COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES GEOLOGY AND GEOPHYSICS

RECORDS:

1966/80

NOTES ON A VISIT TO THE HYDROLOGY, ENGINEERING GEOLOGY AND SOILS SECTION, SOUTH AUSTRALIAN DEPARTMENT OF MINES, ADELAIDE, 5TH - 11TH DECEMBER, 1965.

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C O N T E N T S

SUMMARY

A visit to the Hydrology Section, South Australian Department of Mines has emphasized the need for systematic groundwater investigation in the Territory of Papua and New Guinea. Several techniques which may be of assistance to drillers in the Territory were observed and the correct procedure for developing and pump-testing water bores was discussed.

In the Engineering Geology Section importance is placed on careful attention to detail and the presentation of data in engineering terms.

INTRODUCTION

The Hydrology Section of the South Australian Department of Mines was visited between 5th and 11th December, 1965 in order to inspect and discuss recent developments in methods for the location and extraction of groundwater, with special emphasis on problems which have arisen in the Territory of Papua and New Guinea. In addition the opportunity was taken to visit several projects under investigation and to examine the work being carried out on foundation and damsite geology by the Engineering Geology and Soils Section of the Department of Mines.

HYDROGEOLOGY

The first essential in the investigation of the groundwater regime of any area is systematic investigation. Only by carefully recording data and carrying out tests can the presence, relationship and characteristics of the various water-bearing formations be found and used in the determination of location, depth, yield and quality of a proposed bore. This examination of the aquifer characteristics can be divided into six parts. (1) accumulation of data, (2) geological mapping, (3) drilling, (4) screening of bores, (5) development, and (6) test pumping. The importance of these elements were discussed in Adelaide and various procedures indicated which would enable a thorough and efficient survey to be made.

1. Accumulation of Data

The first step is the accumulation of as much data on the occurrence of water in the area under investigation as can be obtained. There is little sense in continuing with further work until this is completed. Of first importance is a reasonable topographic map on which the position, level and depth of all bores, wells and pits can be plotted. The reduced levels of static water in all excavations, together with diurnal and seasonal fluctuations and all pumping records and analyses of water quality should be recorded. Details of rainfall and streamflow indicate recharge as do water output figures from sewerage works and factories. The compilation of this data can be assisted by the distribution of questionaires and the compulsory registration of details of bores by private drillers.

2. Geological Mapping

Associated with the accumulation of data is the geological mapping of all outcrops and the logging and micropalaeontological examination of bore samples. From this work a general appreciation of the rock types and succession in the area can be obtained. This can be used in conjunction with the results of water levels and yield to indicate possible water-bearing horizons.

3. Drilling

Drilling, based on (1) and (2), can be specified (a) to confirm the geological succession and structure and (b) to penetrate and test the aquifers. Where shallow holes are required air or water jetting can be used; this method would be especially applicable to drilling in beach sands. In clayey material the use of an auger drill of the Gemco type would give best results.

For deep water bores either percussion or rotary drilling is employed. In difficult rock conditions, similar to the coarse gravel encountered in the Markham Valley, progress with a percussion rig is maintained by drilling the largest practicable diameter of hole using a double sinker bar. To prevent the hole moving off line the casing is kept up to the bit and metal guides are welded to the sinker bar. Occasionally an NX diamond drill hole is drilled ahead of the percussion hole and a 2 inch diameter steel rod welded to the face of the percussion bit as a guide.

In hard rock rotary drills are used with, if necessary, a down-hole jack hammer. A complete rotary drill rig with tools would cost in the region of $60,000 but a cable-tool percussion rig could be converted by the addition of a rotary table for about $20,000. Drilling rates depend on the formation being drilled and the skill of the operator but may reach 10 times the footage obtained from a percussion rig. Comparative drilling costs depend very much on drilling conditions.

4. Screening of Bores

During drilling, mechanical size analyses of samples from water-bearing formations are carried out to determine the aperture size of screens required. Normally the aperture size chosen is that which passes about 60% of the aquifer material. In gravels, coarse sands and fractured rocks, such as jointed sandstone and cavernous limestone, slotted casing may be necessary to protect the pump. In fine sands however a careful choice of screen size must be made. Three main types of screens can be used (1) wire-wound screens, (2) plastic screens, and (3) cemented sand screens. Wire-wound screens are the most commonly used type but are rather expensive for small water supply projects. They cost about $20 per foot for a 4" diameter screen, with an additional $60 for fittings. Plastic screens cost about 20% of wire screens but are less robust and have a smaller aperture area per foot of screens, which limits their use in narrow aquifers.

Cemented sand screens are being developed by A.M.D.L. (see references 1. 2. & 3) and consist of silica sand cemented by epoxy resin around a frame of copper rods. The cost of this type of screen is about $20 for a 3-foot screen, including fittings. Sand screens are intended for the extraction of water from fine sands and silts. The experimental work carried out so far has indicated that yields are fairly low but their cost may make them suitable for use for village water supplies in T.P.N.G. They are not yet in production commercially but could be easily constructed in the Territory.

A gravel-packed screen can be made by drilling a large diameter bore, inserting a 2" diameter spear point, dropping gravel round the spear and withdrawing the drill casing.

5. Development of Bores

When the correct size screen has been inserted in its position in the bore the hole must then be developed to enable the maximum amount of water movement into and out of the the bore to take place. Several methods can be used to achieve this including (1) pumping, (2) the use of mechanical surging equipment, (3) compressed air, (4) chemical additives and (5) explosives.

The simplest method of developing the bore is by repeated pumping which draws the finer sand into the bore and forms a natural filter bed around the screen. This process can be accelerated by the use of a solid or valve mechanical surger placed in the hole immediately above the screen (see reference 4). The surging is followed by bailing of the sand which has been drawn into the hole. By pumping compressed air into the hole a similar effect can be produced. The use of chemicals by the addition of a detergent such as Calgon (see appendix 1) or by acid reaction with 10% normal hydrochloric acid, can be extremely effective in some cases. All traces of these chemicals must be removed by pumping before water from the bore is used.

To have the maximum effect all development techniques must use a systematic method of pumping, surging and bailing. If these fail to produce sufficient water, as a last resort the screen can be withdrawn and an orientated charge of explosives detonated at the bottom of the hole in an attempt to open any fissures present. This step should only be taken if it is considered that otherwise the hole would have to be abandoned.

6. Test Pumping

When the hole has been screened and properly developed, the aquifer characteristics, determination of maximum safe yield and water quality can be determined. Samples for simple water quality testing would, of course, be taken from the hole before screening. The two main methods of pump testing are (1) the step-drawdown test where the pumping rate is increased in steps and (2) by prolonged pumping at a steady flow. If possible the step-drawdown test should be used as it will give a more accurate indication of the maximum safe yield from the aquifer. If observation boreholes are available a multiple stage test is not required as practically all relevant data can be obtained from the drawdown data in the observation borehole. The multiple stage test can be used to obtain information on the development of the borehole.

Once again systematic recording and presentation of data is required (see Appendix 2). To record flow an accurate water meter is needed and for details of drawdown and recovery an electric water depth probe is necessary. Water samples taken at regular intervals during the pump test will show whether water quality will be maintained when the bore is in use.

By the compilation of data from drilling, water level observation and test pumping, the overall aquifer characteristics for an area can be determined and used to estimate the position, depth, yield and quality of future bores in that area.

VISITS TO GROUNDWATER PROJECTS UNDER INVESTIGATION

In order to illustrate the principles discussed above, visits were made to three groundwater projects at various stages of investigation.

River Murray Drainage

Waikerie township, about 100 miles north-east of Adelaide, is the centre of a vine and stone-fruit growing area which is extensively irrigated by water pumped from the Murray River. The main problem caused by this irrigation is excess standing water, due to poor drainage, which kills the fruit trees. The poor drainage is caused by a clay layer which overlies porous limestone; by sinking drainage bores through this upper clay the excess water can be removed. Increasing irrigation and a decrease in the efficiency of the bores led to the present investigation to clarify the problem and recommend procedures for the removal of excess drainage water in the future.

The preliminary collection of data from the hundreds of bores in the area indicated that (1) the upper clay layer is not continuous and (2) several porous layers in the limestone are separated by marly zones of low permeability. Geological mapping and microfossil examination confirmed the succession and a number of holes were drilled with an air rotary rig to delimit the upper clay. It was found that many of the lower capacity drainage bores penetrated only the upper porous layers of the limestone and that deepening would increase their efficiency. Another reason for low drainage capacity.

was found to be siltation of the bores. This can be reduced by the installation of a series of settling tanks close to the bore. Tests are in progress to determine the results of washing the hole with Calgon detergent and by acid treatment with 10% normal hydrochloric acid as a means of developing new bores and improving old ones. It has not yet been decided whether it is more economical to drain an area with one large bore or a series of smaller drainage bores. The main advantage of the large bore is easier maintenance.

North Adelaide Plains

The development of market gardens around Virginia, about 20 miles north of Adelaide, has resulted in the sinking of numerous bores for water. Static water levels in the area have shown a steady decline with, in some plans, a reversal of hydraulic gradient which introduces the danger that water of high salinity will move into the aquifer.

Examination of the borehole data has shown that the water-bearing beds consist of an upper Mio-Pliocene aquifer separated from a lower Miocene aquifer by a thin clay layer. The upper aquifer contains good water but is thin or non-existent over much of the area. The lower aquifer carries good water near Virginia but is flanked to the north and south by highly saline areas and to the west by the sea. A lens of saline water which overlies fresh water close to the coast has not been enlarged as a result of the over-pumping of the aquifer and it is thought that it represents a previous shoreline of possibly mangrove swamp type.

A present there are in excess of 2,000 bores in the area (which is rapidly developing) and it is estimated that withdrawal by pumping considerably exceeds recharge. In an attempt to improve the water quality north of Virginia it is proposed to recharge the aquifer in the area with effluent water from Adelaide. In addition, by careful test-pumping, it is hoped to determine accurately the hydraulic characteristics of the aquifer and thus recognise danger areas where water extraction will have to be controlled.

Willunga Basin

Willunga, about 30 miles south of Adelaide, is the centre of the almond growing area. The yield from the trees can be doubled by proper irrigation and recently bores have been sunk to produce water for the purpose. However, results have been disappointing as water yields and quality range widely from bore to bore.

The Willunga Basin is composed of late Tertiary and Quaternary, partially unconsolidated, sedimentary rocks, in a faulted syncline of early Tertiary and older metamporhic rocks. The basin infilling consists of sand, silt and clay, with minor limestone. A preliminary examination of bore data has shown that the limestone, which produces most of the water, is not continuous and also that there are definite areas of good and poor water quality. Close to the Willunga Fault, which follows the south-eastern side of the basin, limestone is rare; fine sand predominates. The sand is commonly too fine for ordinary wire screens but may be suitable for the installation of cemented sand screens. The Palaeozoic slate and shale on either side of the basin give low water yields (less than 1,000 gallons per hour) from joints.

At present the investigation of the basin is in its early stages with siting of bores, regular measurement of water levels and sampling of water for analsis, with the intention of designing a programme to examine tne aquifer characteristics.

ENGINEERING GEOLOGY AND SOILS

The Engineering Geology and Soils Section gives advice on foundation conditions for large and small civil engineering works and also on problems related to slope stability, and location of aggregate. The emphasis is again placed on systematic collection of data, with careful geological mapping and testing before recommendations are made. As the results of these investigations will be used by engineers, geological descriptions are separated from engineering terms and many quantitive data, such as standard penetration test results, moisture content and relative density figures, are given. The soils are described in all cases under the 'Unified Soils Classification' (Reference 5). As there are a large number of minor foundation investigations for private dwellings the use of standard proformae help to reduce the time taken up by the work.

In damsite investigations detailed mapping is combined with supervision of all drilling and testing. One interesting development is the use of a simple borehole periscope for examination of rock structure in the first 20 feet of a drill hole.

VISITS TO ENGINEERING GEOLOGY PROJECTS UNDER INVESTIGATION

Adelaide Opera House

Two types of rigs are being used on this project. One is a normal small percussion rig and the other is a modified diamond drilling rig which uses the hydraulic feed to obtain push-tube samples of the sediments. Both rigs carry out regular standard penetration tests and with the diamond rig a complete succession of undisturbed, waxed tube samples are taken for soils laboratory tests. If the tubes encounter hard strata the diamond rig can be used for normal core drilling.

Kangaroo Creek Damsite

This damsite was originally investigated for a thin arch dam but further detailed mapping and the excavation of two adits on the left abutment has shown that, owing to the rapid downcutting of the gorge, relief of pressure has resulted in planes of weakness, commonly infilled by plastic clay, parallel to the valley sides. The weak zones vary in thickness but can be observed up to 80 feet into the hillside. As a result of this work it has been decided to construct a rock-fill dam on the site.

Sturt Dam

During investigation of the excavation for this arch dam a clay-filled, low-angle, joint was located in the right abutment and subsequently, during construction of the dam, movement of a fairly large rock mass along the joint confirmed that considerably deeper excavation was required than had been planned. In additions prestressed cables have had to be inserted in a part of the dam in which unacceptable tensile stresses could develop.

ACKNOWLEDGEMENTS

The co-operation of the Director of Mines and his staff, especially Dr. K.R. Miles, Mr. D.H. Stapledon, Mr. C. Bloys, Mr. R.G. Shepherd, Mr. G. Roberts, Mr. E.R. Hillwood, Mr. D.M. Watson, Mr. J. Wilson and Mr. R.R. Hanock, is very much appreciated.

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A P P E N D I X I

CALLGON TREATMENT FOR DEVELOPING WATER BORE

(1) Mix 36 lbs. Calgon to every 100 feet of water in bore, use a minimum of 1 drum of bag (80 lb) in any bore.

(2) Mix every 80 lb. drum of Calgon in 30 gallons of water.

(3) Lower 1"-$1\frac{1}{2}$" or $1\frac{1}{2}$" pipes to section of bore to be treated.

(4) Connect pump and pump in Calgon.

(5) Pump through enough water to clean pump and pipe.

(6) Pull pipes from bore.

(7) Connect solid surger to drilling string, lower to within 3 feet of top of screen or section being treated.

(8) Surge for 10 minutes every hour for 2 shifts, leaving bore stand (no surging) overnight.
Calgon should be in bore for 48 hours minimum.

(9) Bail out sludge and silt and develop supply by pumping.

Depending on strata being developed, it may be necessary to give bore a second Calgon treatment.

NOTE:

All surging must be carried out with surger working within 3 feet of top of screen or section being surged.

APPENDIX 2

MULTIPLE STAGE AND SINGLE RATE PUMP TEST PROCEDURE

1. Clean out and develop the bore by pumping at alternate high and low rates. This should be carried out until the water is free from suspended matter; it may take as much as one working day.

2. Allow the water level to <u>fully</u> recover to original level.

3. From provisional pumping rates used in 1. determine the approximate maximum rate of discharge over a short period, of say 1 day (x gallons per minute).

4. Pump at a rate of $\frac{1}{4}$x gallons per minute for exactly 100 minutes taking water levels every minute from 0 to 10 minutes, every 2 minutes from 10 to 30 minutes and every 5 minutes from 30 to 100 minutes.

5. Increase pumping rate immediately at 100 minutes to $\frac{1}{2}$x gallons per minute and repeat the procedure in section 4.

6. Increase pumping rate immediately at 200 minutes from start to $\frac{3}{4}$x gallons per minute and again repeat the procedure in section 4.

7. Increase pumping rate immediately at 300 minutes from start to maximum rate and repeat the procedure in section 4.

8. Stop pumping and allow the water level to recover completely

9. Pump again at a rate between $\frac{3}{4}$x and x gallons a minute repeating the procedure in section 4, and continuing on from 100 minutes to at least 7,200 minutes reading the water level every 50 minutes.

10. Shut off valve completely allowing the pump to run on to keep the column full of water. From time of shutdown measure recovery levels every minute for the first 30 minutes and thereafter every 5 minutes.

11. The rate of discharge should be regularly checked and recorded throughout the tests in sections 1 - 9 by means of a water meter set in the system between the pump and valve.

12. Always start the pump with the valve shut.

13. Only electrical depth probes should be used for water level measurements.