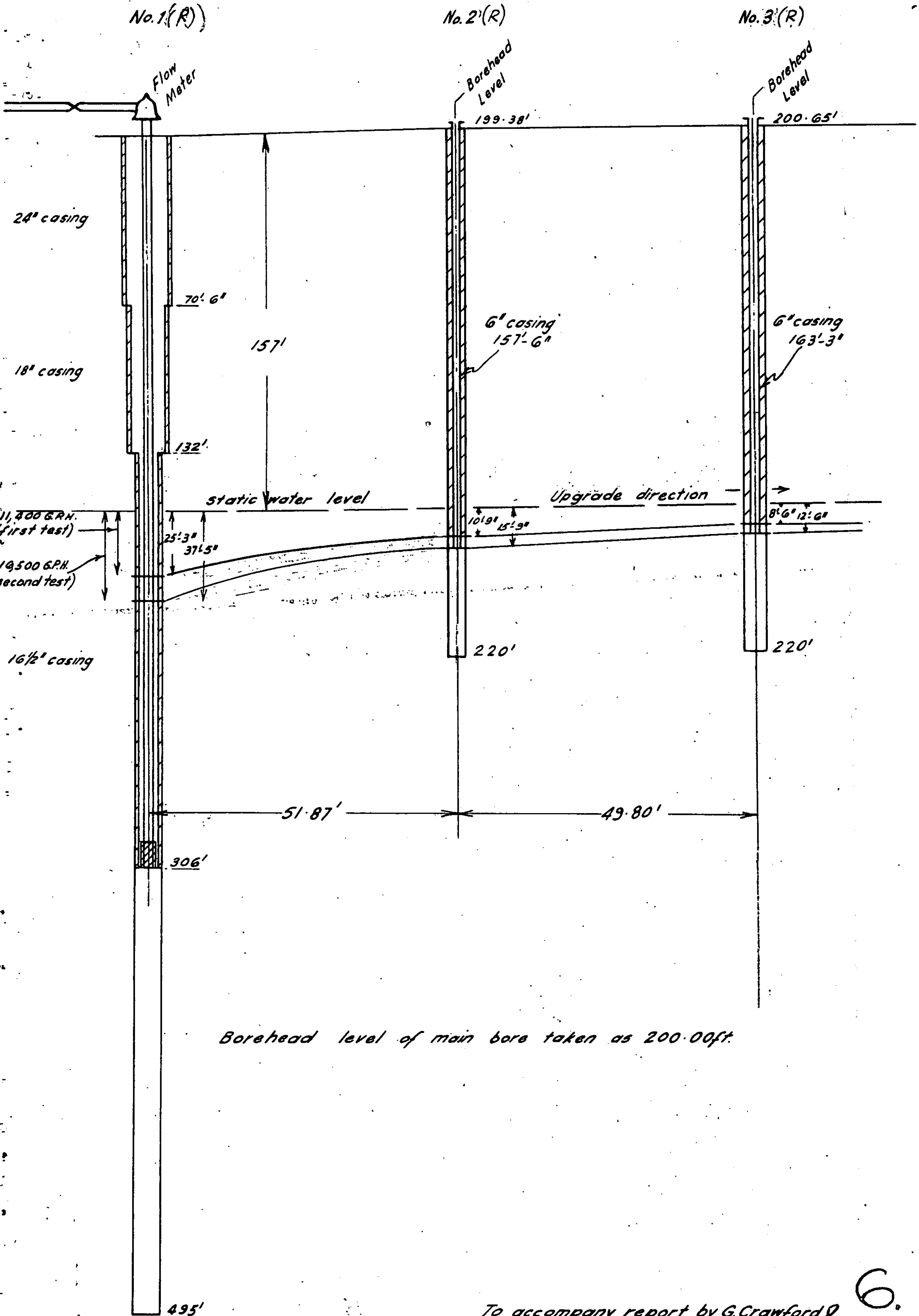
Isopotentials
Contours of waters in Murray - Glenelg Group —50—

after E.P. O'Driscoll
Bulletin 35. 4.

S.A. DEPARTMENT OF MINES

Approved	Passed	Drn.	WANBI TEST BORES	D.M.	Scale 16 mls. to 1"
		Tcd. A.W.	CONTOURS OF HYDRAULIC	Req.	S2563
		Ckd. M.B.L.	SURFACE		Ja 13
Director		Exd.			Date 1-8-60

200--10.58 2918



Borehead level of main bore taken as 200·00ft.

To accompany report by G. Crawford & E.P. O'Driscoll

6.

S.A. DEPARTMENT OF MINES

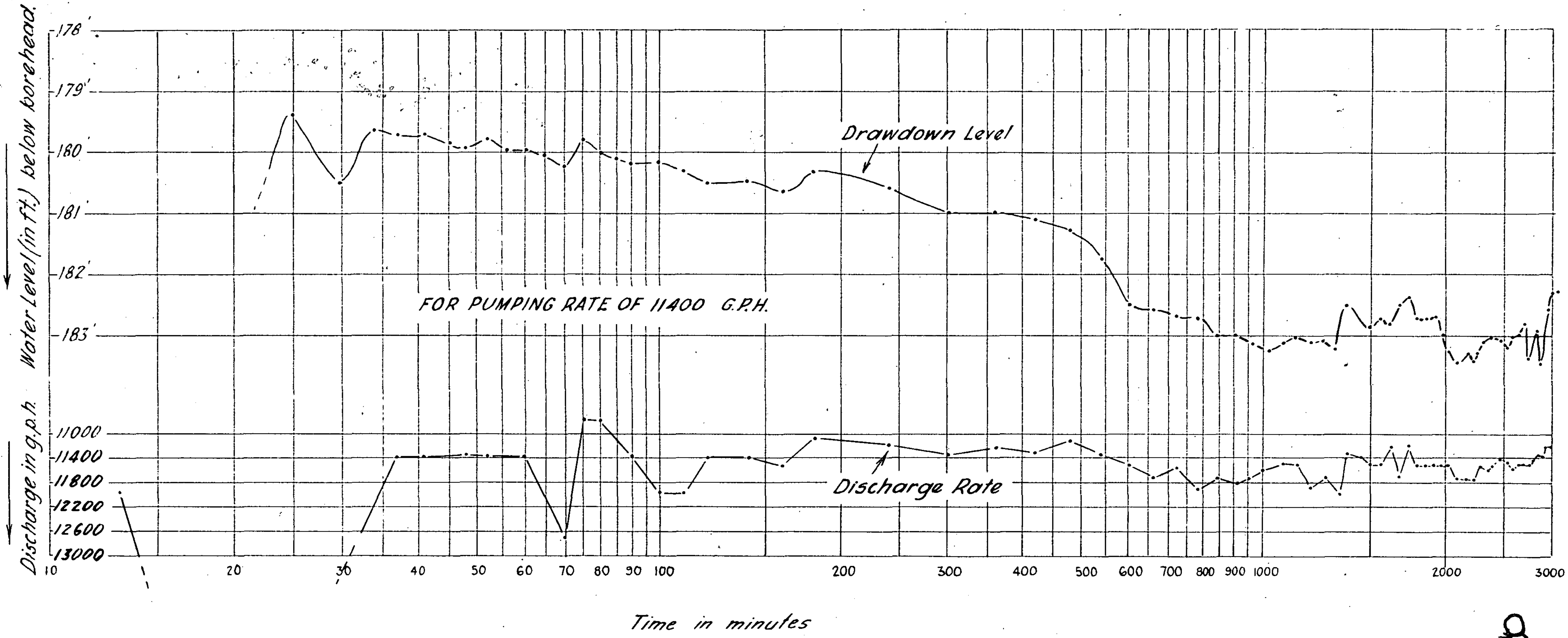
Approved	Passed	Drn.	WANBI PERMEABILITY TEST BORES SHOWING CONE OF INFLUENCE	D.M.	Scale Vert. 50' to 1" Horiz. 20' to 1"
		Tcd. A.O.W.		Req.	S 2492
		Ckd. M.B.L.			Ja 13
Director		Exd.			Date 21-6-60

200—10.58 2918

WANBI PUMP TEST

Main Test Bore, pumped at 11,400 g. p. h.

Fluctuations in Static Water Level compared with fluctuations in pumping rate.



8

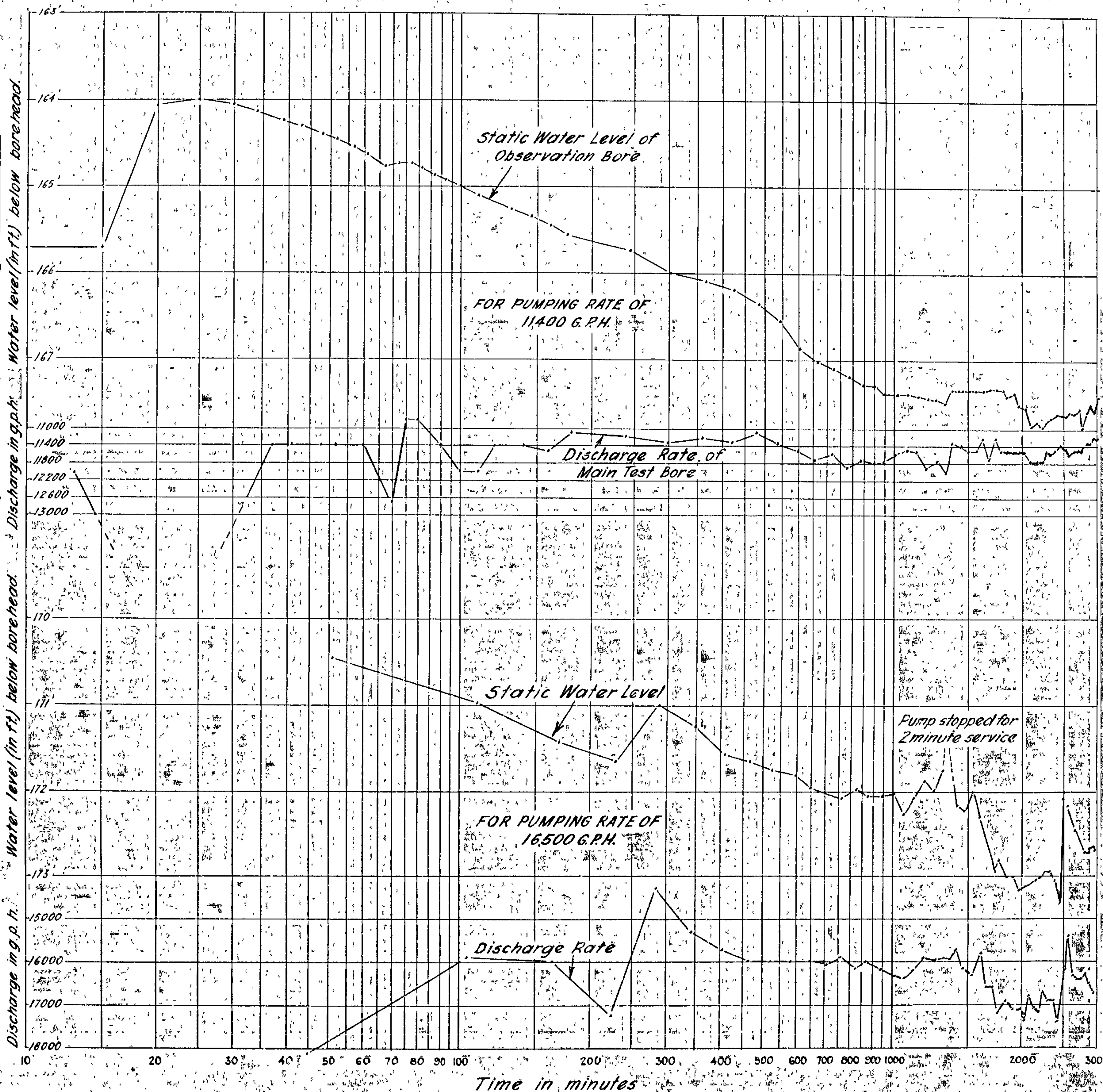
S. A. Dept. of Mines.

S 2564
Ja 13

WANBI PUMP TESTS

Observation Bore, distant 50 ft. from Main Test Bore (pumping).

Fluctuations in Static Water Level compared with fluctuations in pumping rate.

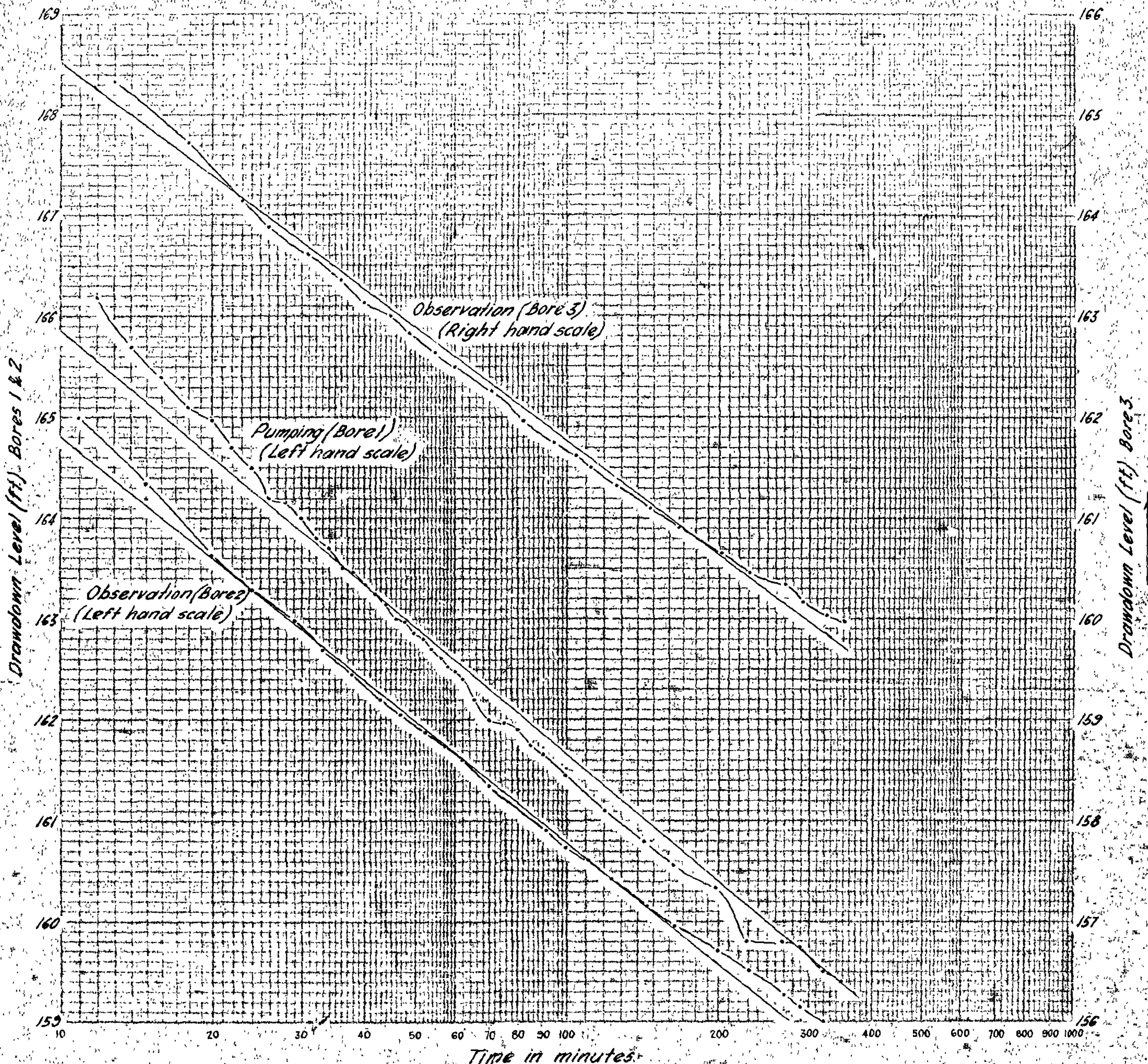


S. A. Dept. of Mines

60-441
Ja 13

WANBI PUMP TEST

Static Water Level Recovery after cessation of pumping at 16,500 g.p.h.

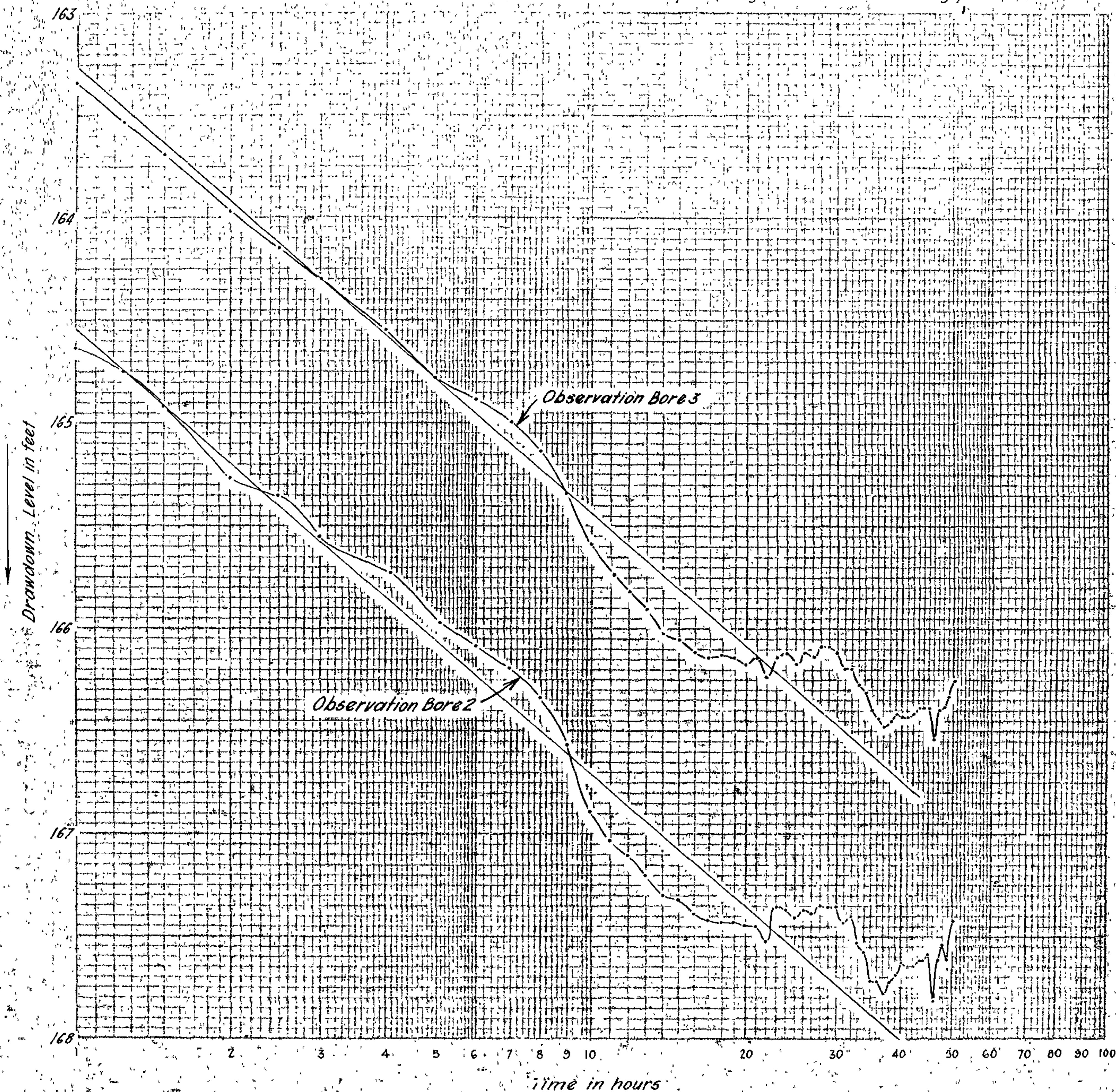


S. A. Dept. of Mines.

60-440
Ja13

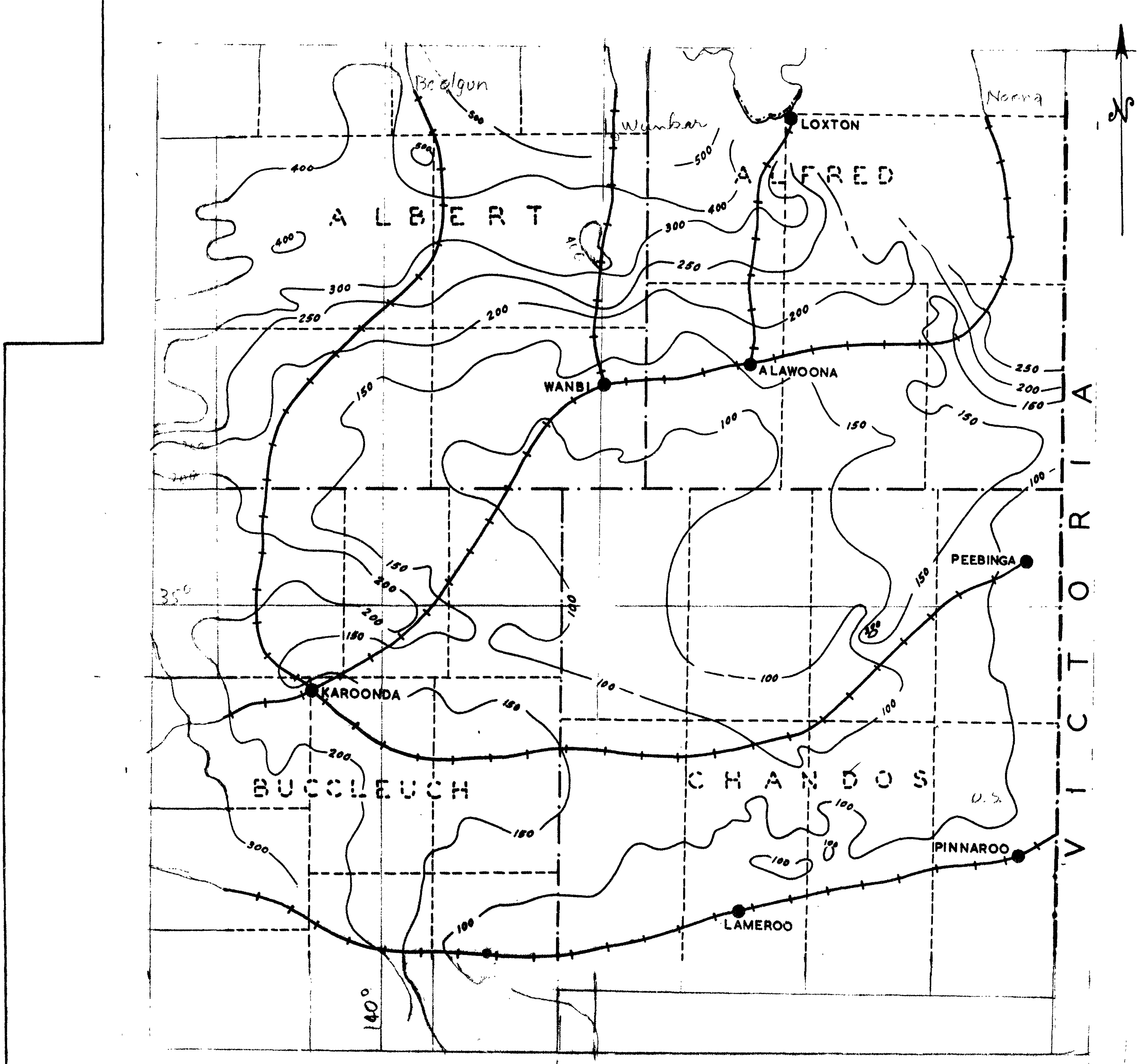
WANBI PUMP TEST

Drawdown Levels in Observation Bores under a pumping rate of 11400 g.p.h.



S. A. Dept. of Mines.

60-439
Ja 13



Recent - Late Tertiary Waters and Murray and Glenelg Group Waters —150—

Values in grains per gallon)

SCALE IN KILOMETRES

10 0 10

report by G. Crawford

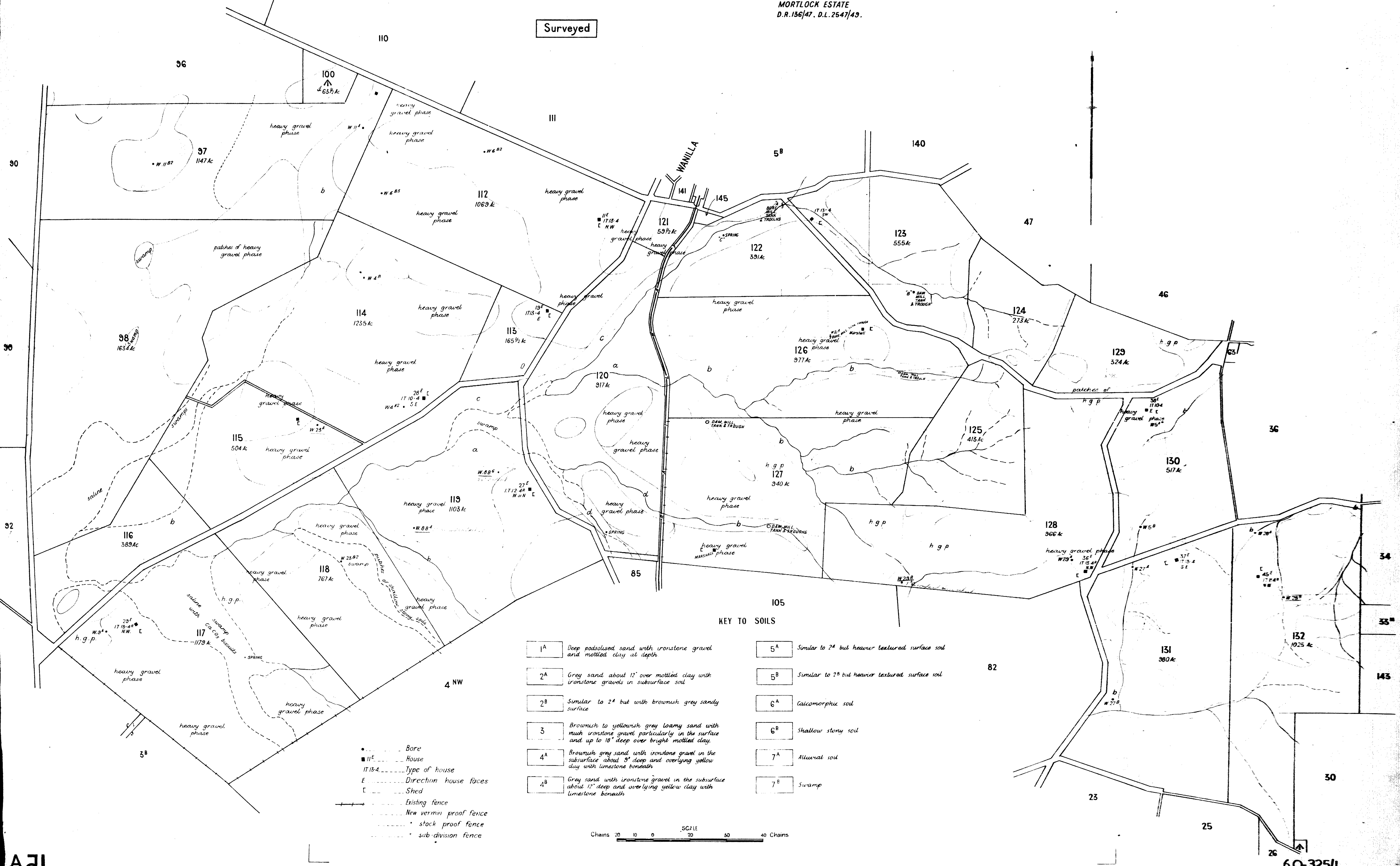
S.A. DEPARTMENT OF MINES

				WANBI TEST BORES	Approved	Passed	Scale : 8mls. to 1"
				SALINITY PLAN OF SURROUNDING AREA		Drn.	60-329
						Tcd. R.W.	Jcd
						Ckd. M.B.L.	
No.	Amendment	Exd.	Date		Director	Exd.	Date 24-6-60

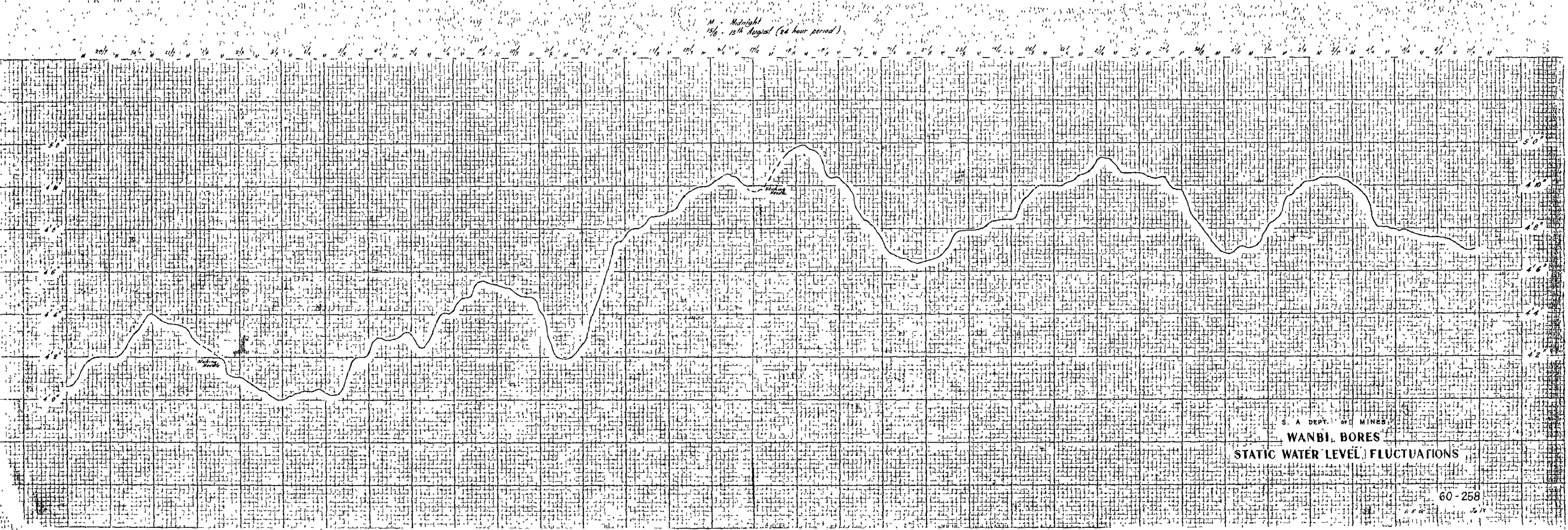
WANILLA

MORTLOCK ESTATE
D.R. 136/47. D.L. 2547/49.

Surveyed



60-3251I


M - Midnight
15/8 - 15th August (24 hour period)
S. A. DEPT. OF MINES
WANBI BORES
STATIC WATER LEVEL FLUCTUATIONS
60-258