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A Pilot Study of Hydraulic Fracturing used on Low Yielding Wells in the Basement Rocks of Masvingo, Zimbabwe.

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2

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Contents

EXECUTIVE SUMMARY

In Masvingo, Zimbabwe 12 low-yielding wells were treated with hydraulic fracturing. In 50% of the cases well yield was increased by an average of 80% in the range 10 to 240%.

Costs of hydraulic fracturing are low and the technique is relatively simple to use. It is recommended that hydraulic fracturing is used as a matter of routine on low-yielding wells. This will reduce the average cost of redrilling by almost one half.

Masvingo has one of the highest rates of drilling failures in Zimbabwe. It is likely that elsewhere, hydraulic fracturing will be even more successful.

Routine pumping test techniques were shown to be difficult to use to estimate yields of wells in these low transmissivity aquifers. A new different type of test is recommended for future work.

1. AIMS

Basement aquifers are important in the arid and semi-arid regions of the world because of (a) their widespread extent, (b) there are no alternative water supplies and (c) as yet only about 30% of the rural population has access to clean water. Occasionally high yielding wells (>5 l/sec) can be drilled in basement, these wells tap highly fractured zones or dykes. Unfortunately the locations where this can be done are few. Basement aquifers are more commonly exploited by drilling slim (4-8" ϕ) boreholes to about 30 or 40 m depth at the point of need using geophysical siting techniques in the hope that the water-filled fissures will be struck and a handpump can be installed. Median yields of these wells are about 0.3 l/sec. However, a large number of dry holes are drilled (10-50%; Wright et al., 1989).

Hydraulic fracturing (HF) is a technique in regular use by the oil industry for increasing the yield of very deep wells in consolidated sedimentary formations. **It was the aim of the project described to determine how effective HF can be in increasing the yields of water supply boreholes drilled in relatively low-yielding basement rocks to fairly shallow depths.**

2. PROJECT ORGANISATION AND LOGISTICS

The Ministry of Energy and Water Resources Development (MEWRD) have responsibility for hydrogeological research for the Government of Zimbabwe. The MEWRD collaborated with the British Geological Survey (BGS) to carry out a pilot project to assess the value of HF. The MEWRD provided an off-the-shelf HF unit, the Atlas Copco Aquasplit HFU-140, and technical staff and BGS provided hydrogeological supervision, borehole geophysics and drilling expertise. Sixteen low-yielding boreholes, drilled in the Masvingo area of Central Southern Zimbabwe, were visited by the project team. Twelve boreholes were treated in September and October 1990 and 4 of the sites were either badly constructed or were of such dimensions the HFU-140 could not be used.

Masvingo was selected because it has one of the worst records of borehole success in Zimbabwe (30-40% with yields <0.1 l/sec) and it had also been the subject of an earlier detailed hydrogeological study by BGS (Wright et al., 1989).

The Overseas Development Administration (ODA) provided funds for BGS involvement and MEWRD funded their own inputs.

3. HYDRAULIC FRACTURING

HF is illustrated in Figures 1 and 2. Figure 1 is stylised, in reality little is known about the geometry of fractures in the geometry of Basement which will probably change from place to place. In addition, there may or may not be a weathered zone and the water table may be within it or in the fractured hard rock beneath. HF is achieved by setting a packer or pair of packers near the base of the borehole. Water is then injected beneath the top packer at great pressures in the hope of creating fractures which will then increase the permeability of the rocks near the borehole and/or connect the borehole with the network of fractures which occur naturally in the rock.

The HFU-140 had several sets of packers made up of separate rubber rings suitable for 4" to 6½" boreholes. For example, the 145 mm packer set could expand to 155 mm. The packers are expanded using a handpump, which can supply pressures up to 700 bars, and the water is injected through the packer up to

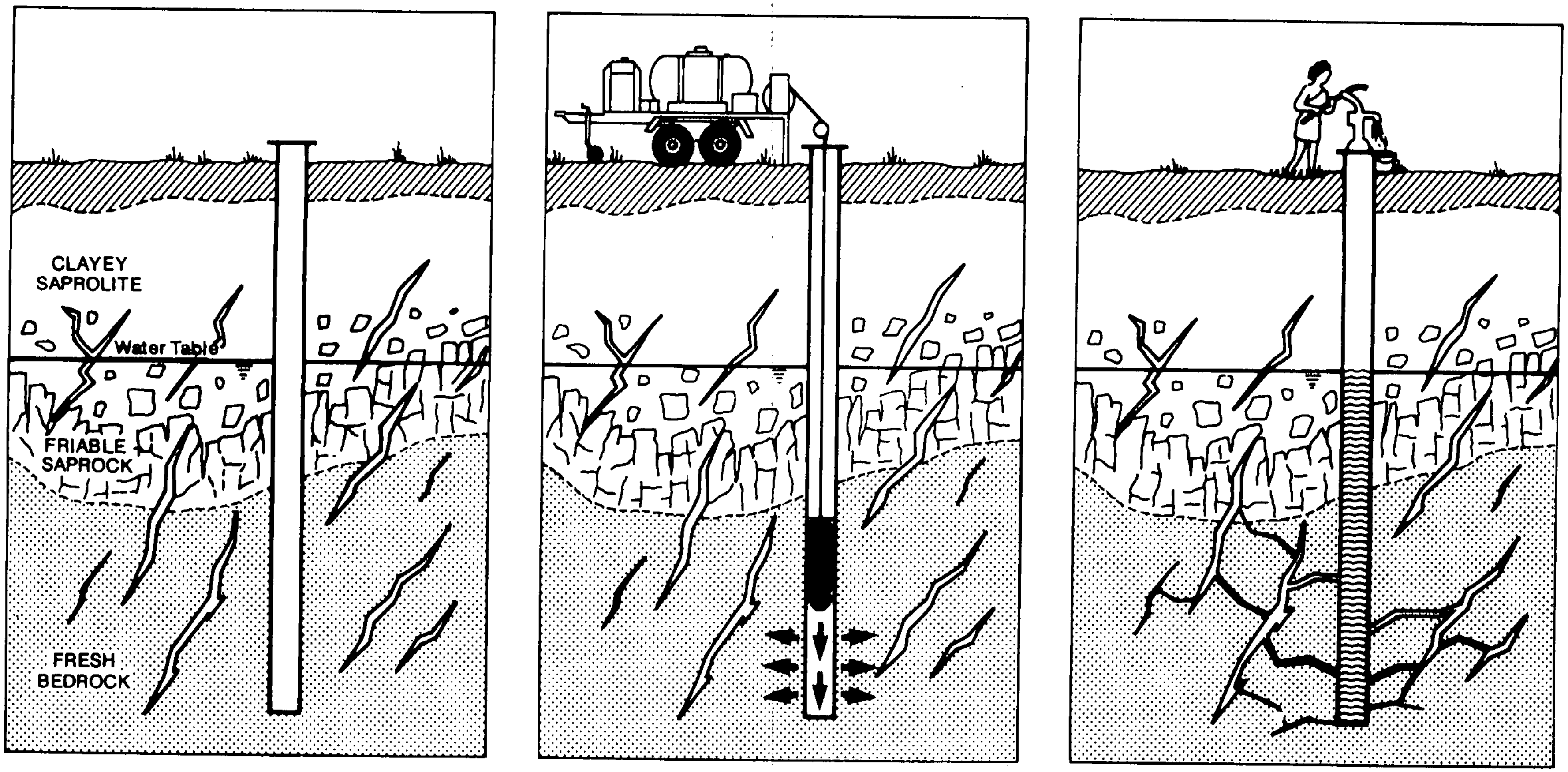


Fig. 1. A Representation of the Hydraulic Fracturing Process.

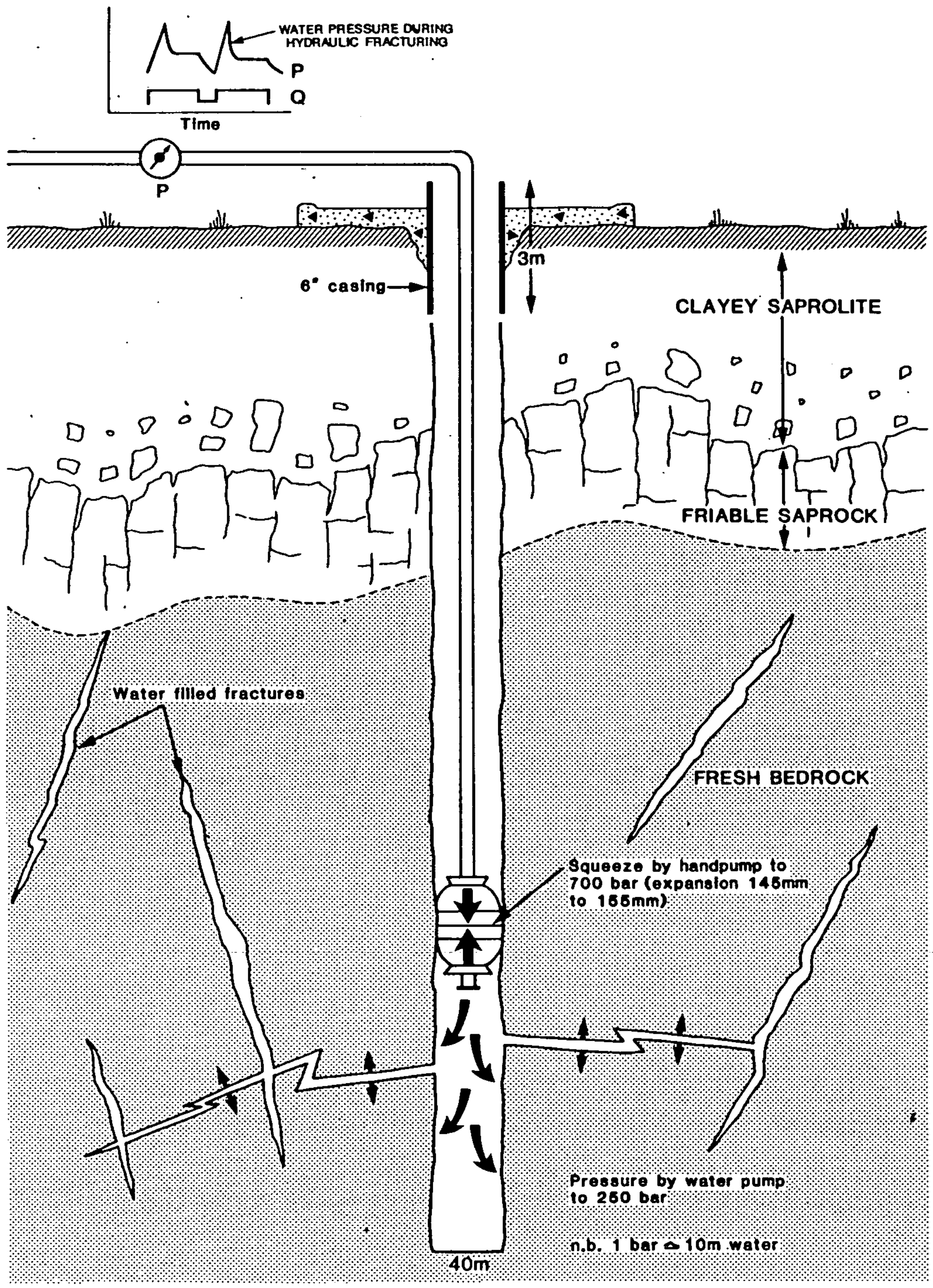


Fig. 2. The Typical Situation when Hydraulic Fracturing in Masvingo.

250 bars or 2500 m head of water. This head is more than sufficient to 'lift' 40 m of saturated rocks.

Using the HFU-140, HF proper takes only about 1 or 2 hours. This includes the lowering and setting of the packer, injection of water at different rates and levels and removal of packers.

A tripod and winch or crane are necessary to remove and replace any existing handpump. This process can take up to two hours.

The packers can only expand in diameter by about 10 mm. This means it is essential to run a down-hole caliper log before packing begins because if there is any internal obstruction in the borehole or the upper casing is too small in relation to the borehole diameter below, the packer will not be able to bind to the borehole.

For the reasons given above a down-hole logging kit is desirable. In addition to needing to know the borehole construction details, the packers must not be set within or near to the upper weathered zone. If this is done HF can cause collapse of the borehole and destroy its usefulness. The full depth of weathering is identified most easily using an SP log or any resistivity log, however, the caliper log was almost as useful. Logging will be discussed in more detail later. A full suite of down-hole logs could be achieved in about one hour. This includes setting up the winch. The logging equipment can be carried in the back of a Landrover.

4. PREVIOUS WORK

HF of wells is a matter of routine in the oil industry and is well reported (Mallinger et al., 1964; Veatch, 1983), in the main, deep consolidated, sedimentary rocks are involved. It is to be expected that the results of HF will be significantly different for crystalline rocks which are the main interest of this study.

HF of water wells in crystalline rocks is becoming more common. Smith (1989) reports on the American experience. There are several American contractors offering HF equipment and services for the water well industry, Flexifrac and Kyle Equipment are two such companies.

Bonnet et al (1989) describe a pilot study, which is similar to this one, which was carried out on 21 village wells in Burkino Faso using American equipment. They report that HF increased yields by a factor of 1.4 to 3.6. Before treatment, four of the wells were dry and six others had yields less than 0.14 l/sec. This report echoes others which report on HF on crystalline wells. Whilst these reports are few in number, all seem to suggest about 100% success for HF. This high success rate for the water industry was achieved without using propants. Propants are widely used by the oil industry when using HF (Mallinger et al., 1964). Propants are of various materials, sand, glass beads, etc which are suspended in the injection fluid in the hope that they will embed themselves in any new cracks and so keep them open when the injection pressure is released. Propants were not used in this project for simplicity of use and because of the reported success of HF without them.

The main difference between this project and earlier ones is that it is probably the first trial held in West Africa and it is sited where there is a particularly high incidence of borehole failure.

5. PUMPING TESTS

The HFU-140 used was supplied with an electric submersible pump and generator which could deliver about 2 l/sec from 30 m. The delivery main was 1½" ϕ and the whole unit could be lowered down the borehole using a winch, also on the HFU-140.

At each borehole, test pumping was done before and after HF for two reasons, (a) to assess the improvement of well yield as a result of HF and (b) to gain insight into the hydraulic properties of the groundwater system.

The pumping of boreholes in low transmissibility aquifers (the situation in this project) has special characteristics not usually met by hydrogeologists. Appendix A describes a brief study of such behaviour. The important things to note are:

(a) If the borehole is pumped above a critical rate, Q_c, the borehole will run dry before contribution from the aquifer can significantly reduce rates of drawdown in the well. For the particular case of a confined aquifer:

$$Q_c \;=\; 1.26\,\ell T$$

where ℓ is the depth of water in the borehole and T is the transmissivity of the aquifer. If Q_c is exceeded, as it generally is during hand-pumping in the Masvingo area, the total volume of water available to the villagers is the volume of water in the borehole, $\pi r_c^2.\ell$, where r_c is the radius of the well.

After exhausting the well the villagers must then wait for water levels to recover, this time of recovery, t_R, is given for a homogeneous unconfined aquifer by:

$$t_R \;=\; 1.5\, r_w^2\, \ell n \left(\left(\frac{\ell}{r_w}\right)\right) /T \quad \text{(for 90\% recovery)}$$

where r_w is the radius of the open borehole and ℓn denotes naperian logarithm.

(b) Because of (a) above the villagers will only be able to identify the effectiveness of HF by the more rapid rate of recovery of water levels.

(c) Also, because of (a) above, the long-term pumping tests carried out for this project, which were designed to determine aquifer properties and the possible maximum long term volume that could be pumped daily per well, both before and after HF, had to be run at a very low rate. The rate chosen was about 2 l/minute. The apparent T of the aquifer, see Section 7.1, was typically 0.2 m^2/day, which is equivalent to a Q_c of 5.70 m^3/day or 4.0 l/min for a saturated thickness of 20 m.

(d) The throttle to the discharging main was on the surface at the well head. In the first test carried out the non-return valve in the discharge main was not working and allowance had to be made for the fact that it would take 2 or 3 minutes to fill the discharging main when pumping at the pump's natural discharging rate of 2 l/sec. In all the other tests a volume of water equal to the volume of discharge main was added to the well just prior to pumping to try to avoid this difficulty.

(e) Because of the long times of recovery in low T aquifers it was noticed that insertion of the pump and rising main below the water in the borehole caused a significant rise in water level which took several hours to recede. For this reason the pumping test had to be set up one day before the actual pumping test was run.

5.1 Assessing the Improvement of Well Yield

There are many ways the yield of a well can be quantified. It is important to note that there is one way it cannot be done: if the well yield is greater than Q_c then neither the rates of pumping nor the drawdowns observed will be affected by aquifer properties. In very low yielding aquifers, like those at Masvingo, normal hand-pumping rates are greater than Q_c. Accordingly, the drawdown phase of pumping tests where Q_c is exceeded give no useful information about well yield or aquifer properties.

For the purpose of this project the following procedure, based on the long-term pumping test, was used.

A plot was made of s/Q, s is drawdown in well, versus log time for both tests before and after HF. A straight line plot was eventually established, the slope of which should be the same for both tests and is a measure of the 'regional' T value. These lines were then projected graphically until the maximum drawdown available could be attained and the time, t_{max}, to do this noted. The total volume of water, V_{max}, that can be extracted was given approximately by:

$$V_{max} = t_{max} . Q$$

V_{max}, before and after HF, can be compared to give one measure of the improvement of well yield resulting from HF.

Appendix C shows many such s/Q vs. log t plots. They often consist of two parts. An early part where the plots before and after HF are the same, when well storage is the sole source of water and a later part when the well treated by HF will give lower values for s/Q than those for the untreated well.

5.2 Special Modelling Studies

Typical borehole water level responses for pumping tests in low yielding aquifers were modelled for cases where a weathered layer did or did not exist and where HF had or had not created a more permeable zone immediately around the well. These results are presented in Appendix B and were used to help interpret the pumping test results carried out and to confirm the relationships developed in Appendix A reported earlier.

6. FULL FIELD PROCEDURE ADOPTED AT EACH BOREHOLE

A routine was adopted for the testing and HF of each borehole. Figure 3 summarises the procedure. Three days were required per site. On the first day the handpump was pulled, the borehole was logged, the test pump was installed and the throttle was set so as to yield the correct rate. The water levels were left to recover overnight. On the second day, the borehole was pumped for five hours or until a plot of drawdown versus log time showed a rising straight line. This slope was indicative of the regional value of T. The well was then subjected to HF and finally the pump was reinstalled and the pumping rate reset. Water levels were left to recover overnight. On the third day the pumping test was repeated, the well was relogged and the handpump was reinstalled. Several annotated photographs are presented showing various aspects of the field procedure.

7. RESULTS

Sixteen wells were visited. Of these one had collapsed internally and could not be treated and three others had man-made linings and also could not be treated. Thus, hydraulic fracturing was attempted on 12 wells in the Masvingo region. Appendix C presents the results in some detail.

7.1 Pumping Tests

Table 1 summarises the findings from the pumping tests carried out in each well.

The very low pumping test rates, which were used to ensure a long period of pumping, caused problems in interpretation. In particular the performance of the well was affected by the storage in the delivery main and this caused a fluctuation in discharge during the early part of the test. Allowance has been made for this in the Amended Results section of Table 1. In all, six of the wells showed an improved yield after hydraulic fracturing. The increases in yield are relatively modest but each bucket of water represents about half the daily supply for one family.

Appendix C gives plots of drawdown versus log time observed in the wells for all the long-term pumping tests carried out. Almost all the plots give a straight-line plot for long times and Jacob's well known straight-line method was used to calculate T values. Back analysis using these T values shows that well storage could still be affecting these plots and so the values given for T in Appendix C should be treated as being only very approximate. Further work is continuing on the interpretation of these results.

The experience above shows that traditional long time constant rate test techniques used by hydrogeologists are not really appropriate for measuring low yielding handpumped well performance. A simpler method is recommended below for the future.

7.2 Borehole Logging

To date numerous studies have been undertaken into hydraulic fracturing but the geophysical investigation of the formations has been limited. Previously these fracturing exercises had been used extensively for the simulation of oil producing boreholes, however more recently, investigations to increase the yield of low production water boreholes penetrating crystalline formations, has gained popularity.

HYDROFRAK PRGM

Pull the handpump Log the well Install test pump&set rate	DAY 1

WATER LEVELS RECOVER

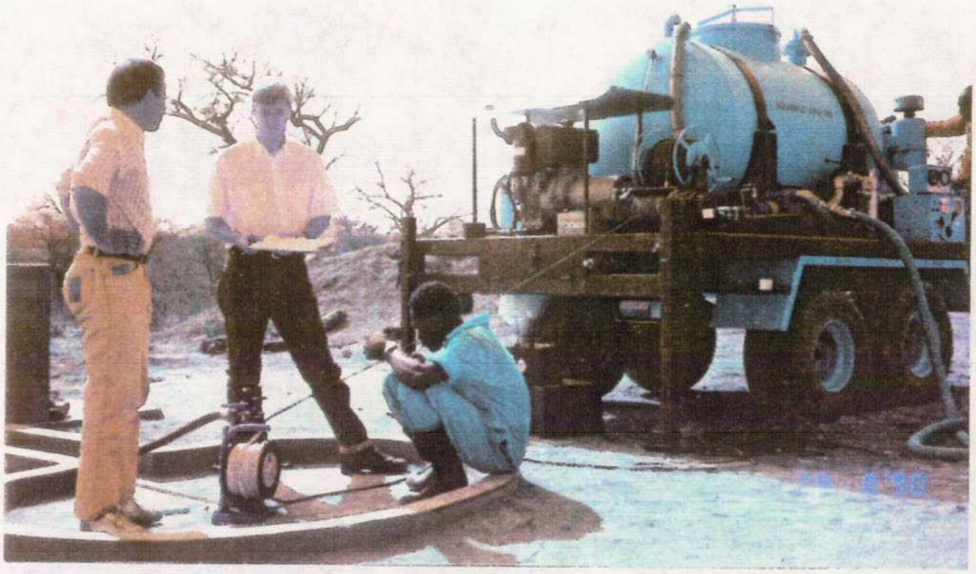
Test pumping for 5hrs Hydrofrak Reinstall pump & set rate	DAY 2

WATER LEVELS RECOVER

Re-test pumping for 5 hrs Re log the well Replace handpump Move site	DAY 3

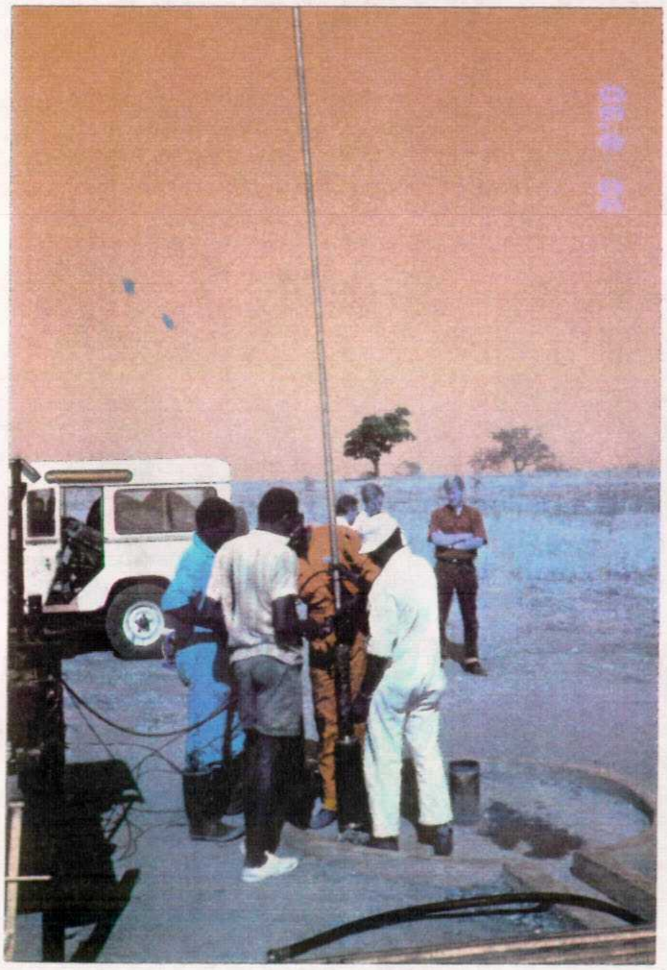
Fig. 3. The Programme of Work adopted at Masvingo.

PHOTOGRAPHS SHOWING SOME OF THE ACTIVITIES CARRIED OUT DURING HYDRAULIC FRACTURING IN ZIMBABWE

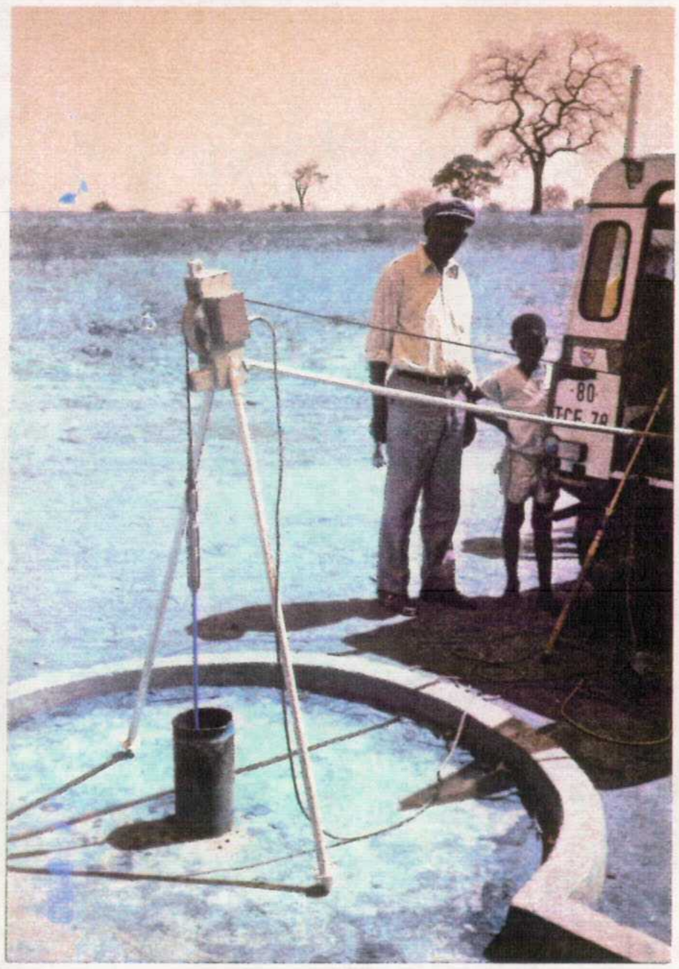


The Hydraulic Fracturing Unit during a pumping test. The unit's generator drives the submersible pump

DAY 1: Discharge during the long pumping test. Rate set at 2 l/min.



DAY 2: Extracting the packer after hydraulic fracturing.



DAY 3: Logging the well after the second pump test.

Table 1. Summary Results of Hydraulically Fractured Wells

Location	Water table below weathered zone	Double packers used?	APPARENT RESULTS % Increase in specific capacity	% Increase in pumpable capacity	No. of extra 20 litre buckets	AMENDED RESULTS Major	Improvement	No change	Worsened
Maramba*	No	No	15	11	78	√			
Mhatiwa	No	No	-61	-41	-11				√
Mhatiwa Valley*	No	No	-12	-194	-19			√	
Zvirikuresch	Yes	Yes	179	124	66	√			
Shazhaume	?	Yes	26	59	3		√		
Guiding Star	Yes	No	42	64	19		√		
Cikadzi**	Yes	Yes	-270	-1020	-			?	
Kuwirirana*	Yes	No	116	241	17	√			
Mashava***	Yes	No	-	-	-			√	
Sarahuru	No	No	9	24	9		√		
Chimbudzi***	Yes	No	-	-	-			√	
Masogwe*	No	No	-38	-34	-9			√	

NB: In total 16 wells were visited, 1 was collapsed and out of use and 3 were lined and could not be treated.

* If, before and after, plots of s/Q are superimposed for early times, as they should be (see text), there would be a significant improvement in results. This is reflected in the column 'Amended Results.

** The pre-HF pumping test dewatered a major fracture which did not fill before post-HF test, therefore performance of HF impossible to judge at this site.

*** Wells too dry, before and after HF, to carry out pumping tests.

Pilot studies with hydraulic fracturing in Zimbabwe have showed that if the packers were set within the weathered zone the hole walls could collapse causing the hole to be abandoned.

It is therefore essential to delineate the depths of weathering prior to hydraulic fracturing. Previous investigations had shown that the degree of weathering can be indicated by a few simple geophysical logging methods, namely natural gamma radiation, normal resistivities, caliper and neutron-neutron. The response of the natural gamma radiation log is predominated by the potassium content of the formation and analysis of the gamma response has shown the highest count rates to be observed within the increased clay content weathered formations. Surface conduction within these clay minerals dominates the resistivity response with low resistivities being recorded within weathered formations. These characteristic responses enables the depth of weathering to be delineated. Thus, a variety of borehole logging techniques can be used to ensure that the packer is placed below weathered rock and against structurally sound rock. Generally the junction between saprolite (weathered) and saprock (partially weathered) is abrupt and hence the more mechanically competent formation may be easily differentiated.

Borehole rugosity, as indicated by the caliper log, will indicate the more significant fractures penetrated by the borehole. This study was sited in an area where only minor fractures occurred and these were not easily identified using caliper logs. There was an indication from this study that these minor fractures can be identified on the resistivity logs as significant discrete reductions in the background resistivity, or horizons of increased porosity on the neutron log. Some weathering may be indicated on permeable fractures with a zone of reducing resistivity being observed above the fracture. Generally weathering is not observed below these productive fractures. On the other hand, there was no discernible difference in borehole logging recordings taken before and after hydraulic fracturing. This is not really surprising when it is realised that permeability of a fracture is related to the third power of fracture width and hence only minor changes need occur to produce significant increases in well yield.

In conclusion, the usefulness of geophysical logging may be limited to the use of resistivity and caliper to determine the borehole geometry and to determine the depth of weathering. In any event, a full suite of borehole logs were taken before and after hydraulic fracturing at each well visited and these are presented in the Appendices.

8. COSTS

The costs of a three-day hydraulic fracturing exercise have been estimated below.

The 1990 costs of the HFU-140 is £58,000.

Assuming (a) the life of the unit is 10 years, (b) annual maintenance runs at ca. 5%, (c) the interest rate of 8% and (d) 100 wells could be treated per year, the present value of this unit/well is **£77.5.**

Local labour (1 supervisor and 2 men) costs are ca. **£20** per well.

The 1990 logging equipment cost (assuming caliper and resistivity tools only) is about £18,000. Assuming the same maintenance and interest rates as for the HFU-140 leads to a present value of logging equipment/well as **£24.0.**

A hydrogeologist would be required to run the logger and do the pumping tests. This cost per well might be **£100**.

Thus, the total cost of HF per well in the manner described in this report is about **£221**. Minor costs for fuel and transport of HFU to site have not been included.

Alternatively, if HF is carried out in a more routine manner, that is to say the HF is always attempted at the base of the well, and no logging or senior staff are involved, the HF cost per well would reduce to **ca. £100**.

The 1990 cost of drilling a new 40 m deep well is about £1,050. Allowing for 40% failure rate, the average drilling cost to ensure a successful replacement well would be ca. £1,470.

8.1 Hydraulic Fracturing vs. Redrilling

In the Masvingo area about 40% of well yields are too low. Also, it seems, hydraulic fracturing will be about 50% successful in increasing their yield. Alternatively, sufficient new wells could be drilled to improve the situation at an average cost of ca. £1,500. The comparable average cost of HF, followed by new drilling in cases when HF is not successful, is ca. £850.

Thus, it is clear that even in areas like Masvingo, where it is thought to be particularly difficult to employ HF successfully, HF should be used as a first measure on all failed wells consequently reducing overall redrilling costs significantly.

9. CONCLUSIONS AND RECOMMENDATIONS

Hydraulic fracturing, without using propants, will increase the yield of about 50% of the low yielding wells drilled in basement in the Masvingo area. In other, more prolific areas, there may be a much higher frequency of success.

Recommendation 1: In Masvingo the results of Table 1 show that, when HF was successful, well yield was increased by 10 to 240% with an average of 80%. If the wells being considered are very dry and this degree of increase in yield will still not meet demand it is probably better to relocate and redrill the well without using HF on the old dry well.

Recommendation 2: Costs of HF are low and it is recommended that it is used as a first measure on all non-dry, failed wells. This will reduce the average 1990 cost of redrilling from £1500 to ca. £850.

A study of the hydraulics of wells in low transmissivity aquifers shows there is a critical yield, Q_c, which if exceeded will result in emptying the well without any significant contribution from the aquifer.

Recommendation 3: When yields of wells are to be assessed, it is recommended that yields greater than Q_c are used and the period of recovery of water level is monitored. The type and time of recovery will indicate the type of aquifer and the daily well yield better than the more usual long-term pumping tests used for this study. They will also take less time in the field and non-specialist staff can be used.

Borehole logging is useful to identify existing borehole construction and the thickness of weathering. It does, however, require skilled staff and is relatively costly. Also, the effects of HF could not be ascertained by any of the probes used in any of the six successfully treated wells.

Recommendation 4: Because of the two reasons above, it is recommended that borehole logging is not used as a matter of routine in every-day HF application.

Recommendation 5: It is recommended that the HFU-140 is continued to be used in other areas than Masvingo and its success rate monitored.

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APPENDIX A

Borehole Behaviour in Low Transmissivity Aquifers

A1. Predicting the rate of pumping Q_c, which will dry the well rapidly.

Papadopulos and Cooper (1967) have published type curves illustrating the drawdown vs. log time relationships which occur in wells in confined aquifers and which have a relatively large diameter. Inspection of these curves shows that, very approximately, almost all water pumped comes from well storage for a time, t_c, after the start of pumping providing:

$$t_c < 2.5\ r_w^2/T \qquad \text{... A1}$$

where r_w is the well radius.

If ℓ is the initial length of the water column in the borehole and it is pumped at rate Q the time taken to pump the well dry (ignoring contributions from the aquifer) will be:

$$t = \pi r_w^2 \ell/Q \qquad \text{... A2}$$

Equating A1 and A2:

$$Q_c > 1.26\ell T \qquad \text{... A3}$$

Where Q_c is the pumping rate, which if exceeded, will ensure a borehole is pumped dry before the aquifer makes a significant contribution.

Note that A3 is approximate: strictly it only applies to confined aquifers. Further work is required to refine this relationship for other aquifers and to allow for the large drawdowns necessary. In an unconfined aquifer drawdowns will be rapid and it is likely there will be little change in position of the water table so that Equation A3 will be fairly accurate.

A2. Time to recover water levels after pumping dry.

Figure A1 shows the situation in a borehole just 'pumped dry' in an unconfined homogeneous aquifer. This would be very like the situation for boreholes in basement (crystalline) rocks where the water table was below the weathered zone.

Hvorslev (1931) shows that the rate of flow q into a borehole with dimensions shown in Figure A1 is given approximately by:

$$q = 2\pi\ell kh/\ln(\ell/D + \sqrt{1 + (\ell/D)^2}) \qquad \text{... A4}$$

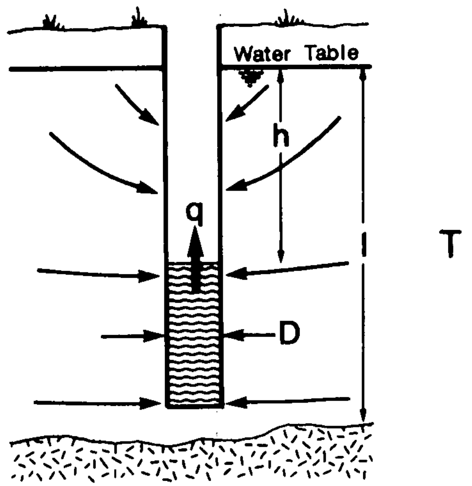

Fig. A1 - The recovery phase of a well in an unconfined aquifer.

Also, we can write:

$$qdt = -\pi r_w^2 dh \qquad \text{... A5}$$

Equating A4 and A5 and integrating from $h = \ell$ and $h = 0.1\ell$ (for 90% recovery) then the time taken to recover by 90% after being pumped dry, t_{90}, is given roughly by:

$$t_{90} = r_w^2.1.15\ell n(2\ell/D)/T \qquad \text{... A6}$$

where $T = k\ell$.

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APPENDIX B

Modelling Borehole Performance

B1. The flow system in hard rocks.

The real flow system to a well in hard rocks is extremely complex. The aquifer is heterogeneous on a very small scale. The aquifer may be patchy, i.e. the well may be in a locally heterogeneous patch of high or low permeability (it may or may not hit the fissure system). The aquifer may be layered. The water table may or may not be in the less permeable, upper, more weathered portion of the weathered layer. The thickness of weathering varies enormously. In fact, each well's flow system will be unique.

B2. Situations modelled.

A finite-difference digital model (Herbert and Kitching, 1981), which simulates time variant radial flow to a well, was used to study well behaviour in several representative flow situations. The idealised flow system studied is shown in Figure B1.

In the first set of results the water table was assumed to lie below the weathered layer and the saturated zone was 20 m thick. In the second set of results the water table was set in the low permeability, weathered layer 10 m above the hard rock. The parameter values used in these simulations are given below in Table B1.

Table B1. Parameter Values for Pumping Test Simulations.

Parameters: Units:	Q l/min	k_1 m/day	k_2 m/day	k_2' m/day	S_1 (-)	S_2 (-)	S_y (-)	Q_c l/min	Expt. No.
SET 1: Water table in hard rock									
	2	-	0.01	0.00033	-	0.00001	0.005	0.11	21
	2	-	0.2	0.0066	-	0.00001	0.005	2.3	22
	2	-	0.1	0.01	-	0.00001	0.005	3.5	23
	2	-	0.2	0.2	-	0.00001	0.005	69.5	24
	2	-	0.01	0.3	-	0.00001	0.005	106	25
SET 2: Water table in weathered layer									
	2	0.0072	0.00024	0.000008	0.00001	0.00001	0.2	1.8	4
	2	0.0072	0.00024	0.00024	0.00001	0.00001	0.2	2.0	5
	2	0.0072	0.00024	0.0072	0.00001	0.00001	0.2	5.6	6
	2	0.0072	0.216	0.0072	0.00001	0.00001	0.2	5.6	7
	2	0.0072	0.216	0.216	0.00001	0.00001	0.2	114	8

In Table B1, Q_c has been calculated as shown in Appendix A, $Q_c = 1.25\ell T$ where ℓ = total saturated thickness and $T = (10k_1 + 20\ k_2')$.

Figures B2 and B3 show the results of the simulations. These results confirm that if Q_c is exceeded then the aquifer contributes no significant water to the well during the drawdown phase, thus giving weight to the findings of Appendix A. Experiment numbers 21, 22, 4 and 5 are straight lines.

Figure B4 replots the results of Experiment numbers 7, 23 and 24 as semi-log plots. All these results are influenced by aquifer properties. Plots 7 and 23 on Figure B4 are almost the same. This suggests that aquifer properties near the well will strongly influence short-term behaviour of the well.

It should also be noted that in every simulation, except for those which had exceptionally high T values, the early time-drawdown behaviour is governed by well storage and is equal for all cases.

Reference.

Herbert, R and Kitching, R 1981. Determination of aquifer parameters from large-diameter dug well pumping tests. Groundwater, 19, 593-599.

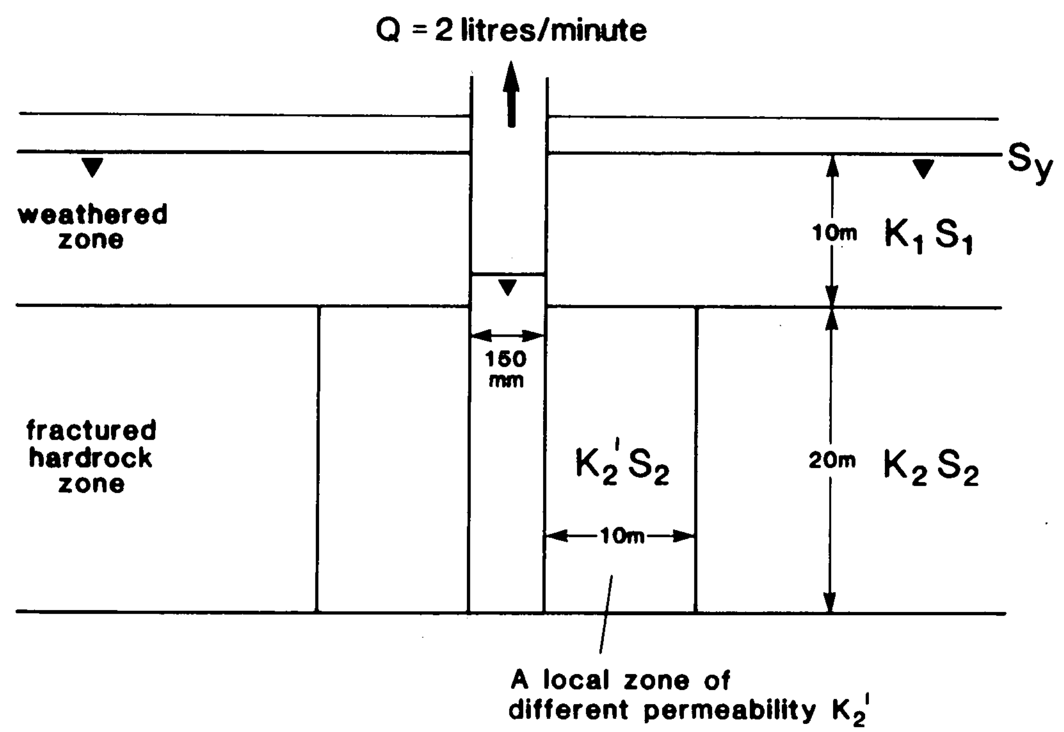


Fig. B1 – The Idealised Flow System Modelled

Figures B2 and B3 show the results of the simulations. These results confirm that if Q_c is exceeded then the aquifer contributes no significant water to the well during the drawdown phase, thus giving weight to the findings of Appendix A. Experiment numbers 21, 22, 4 and 5 are straight lines.

Figure B4 replots the results of Experiment numbers 7, 23 and 24 as semi-log plots. All these results are influenced by aquifer properties. Plots 7 and 23 on Figure B4 are almost the same. This suggests that aquifer properties near the well will strongly influence short-term behaviour of the well.

It should also be noted that in every simulation, except for those which had exceptionally high T values, the early time-drawdown behaviour is governed by well storage and is equal for all cases.

<u>Reference.</u>

Herbert, R and Kitching, R 1981. Determination of aquifer parameters from large-diameter dug well pumping tests. Groundwater, 19, 593-599.

26

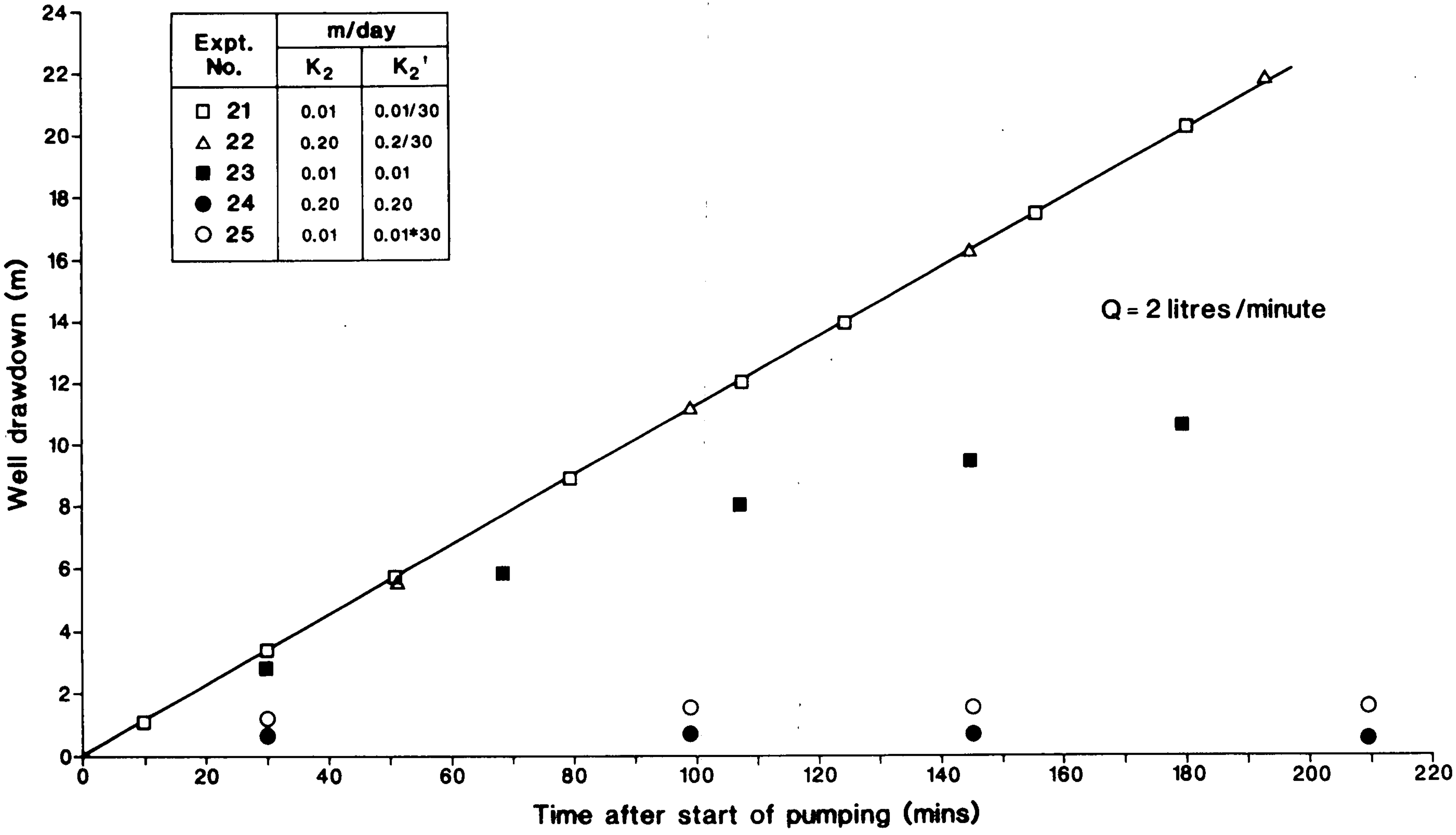


Fig. B2 – Modelled Well Behaviour (no weathered layer)

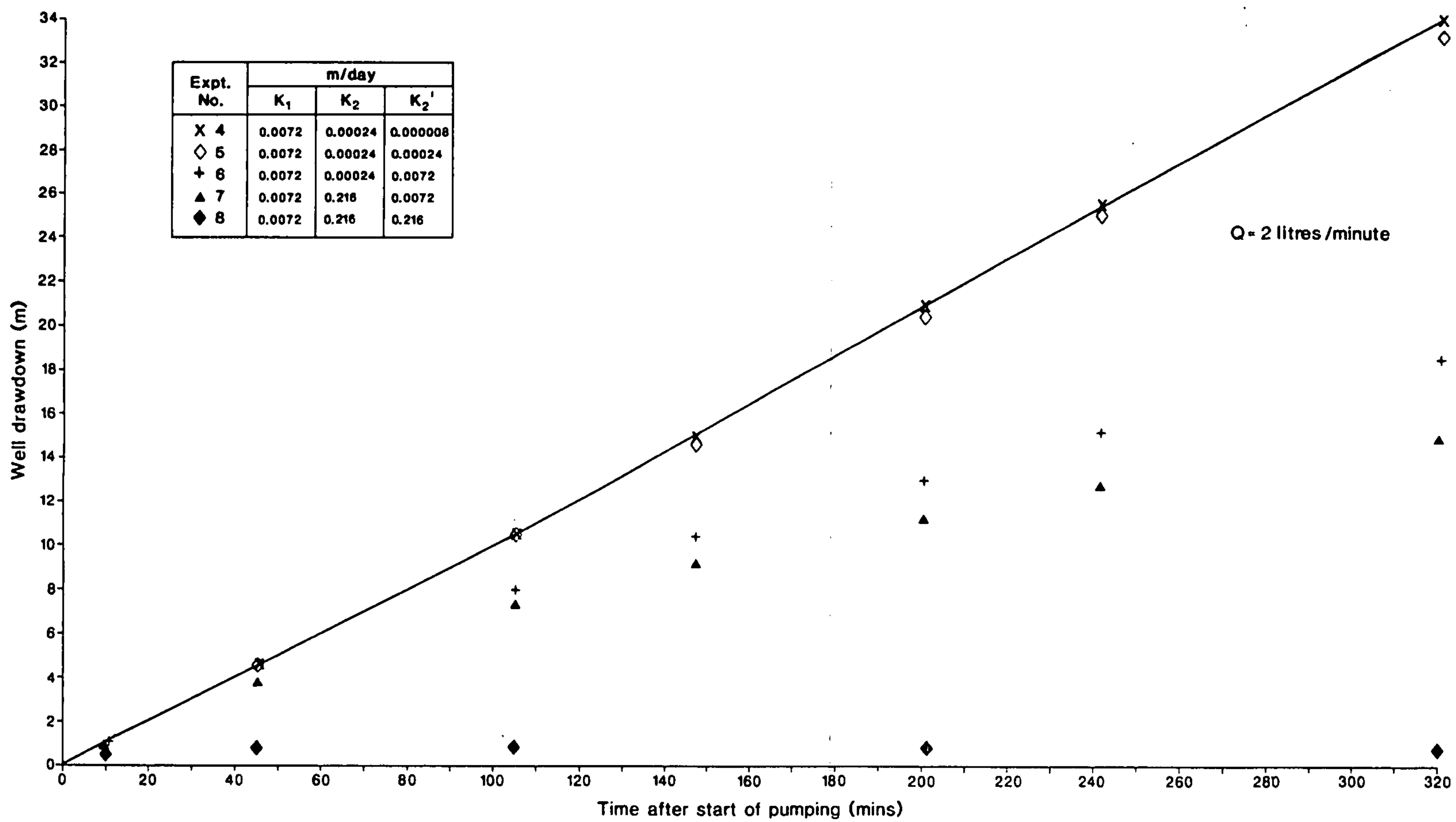


Fig. B3 - Modelled Well Behaviour (with weathered layer)

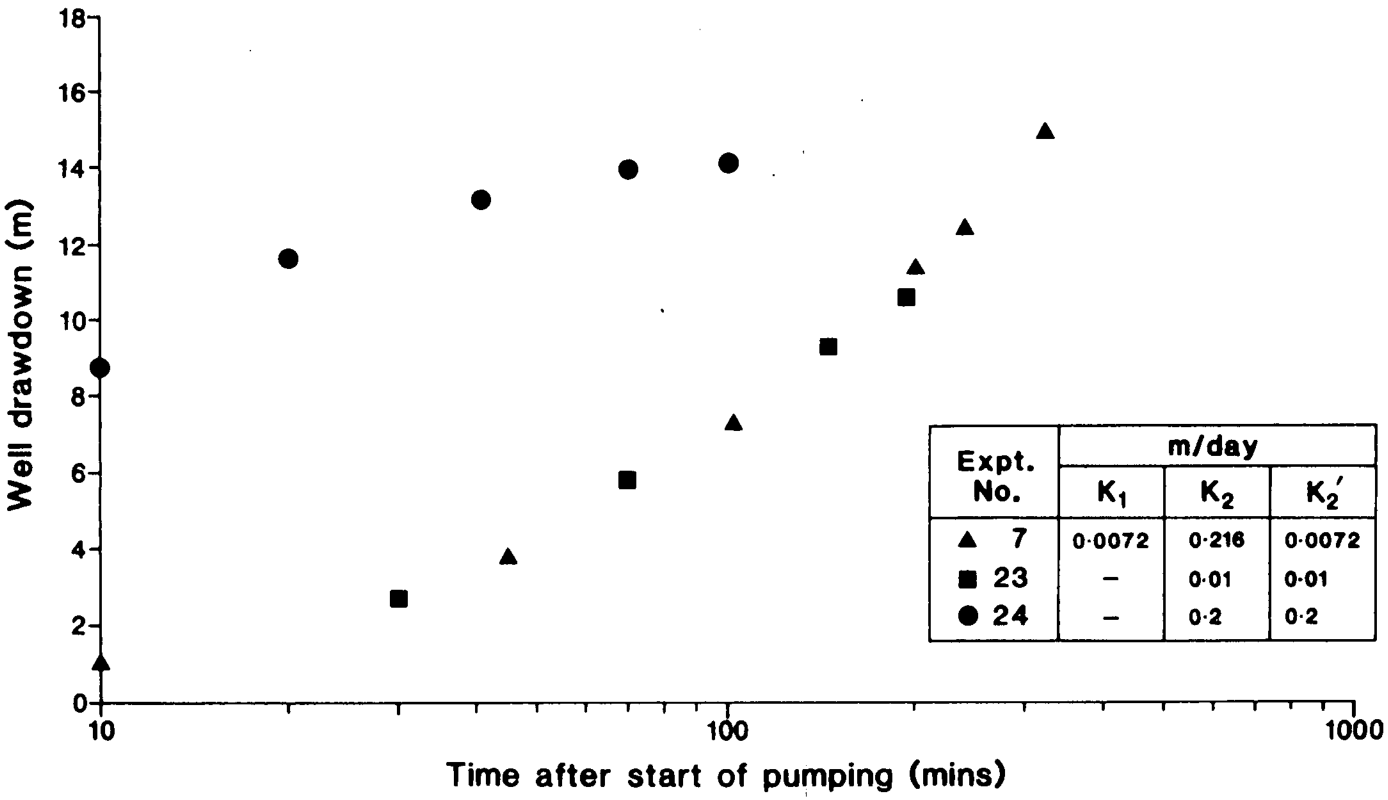


Fig. B4 – Modelled Well Behaviour

APPENDIX C

Field Results

Site :-
Maramba School

Grid Ref. :-
TN 228683

Sequence of Events :-

28/08/90 Bushpump removed
Borehole logging

29/09/90 Test pump installed

30/08/90 Pumptest
Test pump removed
Hydrofracturing

31/08/90 Borehole logging
Test pump installed

01/09/90 Pumptest
Test pump removed
Bushpump replaced

Notes :-

Logging Results :-
Depth of borehole is 44.5m and base of weathering is at approximately 24m. A fracture can be seen at about 32m depth which is unimproved by HF.

Hydrofracturing Results :-
Single packer used with 145mm rubbers. Packer set at 35m where the pressure peaked at 100 bar with running pressure of 40 bar. Packer moved to 30m where the pressure did not build up beyond 50 bar.

Water quality :-
Water before hydrofracturing EC = 770 µS/cm
Water from tank injected EC = 300 µS/cm
Water after hydrofracturing EC = 800 µS/cm

Pumptest Results :-
Pre pumptest lasted the full 300 minutes with a total drawdown of 6.352m at a pumping rate of 0.0352 l/s. Post pumptest lasted the full 300 minutes with a total drawdown of 4.237m at a pumping rate of 0.0271 l/s.

Transmissivity values were 0.083 m^2/day before HF and 0.077 m^2/day after HF, a decrease of 8%.

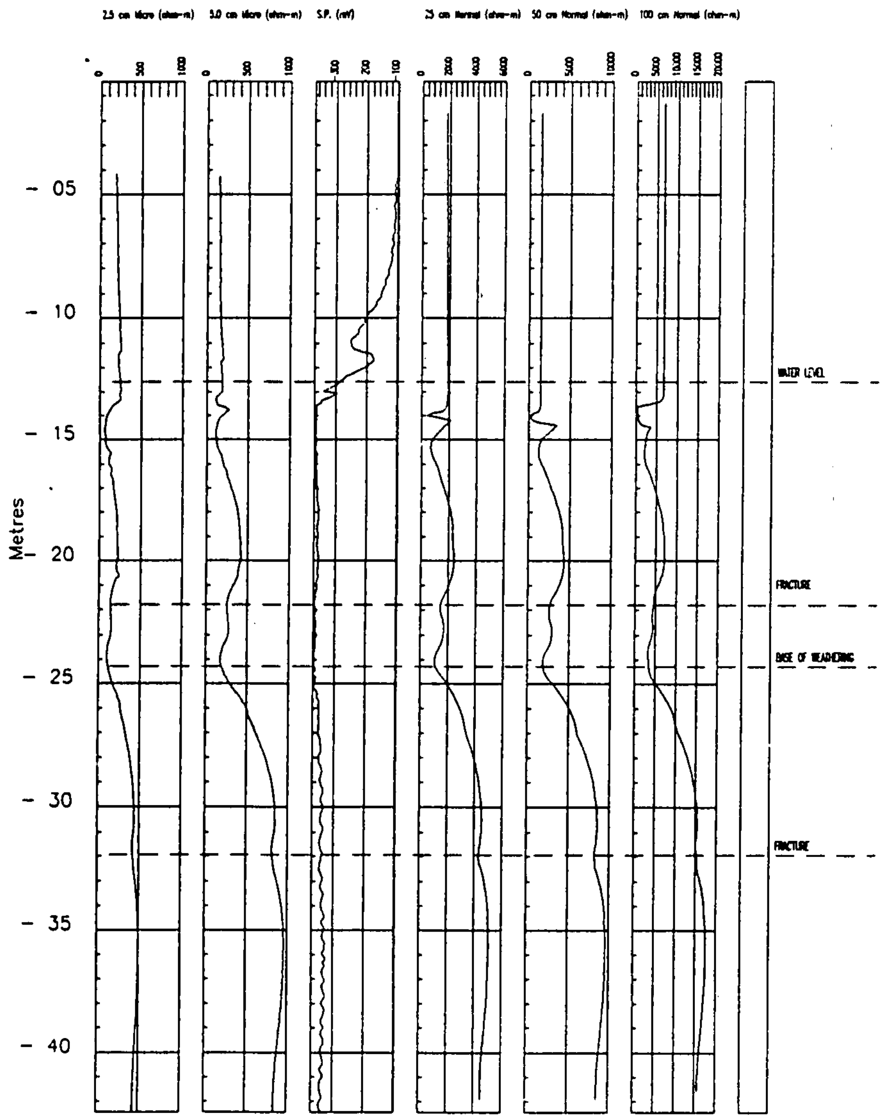
Specific capacity values after 300 minutes pumping were 0.479 m^3/day/m before HF and 0.553 m^3/day/m after HF,an improvement of 15%.

Predicted time to reach the base of weathering (25m) before HF is 1726 minutes giving a volume pumped of 3645 litres, and after HF is 2483 minutes giving a volume pumped of 4037 litres, an improvement of 11%.

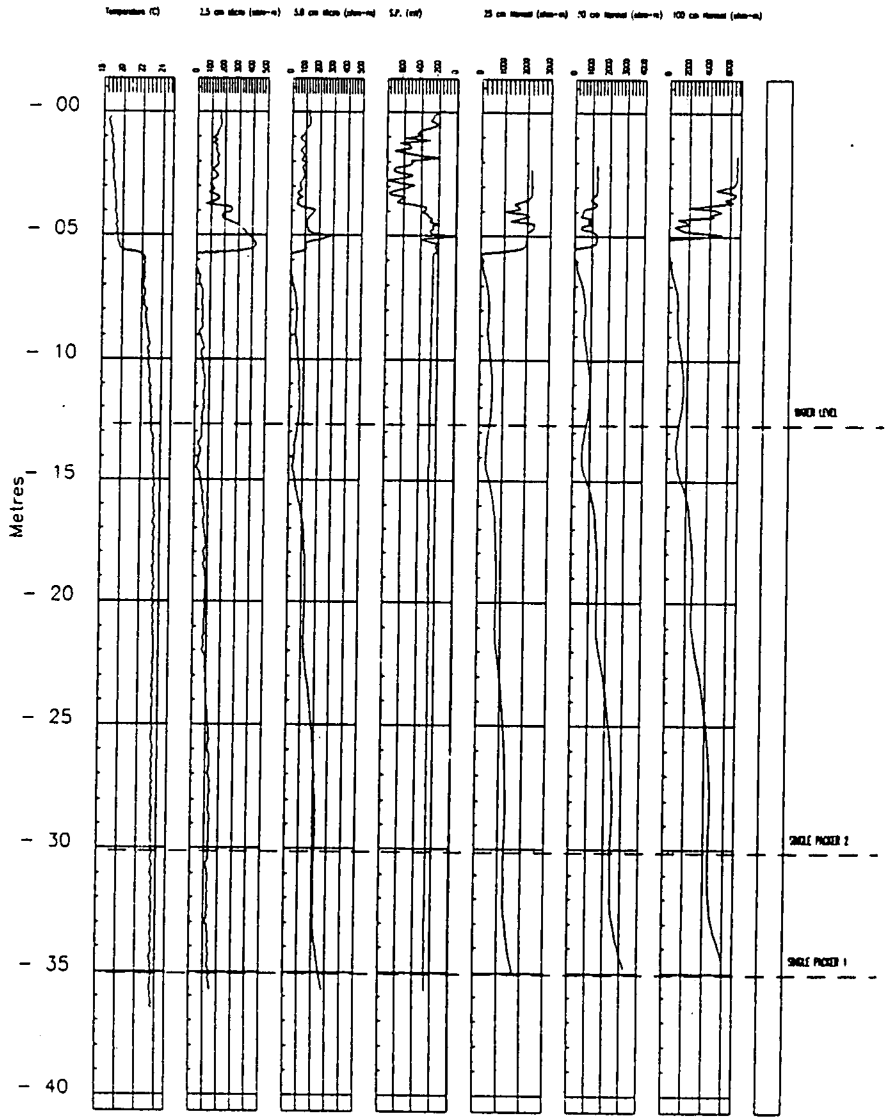
Special Remarks :-
The pumptests for this borehole were unique in operation, at all sites but this a volume of water was added to the borehole prior to pumping to compensate for the volume which had to be pumped initially at a high rate to fill the rising main until the gate valve came into play and throttled down the pumping rate.

It can be argued that s/Q should be the same for early times of both pumping tests i.e. they are unaffected by aquifer properties. If this was done the apparent borehole improvement is much greater than that calculated above.

Wellname MARAMBA SCHOOL
Filename MARAM1
Location Zimbabwe TN 228683
Elevation 0 Reference



Wellname MARAMBA SCHOOL
Filename MARAM2
Location Zimbabwe TN 228683
Elevation 0 Reference



PUMPING TEST - DRAWDOWN DATA

PROJECT: ZIMBABWE
LOCATION: MARAMBA SCHOOL
DATUM POINT: TOP OF CASING
PUMPING RATE: 0.0352 L/S
AQUIFER THICKNESS:
CONDITIONS: UNCONFINED

FILE NO.: BEFORE HF
WELL NO.: 1
ELEV. OF DATUM POINT:
STATIC WATER LEVEL: 12.640
R = ----- FROM
SCREEN INTERVAL: TO

TIME			ELAPSED TIME	WATER LEVEL	DRAWDOWN	(Q)
DY	HR	MN	t (MIN)	(m)	s (m)	(L/S)
30	9	0	0.00	12.640	0.000	0.0352
30	9	1	0.50	13.281	0.641	0.0352
30	9	1	1.00	13.324	0.684	0.0352
30	9	2	1.50	13.357	0.717	0.0352
30	9	2	2.00	13.392	0.752	0.0352
30	9	3	2.50	13.436	0.796	0.0352
30	9	3	3.00	13.468	0.828	0.0352
30	9	4	3.50	13.512	0.872	0.0352
30	9	4	4.00	13.550	0.910	0.0352
30	9	5	4.50	13.584	0.944	0.0352
30	9	5	5.00	13.622	0.982	0.0352
30	9	6	6.00	13.694	1.054	0.0352
30	9	7	7.00	13.763	1.123	0.0352
30	9	8	8.00	13.831	1.191	0.0352
30	9	9	9.00	13.898	1.258	0.0352
30	9	10	10.00	13.964	1.324	0.0352
30	9	12	12.00	14.093	1.453	0.0352
30	9	14	14.00	14.213	1.573	0.0352
30	9	16	16.00	14.334	1.694	0.0352
30	9	18	18.00	14.423	1.783	0.0352
30	9	20	20.00	14.508	1.868	0.0352
30	9	22	22.00	14.587	1.947	0.0352
30	9	24	24.00	14.664	2.024	0.0352
30	9	26	26.00	14.740	2.100	0.0352
30	9	28	28.00	14.817	2.177	0.0352
30	9	30	30.00	14.888	2.248	0.0352
30	9	32	32.00	14.959	2.319	0.0352
30	9	35	35.00	15.063	2.423	0.0352
30	9	40	40.00	15.223	2.583	0.0352
30	9	45	45.00	15.375	2.735	0.0352
30	9	50	50.00	15.521	2.881	0.0352
30	10	0	60.00	15.776	3.136	0.0352
30	10	10	70.00	15.983	3.343	0.0352
30	10	20	80.00	15.992	3.352	0.0352
30	10	30	90.00	15.993	3.353	0.0352
30	10	40	100.00	15.993	3.353	0.0352
30	11	0	120.00	16.118	3.478	0.0352
30	11	20	140.00	16.398	3.758	0.0352
30	11	40	160.00	16.880	4.240	0.0352
30	12	0	180.00	17.352	4.712	0.0352
30	12	20	200.00	17.702	5.062	0.0352
30	12	40	220.00	18.089	5.449	0.0352
30	13	0	240.00	18.315	5.675	0.0352
30	13	20	260.00	18.559	5.919	0.0352
30	13	40	280.00	18.784	6.144	0.0352
30	14	0	300.00	18.992	6.352	0.0352

PUMPING TEST - DRAWDOWN DATA

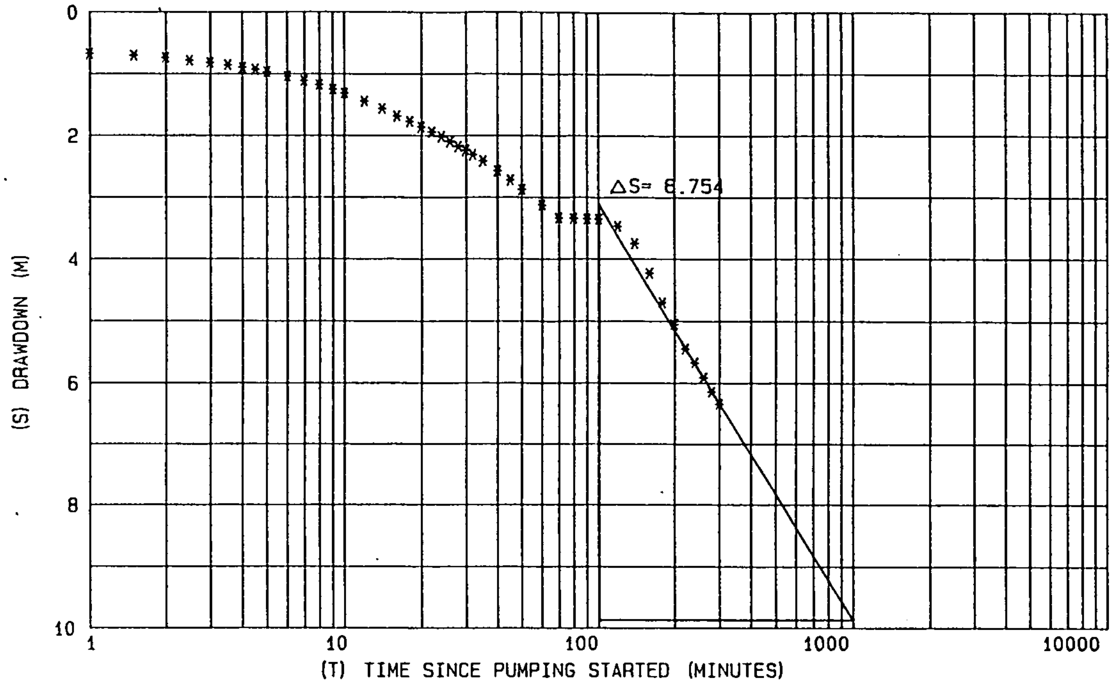
PROJECT: ZIMBABWE
LOCATION: MARAMBA SCHOOL
DATUM POINT: TOP OF CASING
PUMPING RATE: 0.0271 L/S
AQUIFER THICKNESS:
CONDITIONS: UNCONFINED

FILE NO.: AFTER HF
WELL NO.: 1
ELEV. OF DATUM POINT:
STATIC WATER LEVEL: 12.725
R = ----- FROM
SCREEN INTERVAL: TO

TIME			ELAPSED TIME	WATER LEVEL	DRAWDOWN	(Q)
DY	HR	MN	t (MIN)	(m)	s (m)	(L/S)
1	9	0	0.00	12.725	0.000	0.0271
1	9	1	0.50	14.000	1.275	0.0271
1	9	1	1.00	14.063	1.338	0.0271
1	9	2	1.50	14.061	1.336	0.0271
1	9	2	2.00	14.076	1.351	0.0271
1	9	3	2.50	14.095	1.370	0.0271
1	9	3	3.00	14.110	1.385	0.0271
1	9	4	3.50	14.130	1.405	0.0271
1	9	4	4.00	14.150	1.425	0.0271
1	9	5	4.50	14.170	1.445	0.0271
1	9	5	5.00	14.190	1.465	0.0271
1	9	6	6.00	14.228	1.503	0.0271
1	9	7	7.00	14.265	1.540	0.0271
1	9	8	8.00	14.296	1.571	0.0271
1	9	9	9.00	14.332	1.607	0.0271
1	9	10	10.00	14.365	1.640	0.0271
1	9	12	12.00	14.433	1.708	0.0271
1	9	14	14.00	14.495	1.770	0.0271
1	9	16	16.00	14.552	1.827	0.0271
1	9	18	18.00	14.610	1.885	0.0271
1	9	20	20.00	14.661	1.936	0.0271
1	9	22	22.00	14.709	1.984	0.0271
1	9	24	24.00	14.757	2.032	0.0271
1	9	26	26.00	14.804	2.079	0.0271
1	9	28	28.00	14.850	2.125	0.0271
1	9	30	30.00	14.892	2.167	0.0271
1	9	32	32.00	14.931	2.206	0.0271
1	9	35	35.00	14.978	2.253	0.0271
1	9	40	40.00	15.065	2.340	0.0271
1	9	45	45.00	15.146	2.421	0.0271
1	9	50	50.00	15.224	2.499	0.0271
1	10	0	60.00	15.364	2.639	0.0271
1	10	10	70.00	15.500	2.775	0.0271
1	10	20	80.00	15.623	2.898	0.0271
1	10	30	90.00	15.736	3.011	0.0271
1	10	40	100.00	15.849	3.124	0.0271
1	11	0	120.00	15.995	3.270	0.0271
1	11	20	140.00	15.992	3.267	0.0271
1	11	40	160.00	15.993	3.268	0.0271
1	12	0	180.00	15.993	3.268	0.0271
1	12	30	210.00	16.076	3.351	0.0271
1	12	40	220.00	16.125	3.400	0.0271
1	13	0	240.00	16.233	3.508	0.0271
1	13	20	260.00	16.420	3.695	0.0271
1	13	40	280.00	16.660	3.935	0.0271
1	14	0	300.00	16.962	4.237	0.0271

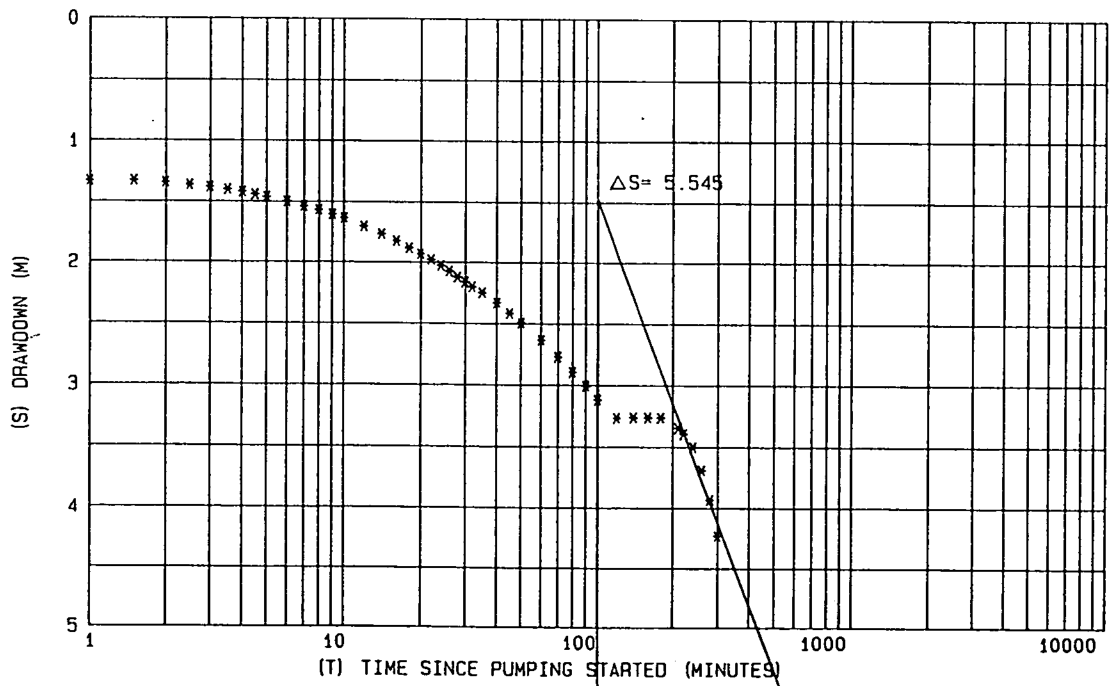
33

PUMPING TEST ANALYSIS   STRAIGHT LINE APPROXIMATION METHOD



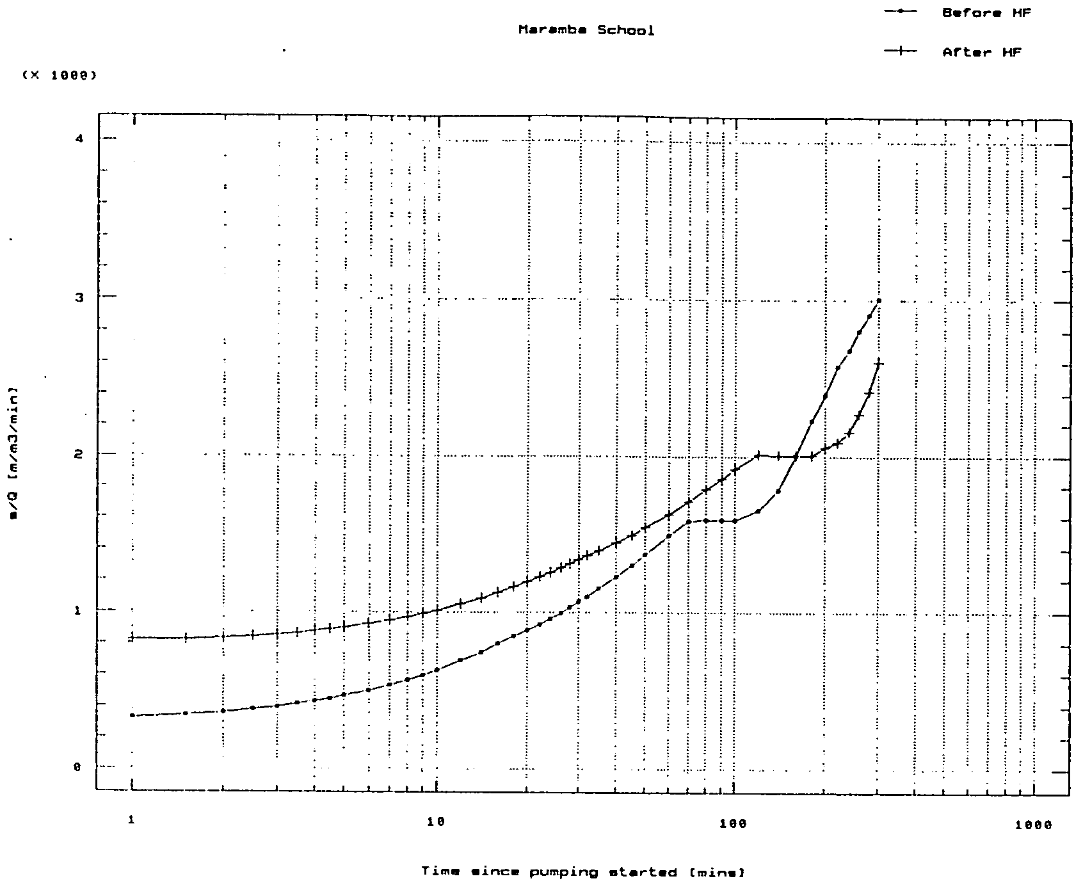
PROJECT: ZIMBABWE FILE: BEFORE HF LOCATION: MARAMBA SCHOOL	WELL NO.: 1 Q= .0352 L/S S.W.L.= 12.640	ΔS= 6.754 M T= .083 M2/DAY S=
BRITISH GEOLOGICAL SURVEY		FIGURE

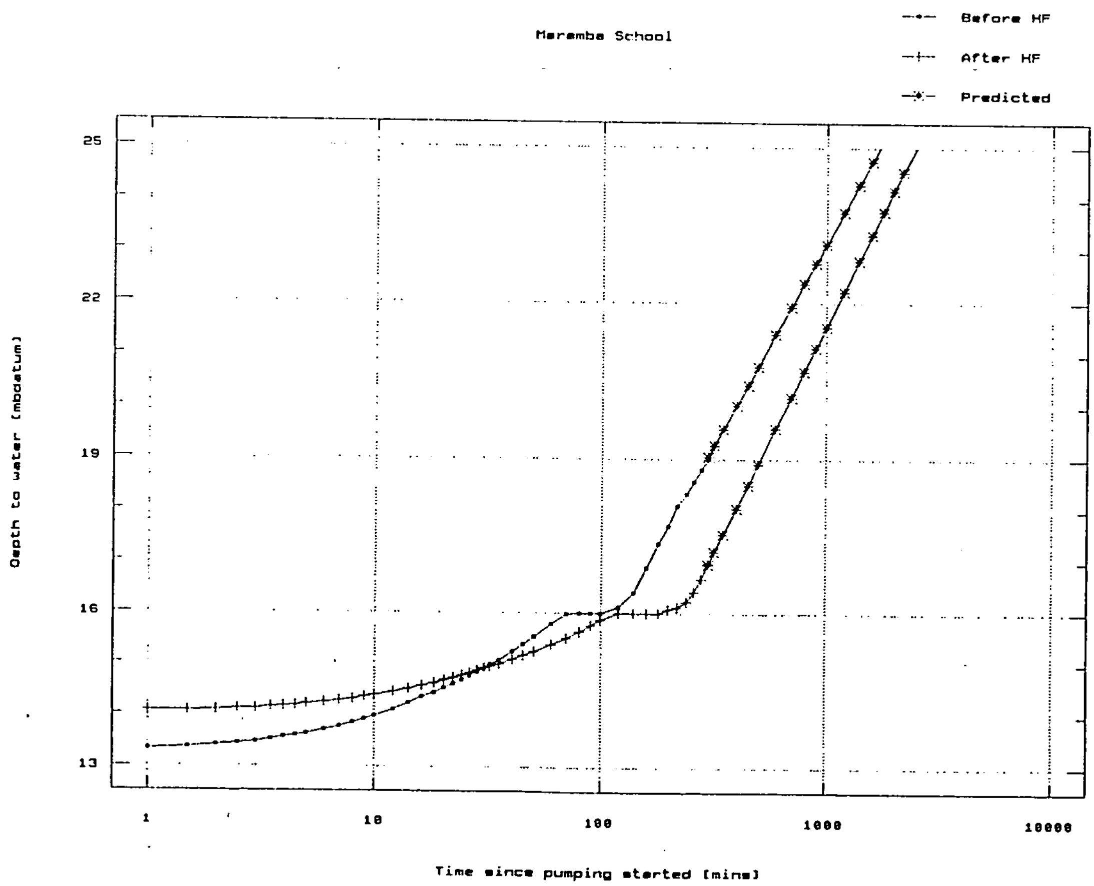
PUMPING TEST ANALYSIS   STRAIGHT LINE APPROXIMATION METHOD



PROJECT: ZIMBABWE FILE: AFTER HF LOCATION: MARAMBA SCHOOL	WELL NO.: 1 Q= .0271 L/S S.W.L.= 12.725	ΔS= 5.545 M T= .077 M2/DAY S=
BRITISH GEOLOGICAL SURVEY		FIGURE

34


Maramba School
Before HF
After HF
(× 1000)
4
3
2
1
0
s/Q (m/m3/min)
1
10
100
1000
Time since pumping started (mins)


Maramba School
Before HF
After HF
Predicted
25
22
19
16
13
Depth to water (mbdatum)
1
10
100
1000
10000
Time since pumping started (mins)

Site :-
Mhatiwa School

Grid Ref. :-
TN 489474

Sequence of Events :-

02/09/90 Bushpump removed
Borehole logging
Test pump installed

03/09/90 Pumptest
Test pump removed
Hydrofracturing
Test pump installed

04/09/90 Pumptest
Test pump removed
Borehole logging
Bushpump replaced

Notes :-

Logging Results :-
Depth of borehole is 35.4m. Base of weathering is at approximately 15m.

Hydrofracturing Results :-
Single packer with 140mm rubbers used set at 23m. Pressure peaked three times at 120 bar, 100 bar and again at 100 bar, with a running pressure between the peaks and after the last peak of about 40 bar. Packer moved and set at 29m where the pressure would not build up beyond 20 bar.

Water Quality :-
Water before hydrofracturing EC = 3100 µS/cm
Water from tank injected EC = 1800 µS/cm
Water after hydrofracturing EC = 1500 µS/cm
Water 24hrs after left site EC = 2750 µS/cm

Pumptest Results :-
Submersible pump suction set at 34m. Pre pumptest lasted the full 300 minutes with a total drawdown of 0.647m at a pumping rate of 0.0288 l/s. Post pumptest also lasted the full 300 minutes with a total drawdown of 1.101m at a pumping rate of 0.0305 l/s.

Transmissivity values were 0.357 m^2/day before HF and 0.130 m^2/day after HF, a decrease of 175%.

Specific capacity values after 300 minutes pumping were 3.846 m^3/day/m before HF and 2.393 m^3/day/m, a decrease of 61%.

Predicted time to reach 6.5m before HF is 444 minutes giving a volume pumped of 767 litres, and after HF is 297 minutes giving a volume pumped of 544 litres, a decrease of 41%.

PUMPING TEST - DRAWDOWN DATA

PROJECT: ZIMBABWE
LOCATION: MHATIWA SCHOOL
DATUM POINT: TOP OF CASING
PUMPING RATE: 0.0288 L/S
AQUIFER THICKNESS:
CONDITIONS: UNCONFINED

FILE NO.: BEFORE HF
WELL NO.: 2
ELEV. OF DATUM POINT:
STATIC WATER LEVEL: 5.535
R = ----- FROM
SCREEN INTERVAL: TO

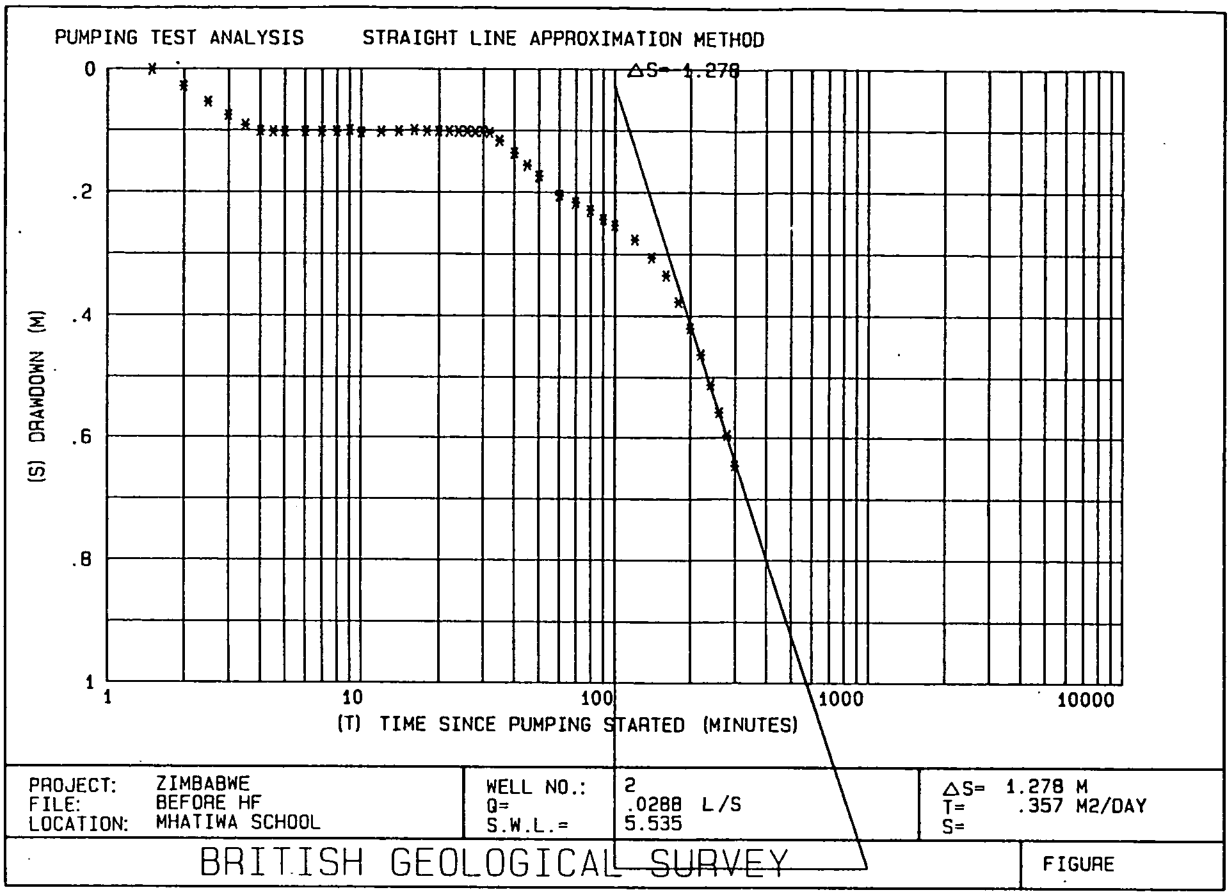
TIME			ELAPSED TIME	WATER LEVEL	DRAWDOWN	(Q)
DY	HR	MN	t (MIN)	(m)	s (m)	(L/S)
3	8	50	0.00	5.535	0.000	0.0288
3	8	51	0.50	5.454	-0.081	0.0288
3	8	51	1.00	5.498	-0.037	0.0288
3	8	52	1.50	5.536	0.001	0.0288
3	8	52	2.00	5.564	0.029	0.0288
3	8	53	2.50	5.590	0.055	0.0288
3	8	53	3.00	5.611	0.076	0.0288
3	8	54	3.50	5.627	0.092	0.0288
3	8	54	4.00	5.637	0.102	0.0288
3	8	55	4.50	5.638	0.103	0.0288
3	8	55	5.00	5.638	0.103	0.0288
3	8	56	6.00	5.638	0.103	0.0288
3	8	57	7.00	5.638	0.103	0.0288
3	8	58	8.00	5.638	0.103	0.0288
3	8	59	9.00	5.636	0.101	0.0288
3	9	0	10.00	5.639	0.104	0.0288
3	9	2	12.00	5.638	0.103	0.0288
3	9	4	14.00	5.637	0.102	0.0288
3	9	6	16.00	5.635	0.100	0.0288
3	9	8	18.00	5.637	0.102	0.0288
3	9	10	20.00	5.637	0.102	0.0288
3	9	12	22.00	5.637	0.102	0.0288
3	9	14	24.00	5.637	0.102	0.0288
3	9	16	26.00	5.637	0.102	0.0288
3	9	18	28.00	5.638	0.103	0.0288
3	9	20	30.00	5.637	0.102	0.0288
3	9	22	32.00	5.639	0.104	0.0288
3	9	25	35.00	5.652	0.117	0.0288
3	9	30	40.00	5.672	0.137	0.0288
3	9	35	45.00	5.692	0.157	0.0288
3	9	40	50.00	5.709	0.174	0.0288
3	9	50	60.00	5.740	0.205	0.0288
3	10	0	70.00	5.752	0.217	0.0288
3	10	10	80.00	5.765	0.230	0.0288
3	10	20	90.00	5.780	0.245	0.0288
3	10	30	100.00	5.790	0.255	0.0288
3	10	50	120.00	5.813	0.278	0.0288
3	11	10	140.00	5.842	0.307	0.0288
3	11	30	160.00	5.871	0.336	0.0288
3	11	50	180.00	5.914	0.379	0.0288
3	12	10	200.00	5.956	0.421	0.0288
3	12	30	220.00	5.999	0.464	0.0288
3	12	50	240.00	6.048	0.513	0.0288
3	13	10	260.00	6.095	0.560	0.0288
3	13	30	280.00	6.132	0.597	0.0288
3	13	50	300.00	6.182	0.647	0.0288

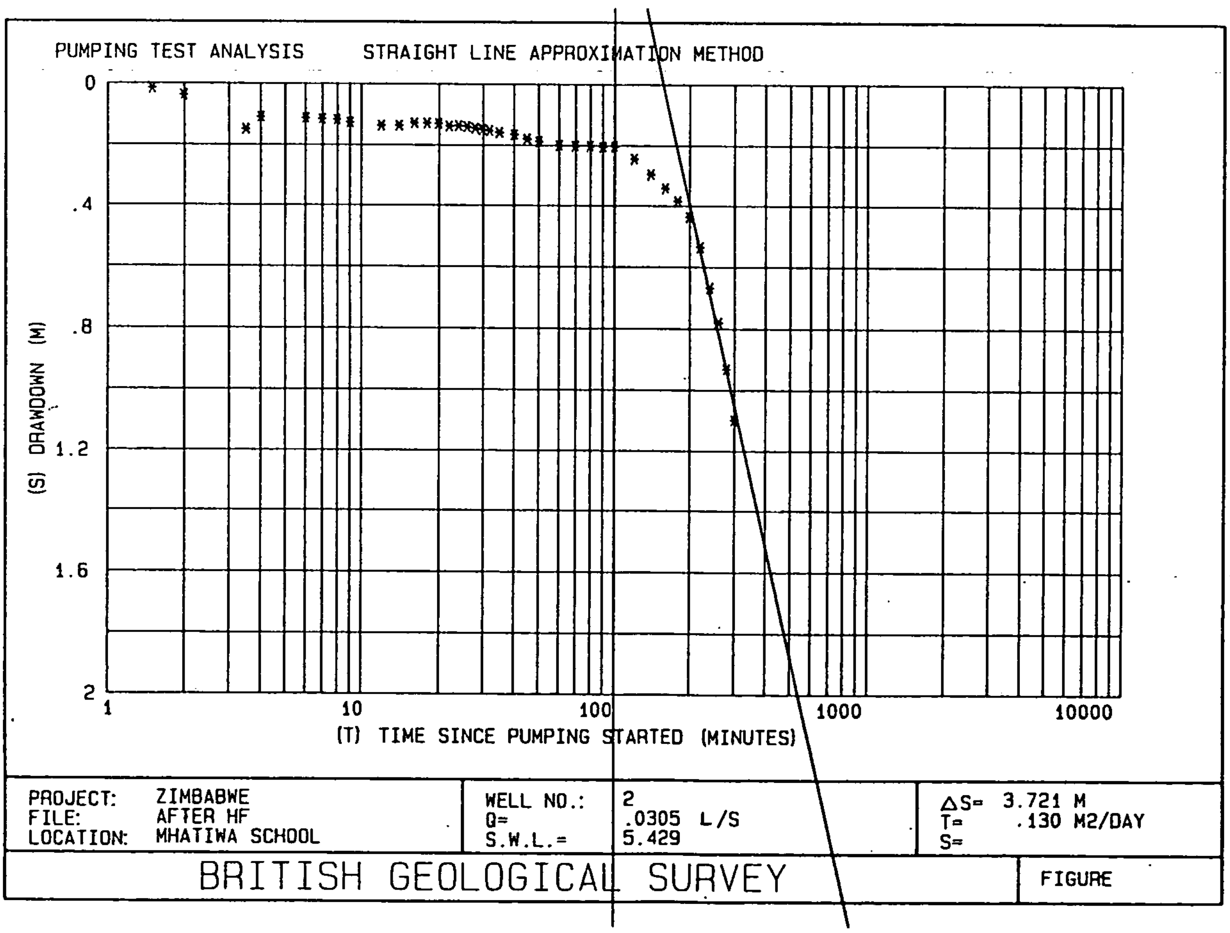
PUMPING TEST - DRAWDOWN DATA

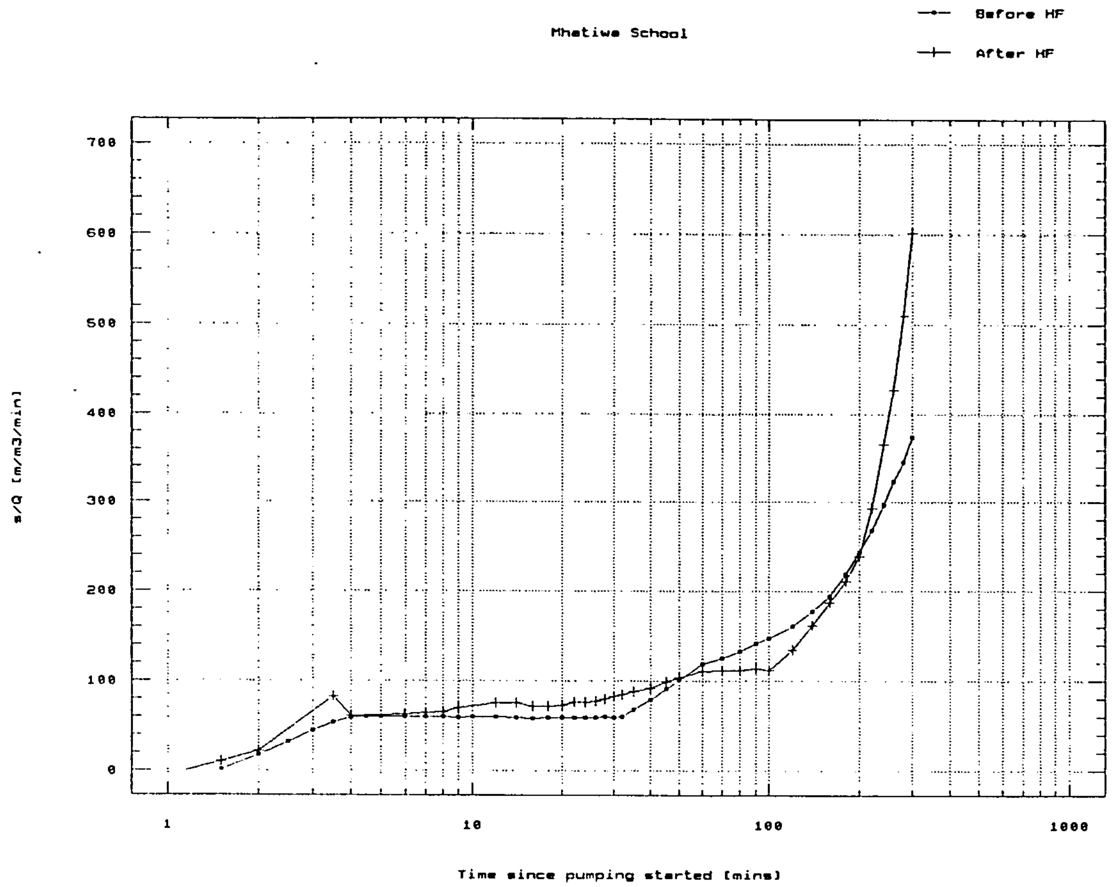
PROJECT: ZIMBABWE
LOCATION: MHATIWA SCHOOL
DATUM POINT: TOP OF CASING
PUMPING RATE: 0.0305 L/S
AQUIFER THICKNESS:
CONDITIONS: UNCONFINED

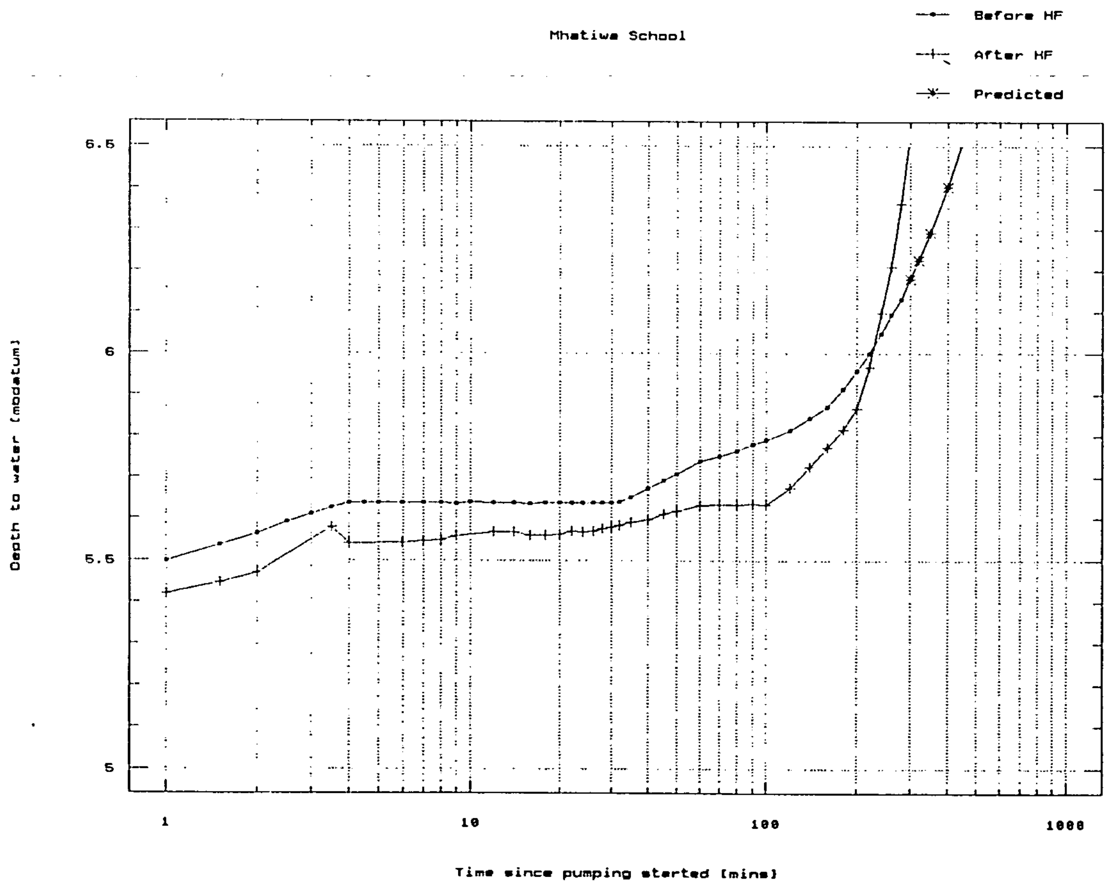
FILE NO.: AFTER HF
WELL NO.: 2
ELEV. OF DATUM POINT:
STATIC WATER LEVEL: 5.429
R = ----- FROM
SCREEN INTERVAL: TO

TIME			ELAPSED TIME	WATER LEVEL	DRAWDOWN	(Q)
DY	HR	MN	t (MIN)	(m)	s (m)	(L/S)
4	9	0	0.00	5.429	0.000	0.0305
4	9	1	0.50	5.380	-0.049	0.0305
4	9	1	1.00	5.420	-0.009	0.0305
4	9	2	1.50	5.446	0.017	0.0305
4	9	2	2.00	5.469	0.040	0.0305
4	9	4	3.50	5.580	0.151	0.0305
4	9	4	4.00	5.540	0.111	0.0305
4	9	6	6.00	5.543	0.114	0.0305
4	9	7	7.00	5.546	0.117	0.0305
4	9	8	8.00	5.548	0.119	0.0305
4	9	9	9.00	5.557	0.128	0.0305
4	9	12	12.00	5.567	0.138	0.0305
4	9	14	14.00	5.567	0.138	0.0305
4	9	16	16.00	5.560	0.131	0.0305
4	9	18	18.00	5.560	0.131	0.0305
4	9	20	20.00	5.561	0.132	0.0305
4	9	22	22.00	5.569	0.140	0.0305
4	9	24	24.00	5.568	0.139	0.0305
4	9	26	26.00	5.570	0.141	0.0305
4	9	28	28.00	5.575	0.146	0.0305
4	9	30	30.00	5.580	0.151	0.0305
4	9	32	32.00	5.583	0.154	0.0305
4	9	35	35.00	5.590	0.161	0.0305
4	9	40	40.00	5.596	0.167	0.0305
4	9	45	45.00	5.610	0.181	0.0305
4	9	50	50.00	5.619	0.190	0.0305
4	10	0	60.00	5.631	0.202	0.0305
4	10	10	70.00	5.633	0.204	0.0305
4	10	20	80.00	5.633	0.204	0.0305
4	10	30	90.00	5.636	0.207	0.0305
4	10	40	100.00	5.634	0.205	0.0305
4	11	0	120.00	5.675	0.246	0.0305
4	11	20	140.00	5.725	0.296	0.0305
4	11	40	160.00	5.772	0.343	0.0305
4	12	0	180.00	5.816	0.387	0.0305
4	12	20	200.00	5.867	0.438	0.0305
4	12	40	220.00	5.966	0.537	0.0305
4	13	0	240.00	6.099	0.670	0.0305
4	13	20	260.00	6.210	0.781	0.0305
4	13	40	280.00	6.362	0.933	0.0305
4	14	0	300.00	6.530	1.101	0.0305


PUMPING TEST ANALYSIS
STRAIGHT LINE APPROXIMATION METHOD
ΔS= 1.278
0
.2
.4
.6
.8
1
(S) DRAWDOWN (M)
1
10
100
1000
10000
(T) TIME SINCE PUMPING STARTED (MINUTES)
PROJECT: ZIMBABWE
FILE: BEFORE HF
LOCATION: MHATIWA SCHOOL
WELL NO.: 2
Q= .0288 L/S
S.W.L.= 5.535
ΔS= 1.278 M
T= .357 M2/DAY
S=
BRITISH GEOLOGICAL SURVEY
FIGURE


PUMPING TEST ANALYSIS
STRAIGHT LINE APPROXIMATION METHOD
0
.4
.8
1.2
1.6
2
(S) DRAWDOWN (M)
1
10
100
1000
10000
(T) TIME SINCE PUMPING STARTED (MINUTES)
PROJECT: ZIMBABWE
FILE: AFTER HF
LOCATION: MHATIWA SCHOOL
WELL NO.: 2
Q= .0305 L/S
S.W.L.= 5.429
ΔS= 3.721 M
T= .130 M2/DAY
S=
BRITISH GEOLOGICAL SURVEY
FIGURE


Mhatiwa School
Before HF
After HF
700
600
500
400
300
200
100
0
s/Q [m/m3/min]
1
10
100
1000
Time since pumping started [mins]


Mhatiwa School
Before HF
After HF
Predicted
6.5
6
5.5
5
Depth to water [mbdatum]
1
10
100
1000
Time since pumping started [mins]

Site :-
Mhatiwa Valley

Grid Ref. :-
TN 490482

Sequence of Events :-

05/09/90 Borehole logging
Test pump installed

06/09/90 Pumptest
Test pump removed
Hydrofracturing
Test pump installed

07/09/90 Pumptest
Test pump removed
Borehole logging

Notes :-
Water level on the morning of the 5th was 4.190m. No bushpump on this borehole.

Logging Results :-
Depth of borehole is 68.0m. Depth of base of weathering is at approximately 35m. A minor fracture is visible at 54.5m.

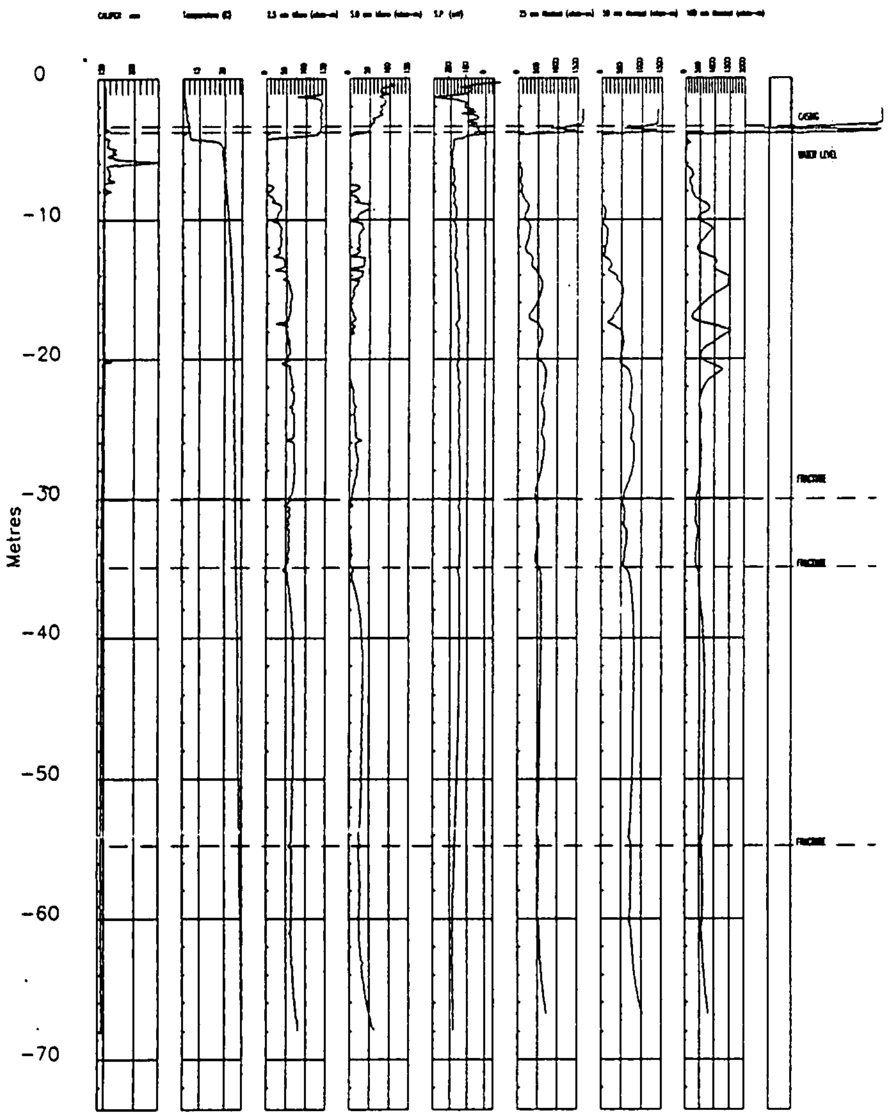
Hydrofracturing Results :-
Single packer with 140mm rubbers set at 44m this being the deepest that the hydraulic line would allow. Pressure peaked at 120 bar at which point the connector from packer to pipes broke.

Water Quality :-
Water before hydrofracturing EC = 1060 µS/cm
Water from tank injected EC = 1760 µS/cm
Water after hydrofracturing EC = 1280 µS/cm

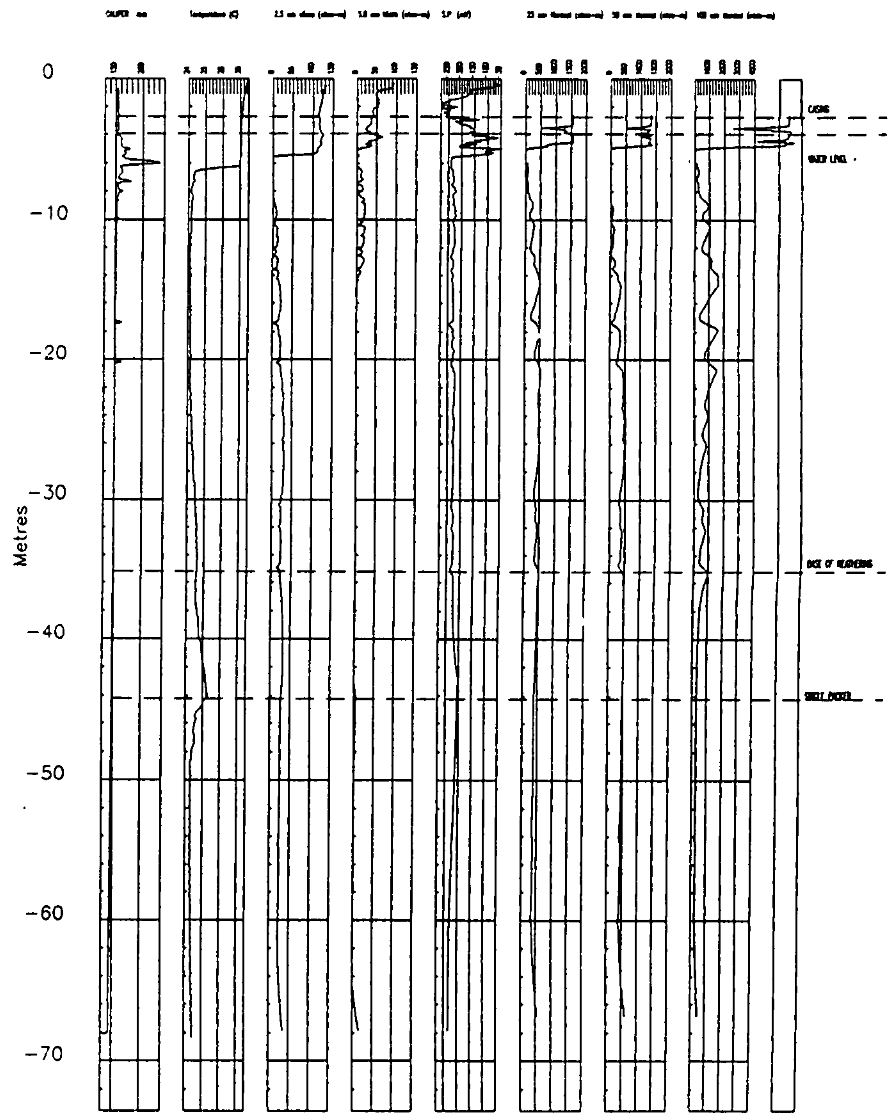
Pumptest Results :-
Submersible pump suction set at 42m. Pre pumptest lasted the full 300 minutes with a total drawdown of 1.477m at a pumping rate of 0.0315 l/s. Post pumptest lasted the full 300 minutes with a total drawdown of 2.717m at a pumping rate of 0.0516 l/s.
Transmissivity values were 0.476 m^2/day before HF and 0.322 m^2/day after HF, a decrease of 48%.
Specific capacity values after 300 minutes pumping were 1.843 m^3/day/m before HF and 1.641 m^3/day/m after HF,a decrease of 12%.
Predicted time for 1.5m drawdown before HF is 308 minutes giving a volume pumped of 582 litres and after HF is 64 minutes giving a pumped volume of 198 litres, a decrease of 194%.

Special Remarks :-
If s/Q values were made the same for very early times (see Special Remarks on Maramba School), it can be concluded that little change has occurred rather than a worsening of yield.

Wellname MHATIWA VALLEY
Filename MHATIWA3
Location Zimbabwe TN 490482
Elevation 0 Reference



Wellname MHATIWA VALLEY
Filename MHATIWA4
Location Zimbabwe TN 490482
Elevation 0 Reference



41

PUMPING TEST - DRAWDOWN DATA

PROJECT: ZIMBABWE
LOCATION: MHATIWA VALLEY
DATUM POINT: TOP OF CASING
PUMPING RATE: 0.0315 L/S
AQUIFER THICKNESS:
CONDITIONS: UNCONFINED

FILE NO.: BEFORE HF
WELL NO.: 3
ELEV. OF DATUM POINT:
STATIC WATER LEVEL: 3.618
R = ----- FROM
SCREEN INTERVAL: TO

TIME			ELAPSED TIME	WATER LEVEL	DRAWDOWN	(Q)
DY	HR	MN	t (MIN)	(m)	s (m)	(L/S)
6	9	0	0.00	3.618	0.000	0.0315
6	9	1	0.50	3.542	-0.076	0.0315
6	9	1	1.00	3.568	-0.050	0.0315
6	9	2	1.50	3.587	-0.031	0.0315
6	9	2	2.00	3.602	-0.016	0.0315
6	9	3	2.50	3.620	0.002	0.0315
6	9	3	3.00	3.631	0.013	0.0315
6	9	4	3.50	3.648	0.030	0.0315
6	9	4	4.00	3.660	0.042	0.0315
6	9	5	4.50	3.677	0.059	0.0315
6	9	5	5.00	3.686	0.068	0.0315
6	9	6	6.00	3.717	0.099	0.0315
6	9	7	7.00	3.736	0.118	0.0315
6	9	8	8.00	3.758	0.140	0.0315
6	9	9	9.00	3.780	0.162	0.0315
6	9	10	10.00	3.804	0.186	0.0315
6	9	12	12.00	3.845	0.227	0.0315
6	9	14	14.00	3.880	0.262	0.0315
6	9	16	16.00	3.910	0.292	0.0315
6	9	18	18.00	3.936	0.318	0.0315
6	9	20	20.00	3.949	0.331	0.0315
6	9	22	22.00	3.963	0.345	0.0315
6	9	24	24.00	3.977	0.359	0.0315
6	9	26	26.00	3.989	0.371	0.0315
6	9	28	28.00	3.999	0.381	0.0315
6	9	30	30.00	4.010	0.392	0.0315
6	9	32	32.00	4.022	0.404	0.0315
6	9	35	35.00	4.039	0.421	0.0315
6	9	40	40.00	4.061	0.443	0.0315
6	9	45	45.00	4.081	0.463	0.0315
6	9	50	50.00	4.106	0.488	0.0315
6	10	0	60.00	4.101	0.483	0.0315
6	10	10	70.00	4.089	0.471	0.0315
6	10	20	80.00	4.060	0.442	0.0315
6	10	30	90.00	4.050	0.432	0.0315
6	10	40	100.00	4.406	0.788	0.0315
6	11	0	120.00	4.591	0.973	0.0315
6	11	20	140.00	4.674	1.056	0.0315
6	11	40	160.00	4.745	1.127	0.0315
6	12	0	180.00	4.860	1.242	0.0315
6	12	20	200.00	4.929	1.311	0.0315
6	12	40	220.00	4.973	1.355	0.0315
6	13	0	240.00	5.017	1.399	0.0315
6	13	20	260.00	5.055	1.437	0.0315
6	13	40	280.00	5.070	1.452	0.0315
6	14	0	300.00	5.095	1.477	0.0315

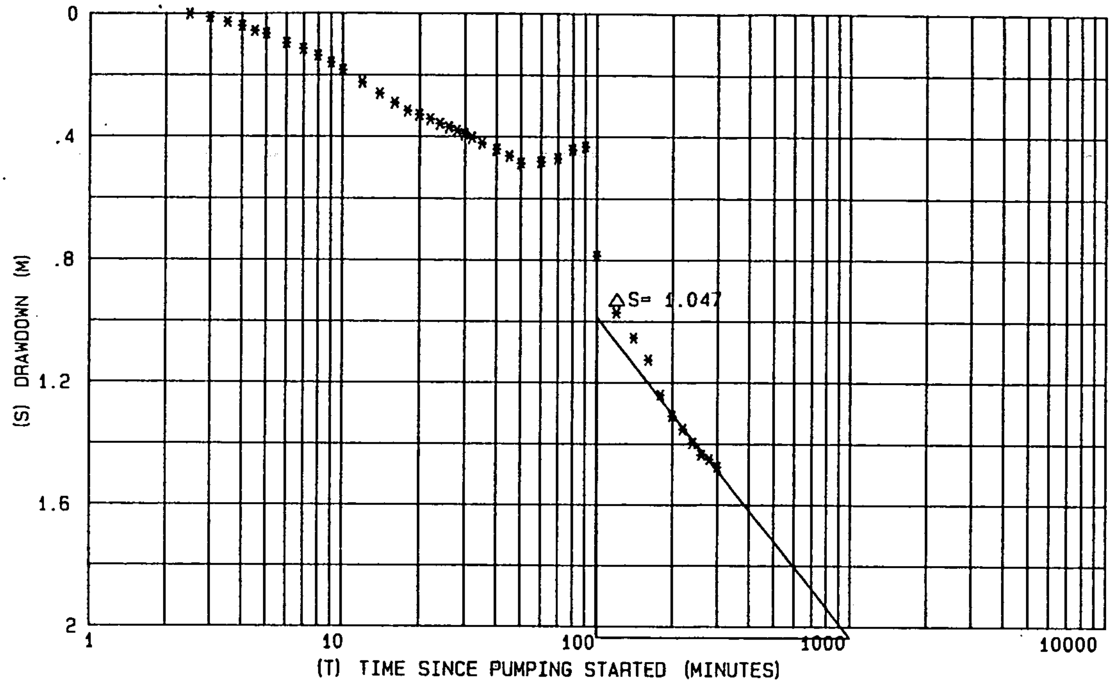
PUMPING TEST - DRAWDOWN DATA

PROJECT: ZIMBABWE
LOCATION: MHATIWA VALLEY
DATUM POINT: TOP OF CASING
PUMPING RATE: 0.0516 L/S
AQUIFER THICKNESS:
CONDITIONS: UNCONFINED

FILE NO.: AFTER HF
WELL NO.: 3
ELEV. OF DATUM POINT:
STATIC WATER LEVEL: 3.987
R = ----- FROM
SCREEN INTERVAL: TO

TIME			ELAPSED TIME	WATER LEVEL	DRAWDOWN	(Q)
DY	HR	MN	t (MIN)	(m)	s (m)	(L/S)
7	8	30	0.00	3.987	0.000	0.0516
7	8	31	0.50	3.902	-0.085	0.0516
7	8	31	1.00	3.963	-0.024	0.0516
7	8	32	1.50	4.020	0.033	0.0516
7	8	32	2.00	4.069	0.082	0.0516
7	8	33	2.50	4.121	0.134	0.0516
7	8	33	3.00	4.155	0.168	0.0516
7	8	34	3.50	4.191	0.204	0.0516
7	8	34	4.00	4.229	0.242	0.0516
7	8	35	4.50	4.267	0.280	0.0516
7	8	35	5.00	4.299	0.312	0.0516
7	8	36	6.00	4.360	0.373	0.0516
7	8	37	7.00	4.410	0.423	0.0516
7	8	38	8.00	4.467	0.480	0.0516
7	8	39	9.00	4.508	0.521	0.0516
7	8	40	10.00	4.555	0.568	0.0516
7	8	42	12.00	4.628	0.641	0.0516
7	8	44	14.00	4.699	0.712	0.0516
7	8	46	16.00	4.760	0.773	0.0516
7	8	48	18.00	4.814	0.827	0.0516
7	8	50	20.00	4.862	0.875	0.0516
7	8	52	22.00	4.910	0.923	0.0516
7	8	54	24.00	4.950	0.963	0.0516
7	8	56	26.00	4.990	1.003	0.0516
7	8	58	28.00	5.028	1.041	0.0516
7	9	0	30.00	5.059	1.072	0.0516
7	9	2	32.00	5.089	1.102	0.0516
7	9	5	35.00	5.130	1.143	0.0516
7	9	10	40.00	5.205	1.218	0.0516
7	9	15	45.00	5.272	1.285	0.0516
7	9	20	50.00	5.332	1.345	0.0516
7	9	30	60.00	5.443	1.456	0.0516
7	9	40	70.00	5.545	1.558	0.0516
7	9	50	80.00	5.632	1.645	0.0516
7	10	0	90.00	5.704	1.717	0.0516
7	10	10	100.00	5.779	1.792	0.0516
7	10	30	120.00	5.898	1.911	0.0516
7	10	50	140.00	5.980	1.993	0.0516
7	11	10	160.00	6.056	2.069	0.0516
7	11	30	180.00	6.150	2.163	0.0516
7	11	50	200.00	6.261	2.274	0.0516
7	12	10	220.00	6.375	2.388	0.0516
7	12	30	240.00	6.472	2.485	0.0516
7	12	50	260.00	6.561	2.574	0.0516
7	13	10	280.00	6.643	2.656	0.0516
7	13	30	300.00	6.704	2.717	0.0516

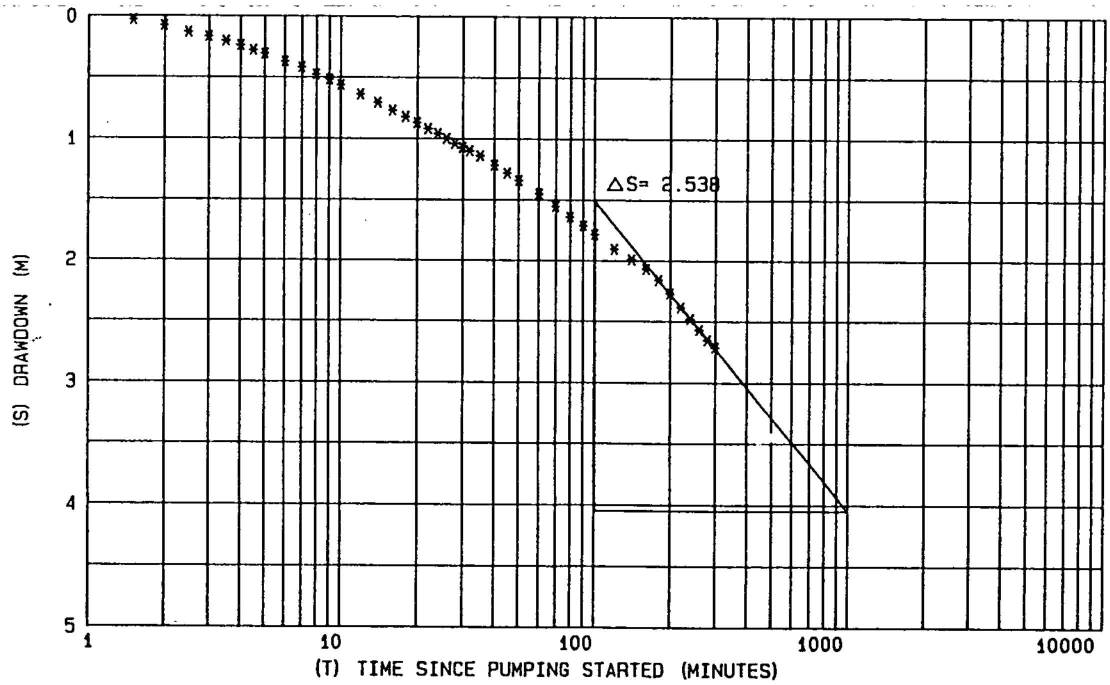
PUMPING TEST ANALYSIS STRAIGHT LINE APPROXIMATION METHOD



PROJECT: ZIMBABWE FILE: BEFORE HF LOCATION: MHATIWA VALLEY	WELL NO.: 3 Q= .0315 L/S S.W.L.= 3.618	ΔS= 1.047 M T= .476 M2/DAY S=

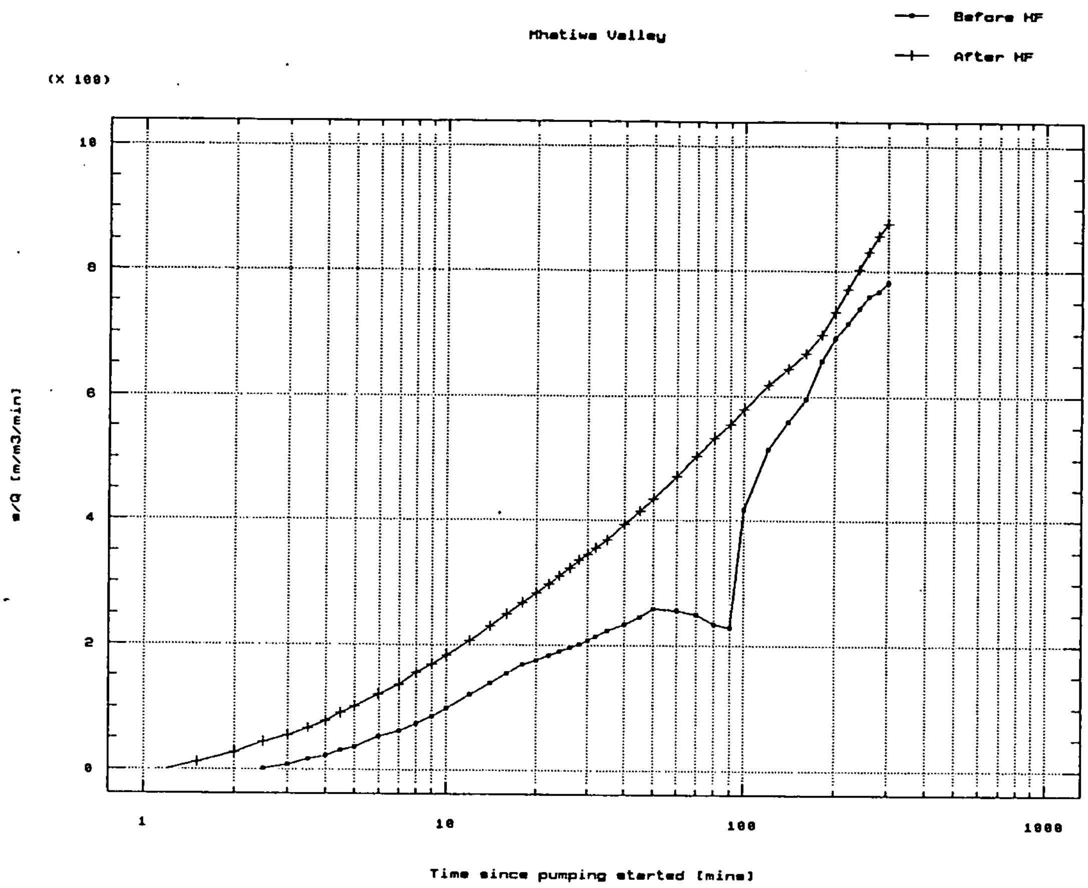
BRITISH GEOLOGICAL SURVEY — FIGURE

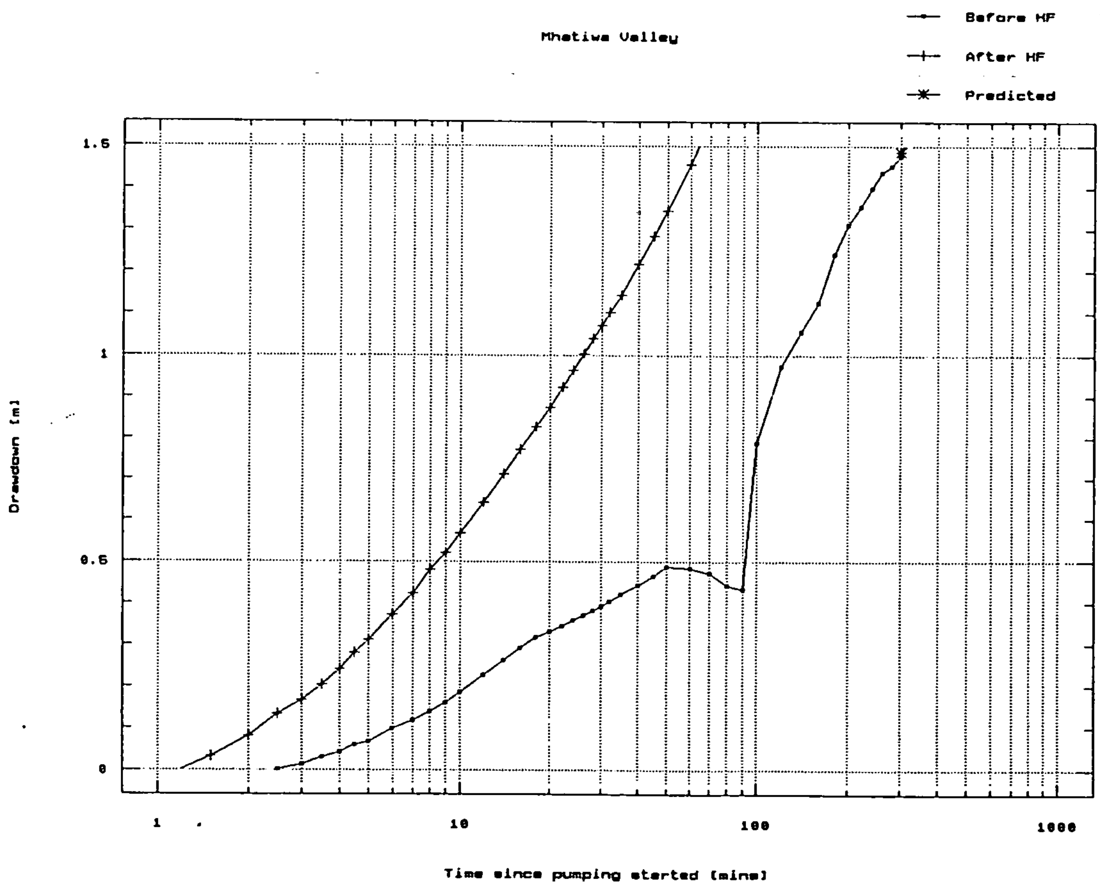
PUMPING TEST ANALYSIS STRAIGHT LINE APPROXIMATION METHOD



PROJECT: ZIMBABWE FILE: AFTER HF LOCATION: MHATIWA VALLEY	WELL NO.: 3 Q= .0516 L/S S.W.L.= 3.987	ΔS= 2.538 M T= .322 M2/DAY S=

BRITISH GEOLOGICAL SURVEY — FIGURE


Mhatiwa Valley
Before HF
After HF
(X 100)
s/Q [m/m3/min]
Time since pumping started [mins]


Mhatiwa Valley
Before HF
After HF
Predicted
Drawdown [m]
Time since pumping started [mins]

Site :-
Zvirikuresch School

Grid Ref. :-
TM 488891

Sequence of Events :-

11/09/90 Bushpump removed
Borehole logging
Test pump installed

12/09/90 Pumptest
Test pump removed
Hydrofracturing
Test pump installed

13/09/90 Pumptest
Test pump removed
Bushpump replaced

Notes :-

Pump is only usable for 15 minutes each morning before the borehole dries up. Headmaster removes one of the top bolts to prevent it being used except at certain times each day. Borehole was drilled 3 months previously. Bushpump suction set at 43m. Water level on the morning of the 11th was 33.25m.

Logging Results :-

Depth of borehole is 44.8m. Water level was below the base of weathering. A fracture is shown to occur at approximately 37m depth. No logging was done after HF because the loggers cable was damaged.

Hydrofracturing Results :-

Single packer initially used set at 35m. Apparently cracked once with a pressure peak of 120 bar but the hydraulic ram was leaking oil (molasses) and was therefore slipping and so the double packer was used. Top packer set at 36m, bottom packer at 39m. The pressure did not build up beyond 40 bar indicating that the water was being pumped into the formation here.

Water Quality :-

Water before hydrofracturing	EC =	540 µS/cm
Water from tank injected	EC =	1370 µS/cm
Water after hydrofracturing	EC =	550 µS/cm

Pumptest Results :-

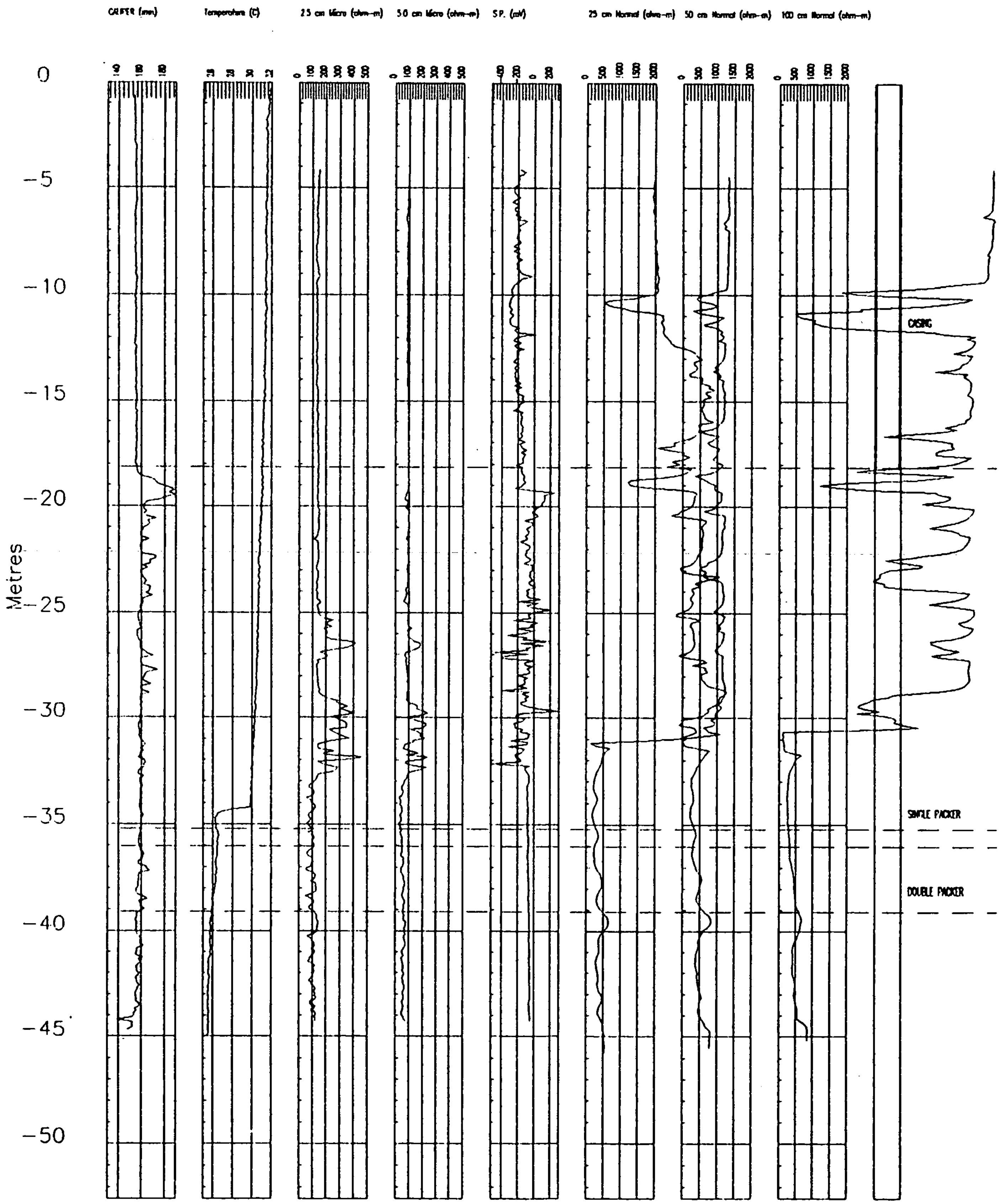
Submersible pump suction set at 43m. Pre pumptest lasted for 295 minutes with a total drawdown of 26.061m at a pumping rate of 0.0608 l/s. Post pumptest lasted the full 300 minutes with a total drawdown of 5.696m at a pumping rate of 0.0361 l/s.

Transmissivity values were 0.018 m^2/day before HF and 0.042 m^2/day after HF, an improvement of 133%.

Specific capacity values after 280 minutes pumping were 0.216 m^3/day/m before HF and 0.603 m^3/day/m after HF, an improvement of 179%.

Predicted time to reach the pump suction (43m) before HF is 299 mins giving a volume of 1091 litres, and after HF is 1128 mins giving a volume of 2444 litres, an improvement of 124%.

Wellname	Zvirikuresch School
Filename	ZVIRIKU1
Location	TM 488891 Zimbabwe
Elevation	0 Reference



PUMPING TEST - DRAWDOWN DATA

PROJECT: ZIMBABWE
LOCATION: ZVIRIKURESCH SCHOOL
DATUM POINT: TOP OF CASING
PUMPING RATE: 0.0608 L/S
AQUIFER THICKNESS:
CONDITIONS: UNCONFINED

FILE NO.: BEFORE HF
WELL NO.: 4
ELEV. OF DATUM POINT:
STATIC WATER LEVEL: 16.680
R = ----- FROM
SCREEN INTERVAL: TO

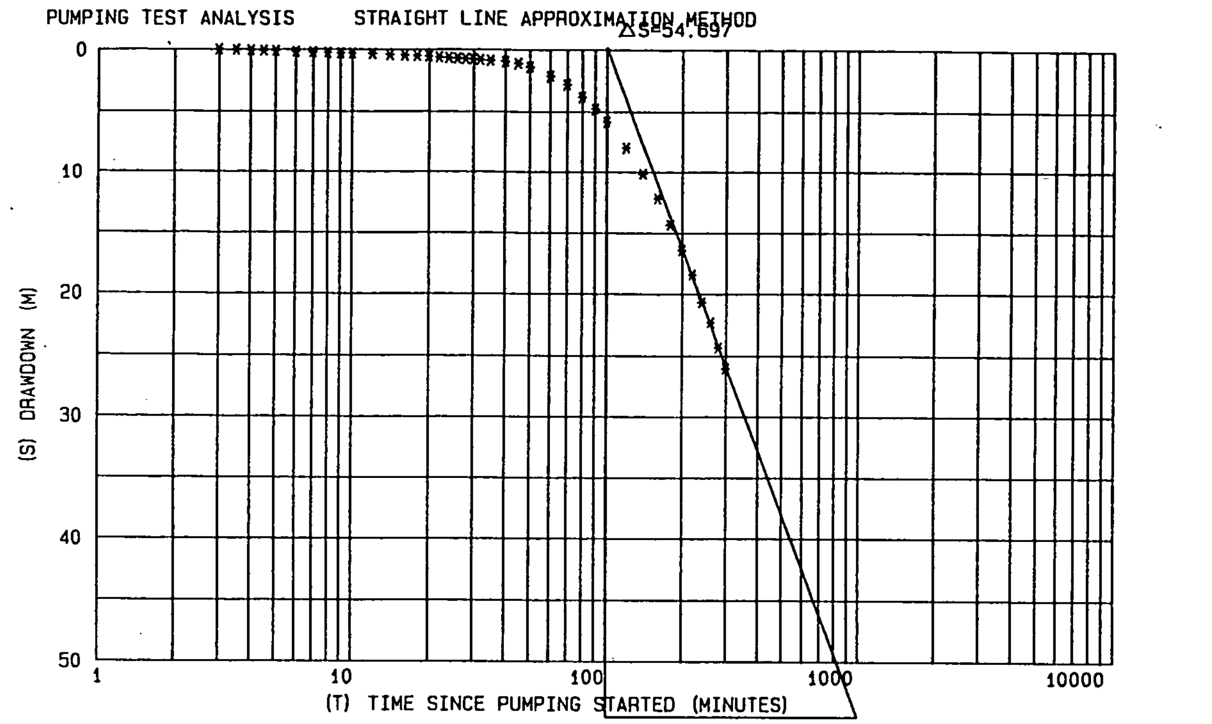
TIME			ELAPSED TIME	WATER LEVEL	DRAWDOWN	(Q)
DY	HR	MN	t (MIN)	(m)	s (m)	(L/S)
12	8	10	0.00	16.680	0.000	0.0608
12	8	11	0.50	16.491	-0.189	0.0608
12	8	11	1.00	16.529	-0.151	0.0608
12	8	12	1.50	16.574	-0.106	0.0608
12	8	12	2.00	16.616	-0.064	0.0608
12	8	13	2.50	16.653	-0.027	0.0608
12	8	13	3.00	16.697	0.017	0.0608
12	8	14	3.50	16.730	0.050	0.0608
12	8	14	4.00	16.768	0.088	0.0608
12	8	15	4.50	16.802	0.122	0.0608
12	8	15	5.00	16.831	0.151	0.0608
12	8	16	6.00	16.890	0.210	0.0608
12	8	17	7.00	16.950	0.270	0.0608
12	8	18	8.00	16.986	0.306	0.0608
12	8	19	9.00	17.009	0.329	0.0608
12	8	20	10.00	17.031	0.351	0.0608
12	8	22	12.00	17.078	0.398	0.0608
12	8	24	14.00	17.121	0.441	0.0608
12	8	26	16.00	17.180	0.500	0.0608
12	8	28	18.00	17.228	0.548	0.0608
12	8	30	20.00	17.277	0.597	0.0608
12	8	32	22.00	17.329	0.649	0.0608
12	8	34	24.00	17.376	0.696	0.0608
12	8	36	26.00	17.402	0.722	0.0608
12	8	38	28.00	17.445	0.765	0.0608
12	8	40	30.00	17.491	0.811	0.0608
12	8	42	32.00	17.532	0.852	0.0608
12	8	45	35.00	17.569	0.889	0.0608
12	8	50	40.00	17.660	0.980	0.0608
12	8	55	45.00	17.838	1.158	0.0608
12	9	0	50.00	18.100	1.420	0.0608
12	9	10	60.00	18.862	2.182	0.0608
12	9	20	70.00	19.543	2.863	0.0608
12	9	30	80.00	20.521	3.841	0.0608
12	9	40	90.00	21.498	4.818	0.0608
12	9	50	100.00	22.548	5.868	0.0608
12	10	10	120.00	24.660	7.980	0.0608
12	10	30	140.00	26.842	10.162	0.0608
12	10	50	160.00	28.905	12.225	0.0608
12	11	10	180.00	31.059	14.379	0.0608
12	11	30	200.00	33.146	16.466	0.0608
12	11	50	220.00	35.130	18.450	0.0608
12	12	10	240.00	37.385	20.705	0.0608
12	12	30	260.00	39.022	22.342	0.0608
12	12	50	280.00	41.045	24.365	0.0608
12	13	10	300.00	42.741	26.061	0.0608

PUMPING TEST - DRAWDOWN DATA

PROJECT: ZIMBABWE
LOCATION: ZVIRIKURESCH SCHOOL
DATUM POINT: TOP OF CASING
PUMPING RATE: 0.0361 L/S
AQUIFER THICKNESS:
CONDITIONS: UNCONFINED

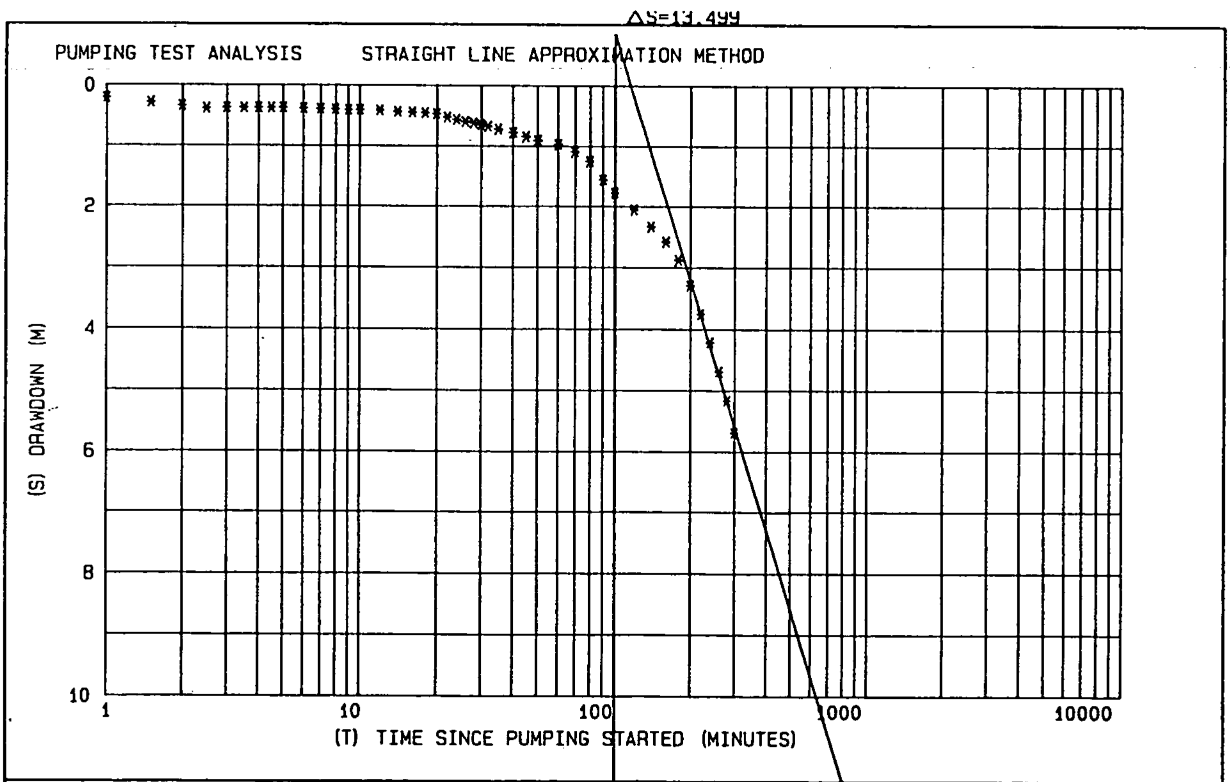
FILE NO.: AFTER HF
WELL NO.: 4
ELEV. OF DATUM POINT:
STATIC WATER LEVEL: 16.609
R = ----- FROM
SCREEN INTERVAL: TO

TIME			ELAPSED TIME	WATER LEVEL	DRAWDOWN	(Q)
DY	HR	MN	t (MIN)	(m)	s (m)	(L/S)
13	7	50	0.00	16.609	0.000	0.0361
13	7	51	0.50	16.659	0.050	0.0361
13	7	51	1.00	16.825	0.216	0.0361
13	7	52	1.50	16.903	0.294	0.0361
13	7	52	2.00	16.957	0.348	0.0361
13	7	53	2.50	16.995	0.386	0.0361
13	7	53	3.00	16.990	0.381	0.0361
13	7	54	3.50	16.985	0.376	0.0361
13	7	54	4.00	16.986	0.377	0.0361
13	7	55	4.50	16.990	0.381	0.0361
13	7	55	5.00	16.991	0.382	0.0361
13	7	56	6.00	16.997	0.388	0.0361
13	7	57	7.00	17.005	0.396	0.0361
13	7	58	8.00	17.010	0.401	0.0361
13	7	59	9.00	17.017	0.408	0.0361
13	8	0	10.00	17.020	0.411	0.0361
13	8	2	12.00	17.032	0.423	0.0361
13	8	4	14.00	17.049	0.440	0.0361
13	8	6	16.00	17.061	0.452	0.0361
13	8	8	18.00	17.071	0.462	0.0361
13	8	10	20.00	17.086	0.477	0.0361
13	8	12	22.00	17.143	0.534	0.0361
13	8	14	24.00	17.177	0.568	0.0361
13	8	16	26.00	17.210	0.601	0.0361
13	8	18	28.00	17.235	0.626	0.0361
13	8	20	30.00	17.265	0.656	0.0361
13	8	22	32.00	17.294	0.685	0.0361
13	8	25	35.00	17.339	0.730	0.0361
13	8	30	40.00	17.393	0.784	0.0361
13	8	35	45.00	17.459	0.850	0.0361
13	8	40	50.00	17.525	0.916	0.0361
13	8	50	60.00	17.590	0.981	0.0361
13	9	0	70.00	17.712	1.103	0.0361
13	9	10	80.00	17.871	1.262	0.0361
13	9	20	90.00	18.176	1.567	0.0361
13	9	30	100.00	18.389	1.780	0.0361
13	9	50	120.00	18.668	2.059	0.0361
13	10	10	140.00	18.945	2.336	0.0361
13	10	30	160.00	19.200	2.591	0.0361
13	10	50	180.00	19.492	2.883	0.0361
13	11	10	200.00	19.911	3.302	0.0361
13	11	30	220.00	20.373	3.764	0.0361
13	11	50	240.00	20.832	4.223	0.0361
13	12	10	260.00	21.312	4.703	0.0361
13	12	30	280.00	21.781	5.172	0.0361
13	12	50	300.00	22.305	5.696	0.0361



PROJECT: ZIMBABWE FILE: BEFORE HF LOCATION: ZVIRIKURESCH SCHOOL	WELL NO.: 4 Q= .0608 L/S S.W.L.= 16.680	ΔS= 54.697 M T= .018 M2/DAY S=

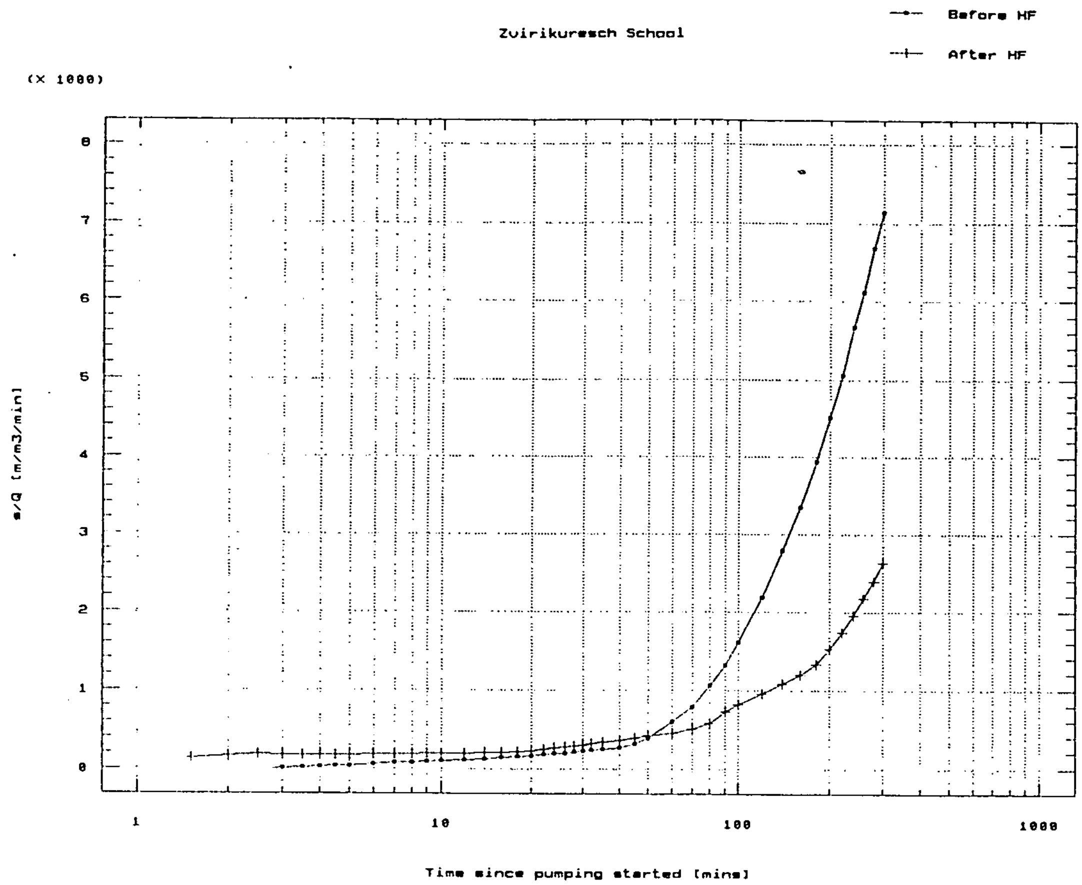
BRITISH GEOLOGICAL SURVEY — FIGURE



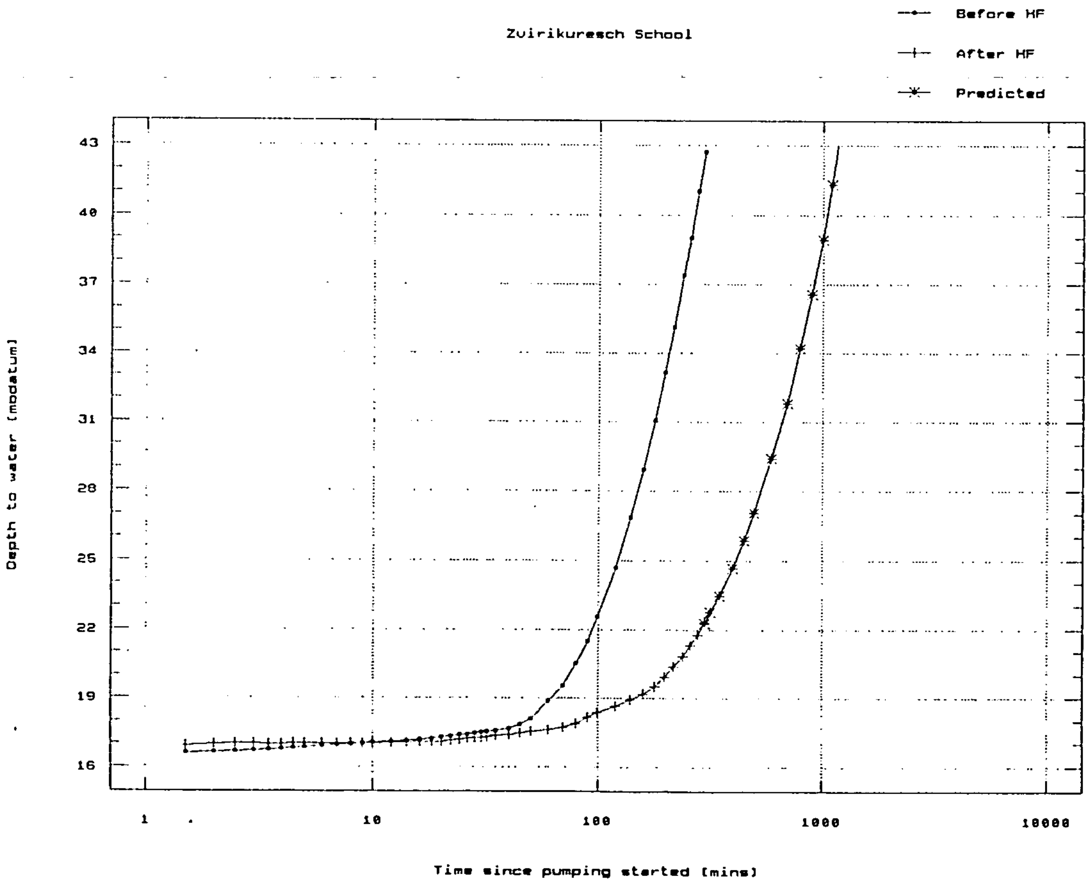
PROJECT: ZIMBABWE FILE: AFTER HF LOCATION: ZVIRIKURESCH SCHOOL	WELL NO.: 4 Q= .0361 L/S S.W.L.= 16.609	ΔS= 13.499 M T= .042 M2/DAY S=

BRITISH GEOLOGICAL SURVEY — FIGURE

48



Zvirikuresch School
Before HF
After HF
(x 1000)
s/Q [m/m3/min]
8
7
6
5
4
3
2
1
0
1
10
100
1000
Time since pumping started [mins]



Zvirikuresch School
Before HF
After HF
Predicted
Depth to water [mbdatum]
43
40
37
34
31
28
25
22
19
16
1
10
100
1000
10000
Time since pumping started [mins]

Site :-
Shazhaume School

Grid Ref. :-
TM 464940

Sequence of Events :-

14/09/90 Bushpump removed
Borehole logging
Test pump installed

15/09/90 Pumptest
Test pump removed
Hydrofracturing
Test pump installed

16/09/90 Pumptest
Test pump removed
Borehole logging
Bushpump replaced

Notes :-

Water level on the morning of the 14th was 12.86m. Bushpump suction was set at 25m and it was replaced at 31m.

Logging Results :-

Depth of borehole is 35.0m. Depth of base of weathering is at approximately 22m. Two minor fractures are visible at approximately 27m and 29m. After HF the fracture at 29m appears to be more pronounced.

Hydrofracturing Results :-

Double packer used top set at 30.5m, bottom at 33.5m pressure peaked at 80 bar with a running pressure of 40 bar. Top set at 26m, bottom at 29m pressure did not build up with a running pressure of 50 bar. Top set at 28m, bottom at 31m pressure did not build up with a running pressure of 60 bar.

Water Quality :-

Water before hydrofracturing EC = 1270 µS/cm
Water from tank injected EC = 1445 µS/cm
Water after hydrofracturing EC = 1420 µS/cm

Pumptest Results :-

Submersible pump suction set at 31m. Pre pumptest lasted for the full 300 minutes with a total drawdown of 6.756m at a pumping rate of 0.0615 l/s. Post pumptest lasted the full 300 minutes with a total drawdown of 3.481m at a pumping rate of 0.0399 l/s.

Transmissivity values were 0.258 m^2/day before HF and 0.249 m^2/day after HF, a decrease of 4%.

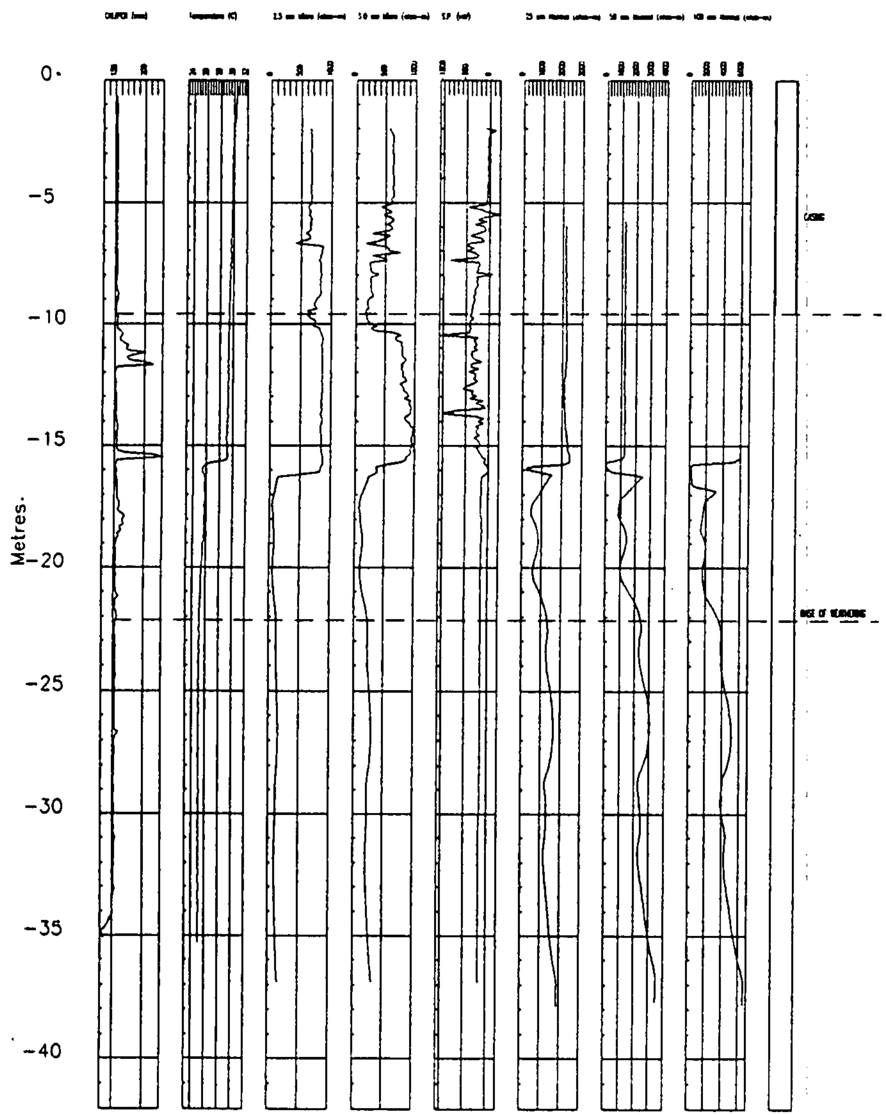
Specific capacity values after 300 minutes pumping were 0.787 m^3/day/m before HF and 0.990 m^3/day/m after HF, an improvement of 26%.

Predicted time to reach 14m is 25 minutes before HF giving a volume pumped of 92 litres and after HF is 61 minutes after HF giving a volume pumped of 146 litres, an improvement of 59%.

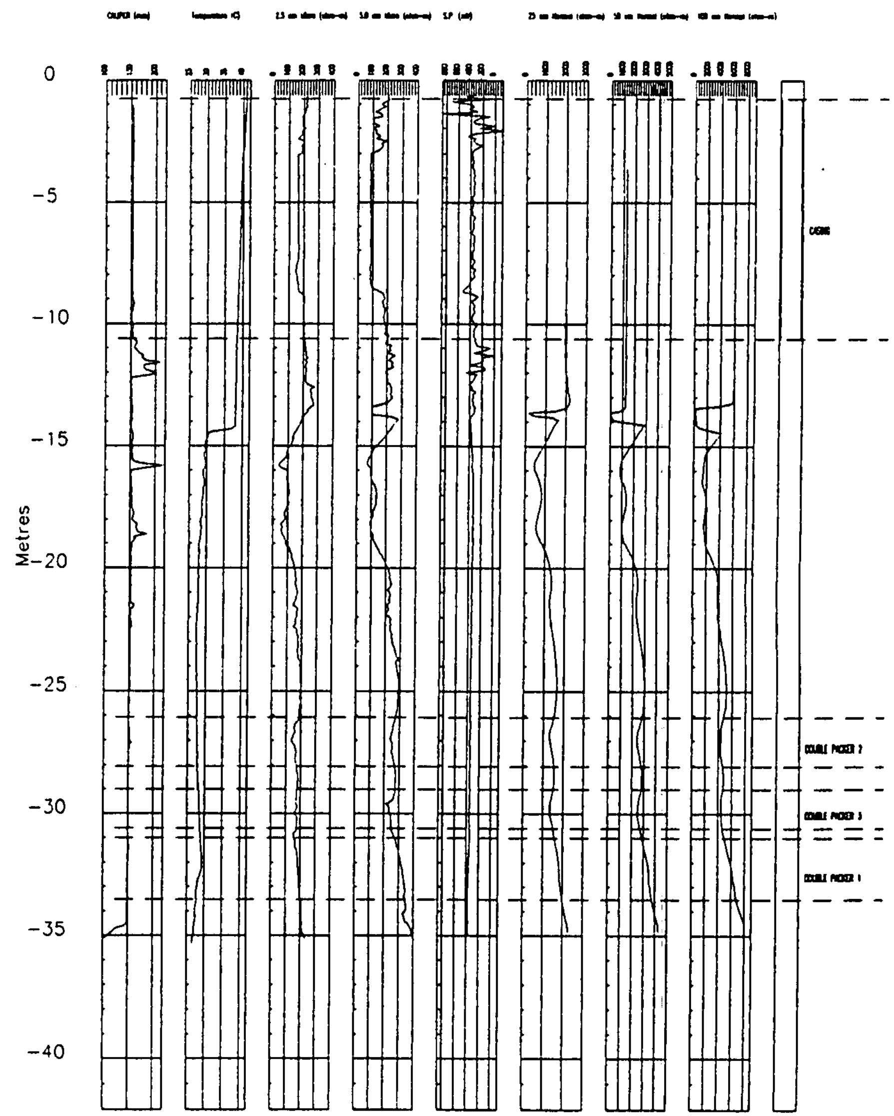
Special Remarks :-

Very difficult to interpret precisely. No question that there has been an improvement in the order of about 30 - 60%.

Wellname
Filename SHAZHAU1
Location
Elevation 0 Reference



Wellname Shazhaume School
Filename SHAZHAU2
Location Zimbabwe
Elevation 0 Reference



5

PUMPING TEST - DRAWDOWN DATA

PROJECT: ZIMBABWE
LOCATION: SHAZHAUME SCHOOL
DATUM POINT: TOP OF CASING
PUMPING RATE: 0.0615 L/S
AQUIFER THICKNESS:
CONDITIONS: UNCONFINED

FILE NO.: BEFORE HF
WELL NO.: 5
ELEV. OF DATUM POINT:
STATIC WATER LEVEL: 11.730
R = ----- FROM
SCREEN INTERVAL: TO

TIME			ELAPSED TIME	WATER LEVEL	DRAWDOWN	(Q)
DY	HR	MN	t (MIN)	(m)	s (m)	(L/S)
15	8	15	0.00	11.730	0.000	0.0615
15	8	16	0.50	11.632	-0.098	0.0615
15	8	16	1.00	11.650	-0.080	0.0615
15	8	17	1.50	11.667	-0.063	0.0615
15	8	17	2.00	11.691	-0.039	0.0615
15	8	18	2.50	11.710	-0.020	0.0615
15	8	18	3.00	11.735	0.005	0.0615
15	8	19	3.50	11.809	0.079	0.0615
15	8	19	4.00	11.889	0.159	0.0615
15	8	20	4.50	11.967	0.237	0.0615
15	8	20	5.00	12.041	0.311	0.0615
15	8	21	6.00	12.199	0.469	0.0615
15	8	22	7.00	12.343	0.613	0.0615
15	8	23	8.00	12.472	0.742	0.0615
15	8	24	9.00	12.609	0.879	0.0615
15	8	25	10.00	12.722	0.992	0.0615
15	8	27	12.00	12.947	1.217	0.0615
15	8	29	14.00	13.152	1.422	0.0615
15	8	31	16.00	13.331	1.601	0.0615
15	8	33	18.00	13.510	1.780	0.0615
15	8	35	20.00	13.660	1.930	0.0615
15	8	37	22.00	13.808	2.078	0.0615
15	8	39	24.00	13.936	2.206	0.0615
15	8	41	26.00	14.060	2.330	0.0615
15	8	43	28.00	14.181	2.451	0.0615
15	8	45	30.00	14.286	2.556	0.0615
15	8	47	32.00	14.395	2.665	0.0615
15	8	50	35.00	14.545	2.815	0.0615
15	8	55	40.00	14.780	3.050	0.0615
15	9	0	45.00	14.977	3.247	0.0615
15	9	5	50.00	15.152	3.422	0.0615
15	9	15	60.00	15.321	3.591	0.0615
15	9	25	70.00	15.320	3.590	0.0615
15	9	35	80.00	15.320	3.590	0.0615
15	9	45	90.00	15.320	3.590	0.0615
15	9	55	100.00	15.342	3.612	0.0615
15	10	15	120.00	15.440	3.710	0.0615
15	10	35	140.00	16.292	4.562	0.0615
15	10	55	160.00	16.979	5.249	0.0615
15	11	15	180.00	17.422	5.692	0.0615
15	11	35	200.00	17.738	6.008	0.0615
15	11	55	220.00	17.855	6.125	0.0615
15	12	15	240.00	18.061	6.331	0.0615
15	12	35	260.00	18.153	6.423	0.0615
15	12	55	280.00	18.334	6.604	0.0615
15	13	15	300.00	18.486	6.756	0.0615

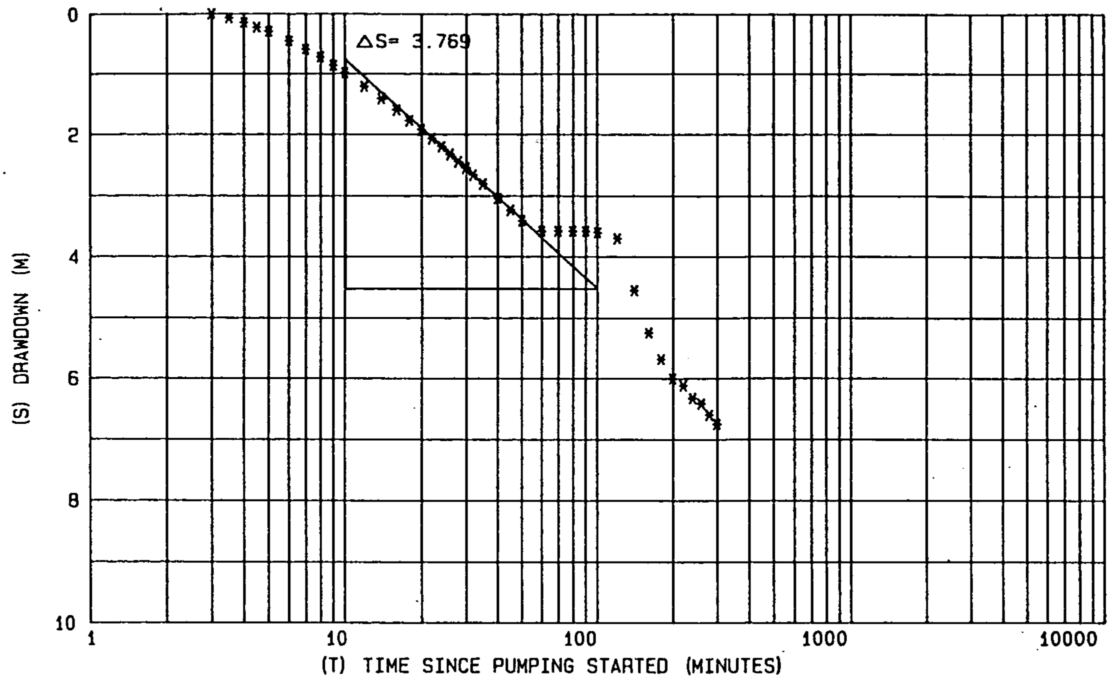
PUMPING TEST - DRAWDOWN DATA

PROJECT: ZIMBABWE
LOCATION: SHAZHAUME SCHOOL
DATUM POINT: TOP OF CASING
PUMPING RATE: 0.0399 L/S
AQUIFER THICKNESS:
CONDITIONS: UNCONFINED

FILE NO.: AFTER HF
WELL NO.: 5
ELEV. OF DATUM POINT:
STATIC WATER LEVEL: 11.689
R = ----- FROM
SCREEN INTERVAL: TO

TIME			ELAPSED TIME	WATER LEVEL	DRAWDOWN	(Q)
DY	HR	MN	t (MIN)	(m)	s (m)	(L/S)
16	8	10	0.00	11.689	0.000	0.0399
16	8	11	0.50	11.592	-0.097	0.0399
16	8	11	1.00	11.602	-0.087	0.0399
16	8	12	1.50	11.613	-0.076	0.0399
16	8	12	2.00	11.623	-0.066	0.0399
16	8	13	2.50	11.635	-0.054	0.0399
16	8	13	3.00	11.646	-0.043	0.0399
16	8	14	3.50	11.660	-0.029	0.0399
16	8	14	4.00	11.671	-0.018	0.0399
16	8	15	4.50	11.686	-0.003	0.0399
16	8	15	5.00	11.696	0.007	0.0399
16	8	16	6.00	11.735	0.046	0.0399
16	8	17	7.00	11.819	0.130	0.0399
16	8	18	8.00	11.921	0.232	0.0399
16	8	19	9.00	12.009	0.320	0.0399
16	8	20	10.00	12.100	0.411	0.0399
16	8	22	12.00	12.266	0.577	0.0399
16	8	24	14.00	12.413	0.724	0.0399
16	8	26	16.00	12.546	0.857	0.0399
16	8	28	18.00	12.674	0.985	0.0399
16	8	30	20.00	12.791	1.102	0.0399
16	8	32	22.00	12.899	1.210	0.0399
16	8	34	24.00	12.998	1.309	0.0399
16	8	36	26.00	13.088	1.399	0.0399
16	8	38	28.00	13.170	1.481	0.0399
16	8	40	30.00	13.249	1.560	0.0399
16	8	42	32.00	13.322	1.633	0.0399
16	8	45	35.00	13.419	1.730	0.0399
16	8	50	40.00	13.566	1.877	0.0399
16	8	55	45.00	13.689	2.000	0.0399
16	9	0	50.00	13.799	2.110	0.0399
16	9	10	60.00	13.988	2.299	0.0399
16	9	20	70.00	14.142	2.453	0.0399
16	9	30	80.00	14.273	2.584	0.0399
16	9	40	90.00	14.389	2.700	0.0399
16	9	50	100.00	14.495	2.806	0.0399
16	10	10	120.00	14.666	2.977	0.0399
16	10	30	140.00	14.793	3.104	0.0399
16	10	50	160.00	14.889	3.200	0.0399
16	11	10	180.00	14.962	3.273	0.0399
16	11	30	200.00	15.020	3.331	0.0399
16	11	50	220.00	15.055	3.366	0.0399
16	12	10	240.00	15.097	3.408	0.0399
16	12	30	260.00	15.122	3.433	0.0399
16	12	50	280.00	15.149	3.460	0.0399
16	13	10	300.00	15.170	3.481	0.0399

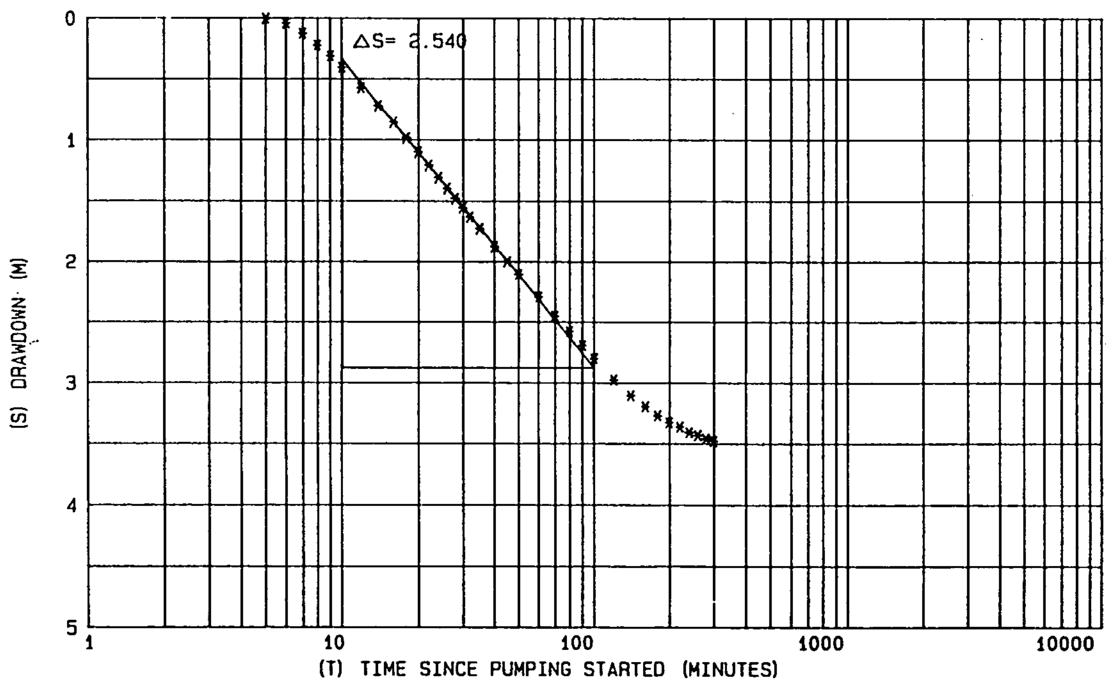
PUMPING TEST ANALYSIS STRAIGHT LINE APPROXIMATION METHOD



PROJECT: ZIMBABWE FILE: BEFORE HF LOCATION: SHAZHAUME SCHOOL	WELL NO.: 5 Q= .0615 L/S S.W.L.= 11.730	ΔS= 3.769 M T= .258 M2/DAY S=

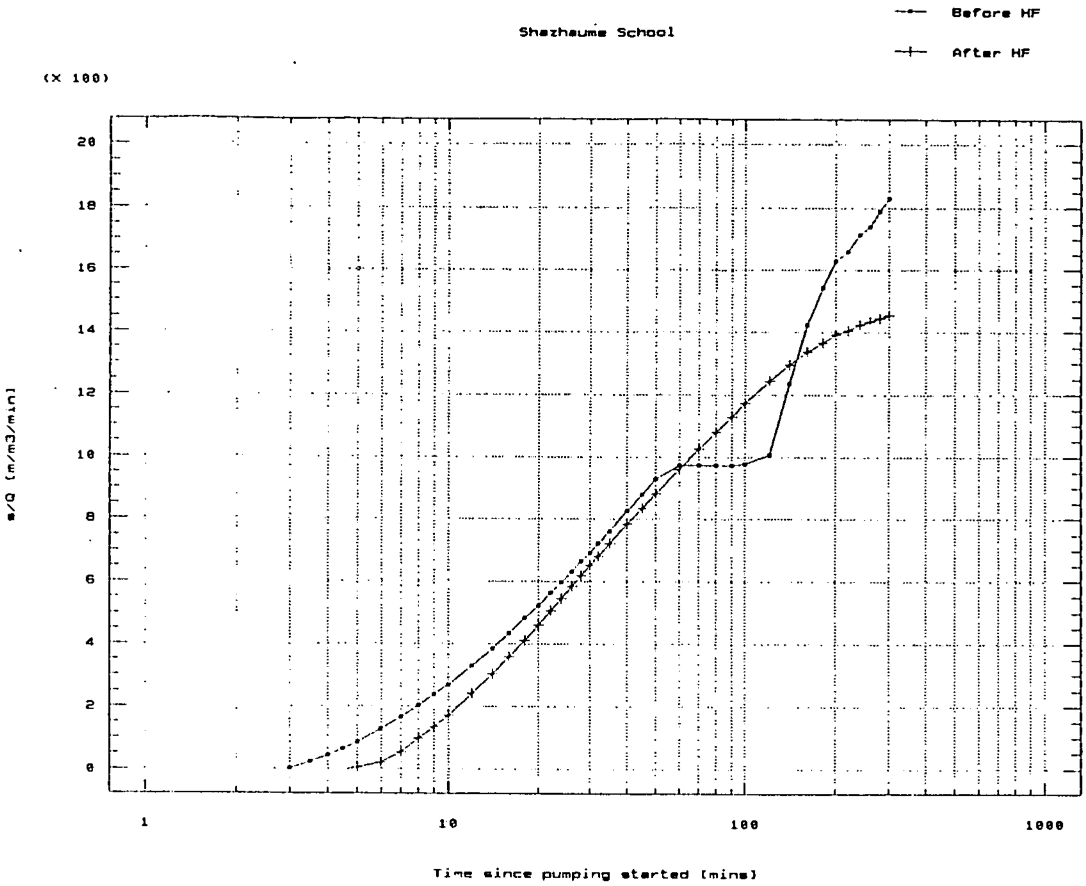
BRITISH GEOLOGICAL SURVEY	FIGURE

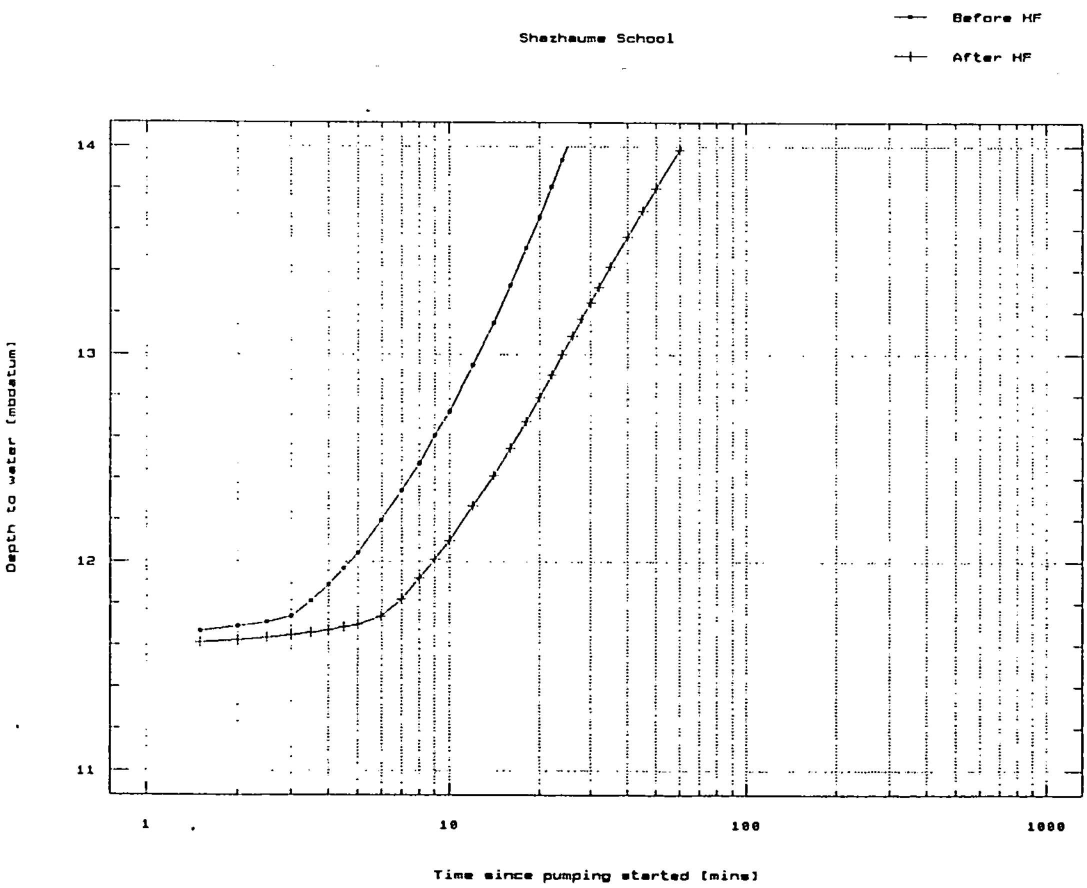
PUMPING TEST ANALYSIS STRAIGHT LINE APPROXIMATION METHOD



PROJECT: ZIMBABWE FILE: AFTER HF LOCATION: SHAZHAUME SCHOOL	WELL NO.: 5 Q= .0399 L/S S.W.L.= 11.689	ΔS= 2.540 M T= .249 M2/DAY S=

BRITISH GEOLOGICAL SURVEY	FIGURE


Shezhaume School
Before HF
After HF
(x 100)
s/Q (m/m3/min)
20
18
16
14
12
10
8
6
4
2
0
1
10
100
1000
Time since pumping started (mins)


Shezhaume School
Before HF
After HF
Depth to water (mbdatum)
14
13
12
11
1
10
100
1000
Time since pumping started (mins)

Site :-
Guiding Star School

Grid Ref. :-
TM 520903

Sequence of Events :-

17/09/90 Bushpump removed
Borehole logging
Test pump installed

18/09/90 Pumptest
Test pump removed
Hydrofracturing
Test pump installed

19/09/90 Pumptest
Test pump removed
Bushpump replaced

Notes :-
This borehole supplies approximately 20 buckets (400 litres) in the morning and afternoon. The school 'imports' water from the nearby Rata School which has an excellent borehole. The bushpump suction was set at 46m. Water level on the morning of the 17th was approximately 45m.

Logging Results :-
Borehole is about 46m deep. Only calliper log done before HF because of the lack of water. After the HF the calliper was not working so no log was done.

Hydrofracturing Results :-
Single packer used set at 28m. Pressure peaked at 130 bar, at which point one of the pipes broke at the thread.

Water Quality :-
Water before hydrofracturing EC = 1300 μS/cm
Water from tank injected EC = 1440 μS/cm
Water after hydrofracturing EC = 1260 μS/cm

Pumptest Results :-
Submersible pump suction set at 46m. Pre pumptest lasted 295 minutes with a total drawdown of 18.324m at a pumping rate of 0.0239 l/s. Post pumptest lasted the full 300 minutes with a total drawdown of 20.230m at a pumping rate of 0.0345 l/s.

Transmissivity values were 0.011 m^2/day before HF and 0.010 m^2/day after HF, a decrease of 10%.

Specific capacity values after 280 minutes pumping were 0.113 m^3/day/m before HF and 0.161 m^3/day/m after HF, an improvement of 42%.

Predicted time to reach the pump suction (46m) before HF is 305 minutes giving a volume of 438 litres, and after HF is 348 giving a volume of 719 litres, an improvement of 64%.

PUMPING TEST - DRAWDOWN DATA

PROJECT: ZIMBABWE
LOCATION: GUIDING STAR SCHOOL
DATUM POINT: TOP OF CASING
PUMPING RATE: 0.0239 L/S
AQUIFER THICKNESS:
CONDITIONS: UNCONFINED

FILE NO.: BEFORE HF
WELL NO.: 6
ELEV. OF DATUM POINT:
STATIC WATER LEVEL: 26.577
R = ----- FROM
SCREEN INTERVAL: TO

TIME			ELAPSED TIME	WATER LEVEL	DRAWDOWN	(Q)
DY	HR	MN	t (MIN)	(m)	s (m)	(L/S)
18	8	40	0.00	26.577	0.000	0.0239
18	8	41	0.50	25.452	-1.125	0.0239
18	8	41	1.00	25.486	-1.091	0.0239
18	8	42	1.50	25.569	-1.008	0.0239
18	8	42	2.00	25.638	-0.939	0.0239
18	8	43	2.50	25.723	-0.854	0.0239
18	8	43	3.00	25.797	-0.780	0.0239
18	8	44	3.50	25.870	-0.707	0.0239
18	8	44	4.00	25.935	-0.642	0.0239
18	8	45	4.50	26.008	-0.569	0.0239
18	8	45	5.00	26.075	-0.502	0.0239
18	8	46	6.00	26.219	-0.358	0.0239
18	8	47	7.00	26.359	-0.218	0.0239
18	8	48	8.00	26.502	-0.075	0.0239
18	8	49	9.00	26.642	0.065	0.0239
18	8	50	10.00	26.783	0.206	0.0239
18	8	52	12.00	27.062	0.485	0.0239
18	8	54	14.00	27.376	0.799	0.0239
18	8	56	16.00	27.585	1.008	0.0239
18	8	58	18.00	27.795	1.218	0.0239
18	9	0	20.00	28.008	1.431	0.0239
18	9	2	22.00	28.177	1.600	0.0239
18	9	4	24.00	28.345	1.768	0.0239
18	9	6	26.00	28.526	1.949	0.0239
18	9	8	28.00	28.700	2.123	0.0239
18	9	10	30.00	28.889	2.312	0.0239
18	9	12	32.00	29.062	2.485	0.0239
18	9	15	35.00	29.336	2.759	0.0239
18	9	20	40.00	29.631	3.054	0.0239
18	9	25	45.00	29.977	3.400	0.0239
18	9	30	50.00	30.304	3.727	0.0239
18	9	40	60.00	30.995	4.418	0.0239
18	9	50	70.00	31.654	5.077	0.0239
18	10	0	80.00	32.295	5.718	0.0239
18	10	10	90.00	32.969	6.392	0.0239
18	10	20	100.00	33.621	7.044	0.0239
18	10	40	120.00	34.920	8.343	0.0239
18	11	0	140.00	36.221	9.644	0.0239
18	11	20	160.00	37.522	10.945	0.0239
18	11	40	180.00	38.779	12.202	0.0239
18	12	0	200.00	40.035	13.458	0.0239
18	12	20	220.00	41.265	14.688	0.0239
18	12	40	240.00	42.470	15.893	0.0239
18	13	0	260.00	43.722	17.145	0.0239
18	13	20	280.00	44.901	18.324	0.0239

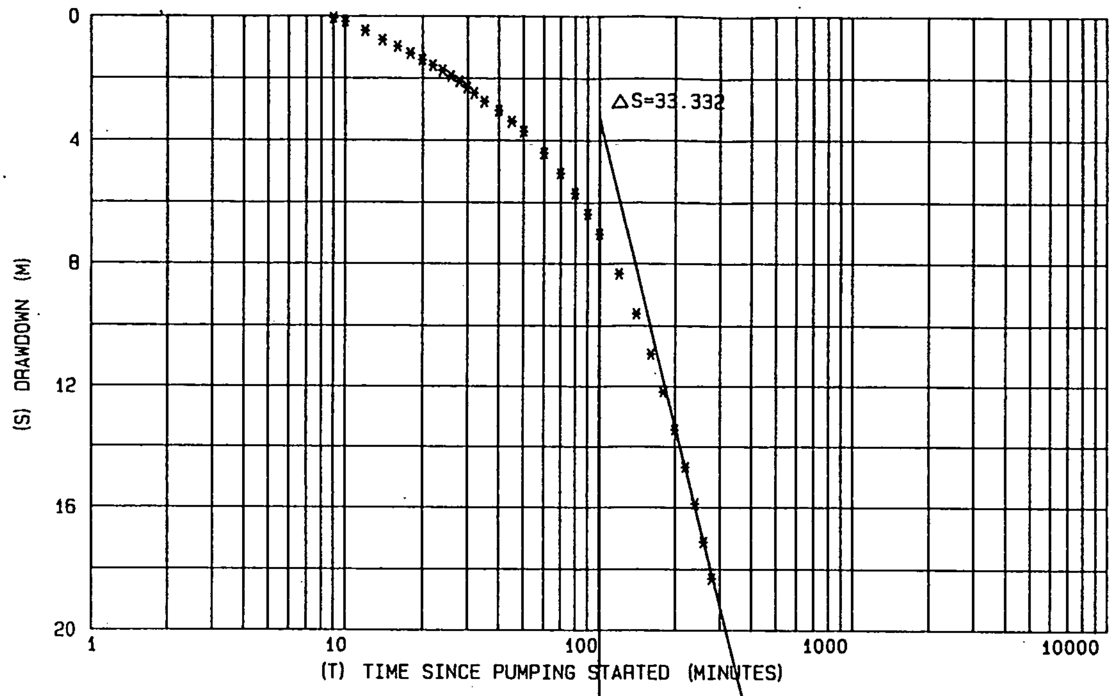
PUMPING TEST - DRAWDOWN DATA

PROJECT: ZIMBABWE
LOCATION: GUIDING STAR SCHOOL
DATUM POINT: TOP OF CASING
PUMPING RATE: 0.0345 L/S
AQUIFER THICKNESS:
CONDITIONS: UNCONFINED

FILE NO.: AFTER HF
WELL NO.: 6
ELEV. OF DATUM POINT:
STATIC WATER LEVEL: 21.960
R = ----- FROM
SCREEN INTERVAL: TO

TIME			ELAPSED TIME	WATER LEVEL	DRAWDOWN	(Q)
DY	HR	MN	t (MIN)	(m)	s (m)	(/S)
19	7	50	0.00	21.960	0.000	0.0345
19	7	51	1.00	21.925	-0.035	0.0345
19	7	52	1.50	21.931	-0.029	0.0345
19	7	52	2.00	21.930	-0.030	0.0345
19	7	53	2.50	21.935	-0.025	0.0345
19	7	53	3.00	21.934	-0.026	0.0345
19	7	54	3.50	21.940	-0.020	0.0345
19	7	54	4.00	21.940	-0.020	0.0345
19	7	55	4.50	21.940	-0.020	0.0345
19	7	55	5.00	21.943	-0.017	0.0345
19	7	56	6.00	21.950	-0.010	0.0345
19	7	57	7.00	21.957	-0.003	0.0345
19	7	58	8.00	21.960	0.000	0.0345
19	7	59	9.00	21.965	0.005	0.0345
19	8	0	10.00	21.970	0.010	0.0345
19	8	2	12.00	21.980	0.020	0.0345
19	8	4	14.00	21.992	0.032	0.0345
19	8	6	16.00	22.002	0.042	0.0345
19	8	8	18.00	22.020	0.060	0.0345
19	8	10	20.00	22.029	0.069	0.0345
19	8	12	22.00	22.044	0.084	0.0345
19	8	14	24.00	22.056	0.096	0.0345
19	8	16	26.00	22.075	0.115	0.0345
19	8	18	28.00	22.095	0.135	0.0345
19	8	20	30.00	22.122	0.162	0.0345
19	8	22	32.00	22.131	0.171	0.0345
19	8	25	35.00	22.159	0.199	0.0345
19	8	30	40.00	22.210	0.250	0.0345
19	8	35	45.00	22.264	0.304	0.0345
19	8	40	50.00	22.330	0.370	0.0345
19	8	50	60.00	22.468	0.508	0.0345
19	9	0	70.00	22.621	0.661	0.0345
19	9	10	80.00	22.774	0.814	0.0345
19	9	20	90.00	22.930	0.970	0.0345
19	9	30	100.00	23.309	1.349	0.0345
19	9	50	120.00	25.100	3.140	0.0345
19	10	10	140.00	27.002	5.042	0.0345
19	10	30	160.00	29.002	7.042	0.0345
19	10	50	180.00	31.001	9.041	0.0345
19	11	10	200.00	32.950	10.990	0.0345
19	11	30	220.00	34.900	12.940	0.0345
19	11	50	240.00	36.800	14.840	0.0345
19	12	10	260.00	38.670	16.710	0.0345
19	12	30	280.00	40.470	18.510	0.0345
19	12	50	300.00	42.190	20.230	0.0345

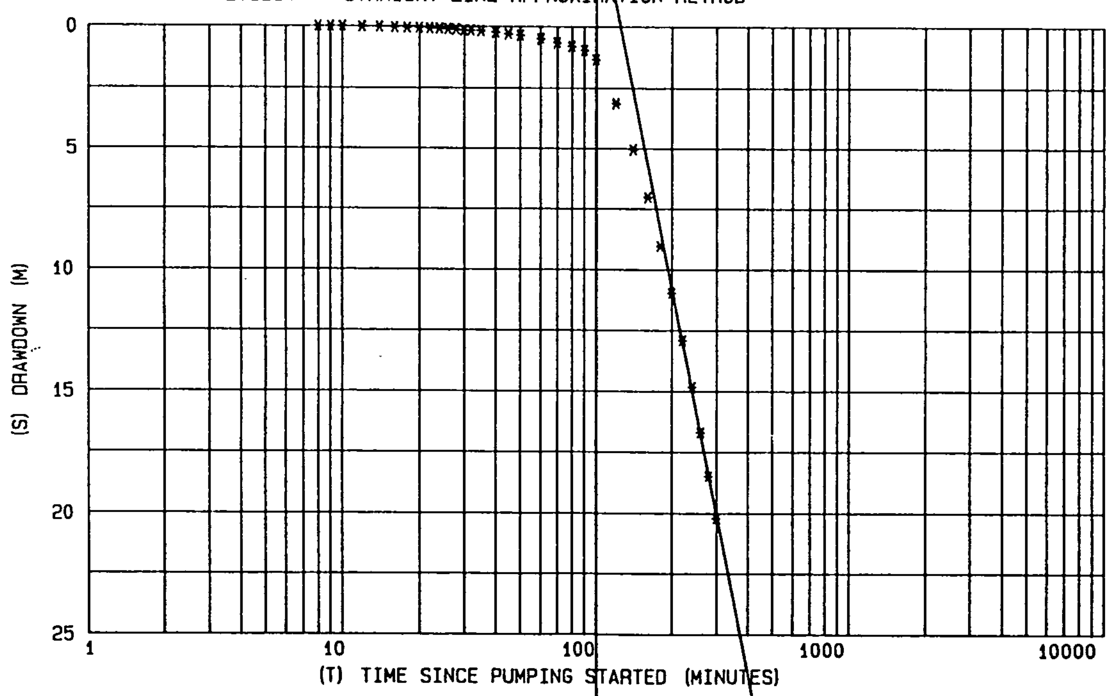
PUMPING TEST ANALYSIS STRAIGHT LINE APPROXIMATION METHOD



PROJECT:	ZIMBABWE	WELL NO.:	6	ΔS=	33.332 M
FILE:	BEFORE HF	Q=	.0239 L/S	T=	.011 M2/DAY
LOCATION:	GUIDING STAR SCHOOL	S.W.L.=	26.577	S=	

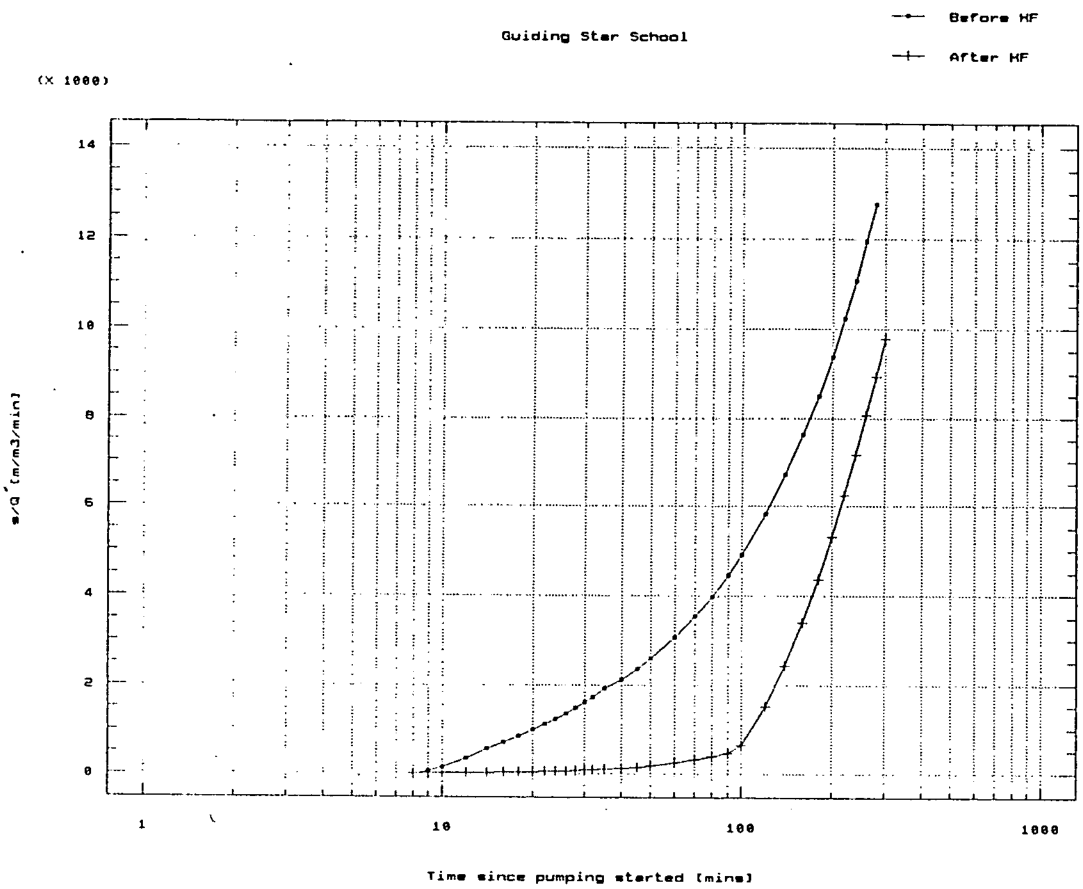
BRITISH GEOLOGICAL SURVEY — FIGURE

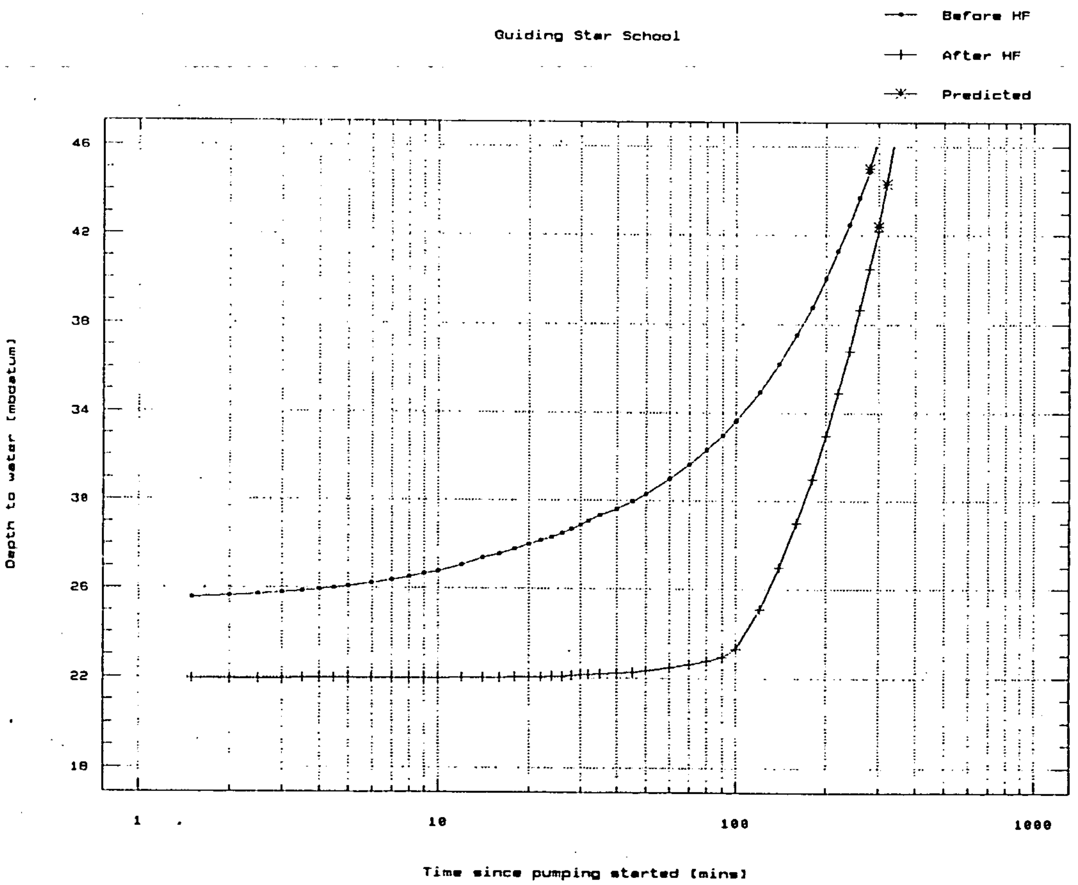
PUMPING TEST ANALYSIS STRAIGHT LINE APPROXIMATION METHOD



PROJECT:	ZIMBABWE	WELL NO.:	6	ΔS=	52.572 M
FILE:	AFTER HF	Q=	.0345 L/S	T=	.010 M2/DAY
LOCATION:	GUIDING STAR SCHOOL	S.W.L.=	21.960	S=	

BRITISH GEOLOGICAL SURVEY — FIGURE


Guiding Star School
Before HF
After HF
(X 1000)
s/Q' (m/m3/min)
14
12
10
8
6
4
2
0
1
10
100
1000
Time since pumping started (mins)


Guiding Star School
Before HF
After HF
Predicted
Depth to water (mbdatum)
46
42
38
34
30
26
22
18
1
10
100
1000
Time since pumping started (mins)

Site :-
Cikadzi School

Grid Ref :-
TM 527776

Sequence of Events :-

28/09/90 Bushpump removed
Borehole logging
Test pump installed

29/09/90 Pumptest
Test pump removed
Hydrofracturing
Test pump installed

30/09/90 Pumptest
Test pump removed
Borehole logging
Bushpump replaced

Notes :-

Headmaster said that this borehole dries up very quickly. Apparently has a large community using the water as well as the school. The school has built tanks for water which they hoped would be filled, but they had not been.

Logging Results :-

Depth of borehole is approximately 44m. Base of weathering is at approximately 30m. No major features are visible below this on the logs.

Hydrofracturing Results :-

Double packer used top set at 29m, bottom at 32m. Pressure did not build up at all the water being pumped into the formation. Single packer then used set at 32m. Pressure peaked at 140 bar but formation did not crack and a pipe broke at the thread.

Water Quality :-

Water before hydrofracturing EC = 355 µS/cm
Water from tank injected EC = 1280 µS/cm
Water after hydrofracturing EC = 760 µS/cm

Pumptest Results :-

Submersible pump suction set at 43m. Pre pumptest lasted the full 300 minutes with a total drawdown of 0.221m at a pumping rate of 0.0386 l/s. Post pumptest lasted the full 300 minutes with a total drawdown of 0.637m at a pumping rate of 0.0301 l/s.

Transmissivity values were 1.925 m^2/day before HF and 1.259 m^2/day after HF, a decrease of 53%.

Specific capacity values after 300 minutes pumping were 15.091 m^3/day/m before HF and 4.083 m^3/day/m after HF, a decrease of 270%.

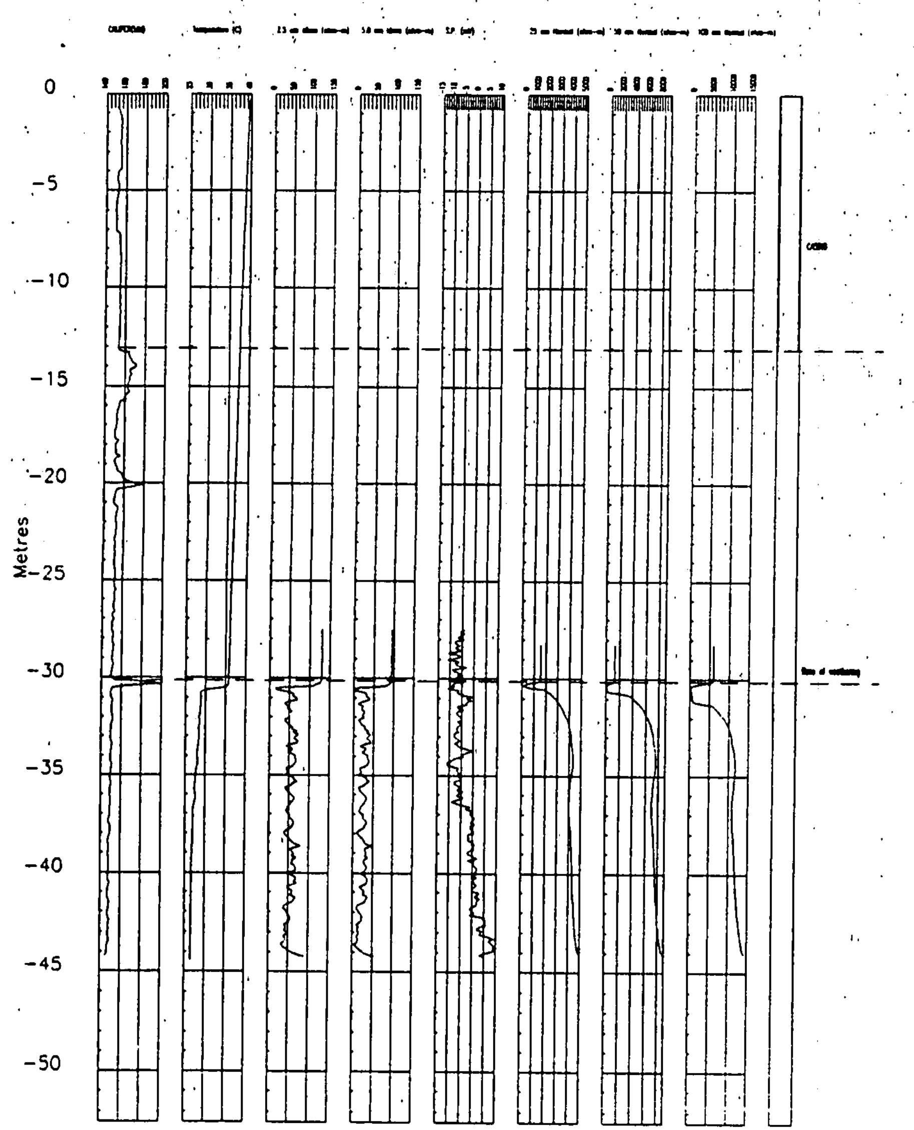
Predicted time for 0.2m drawdown is 271 minutes before HF giving a volume pumped of 628 litres and after HF is 31 minutes giving a volume pumped of 56 litres, a decrease of 1020%.

Special Remarks :-

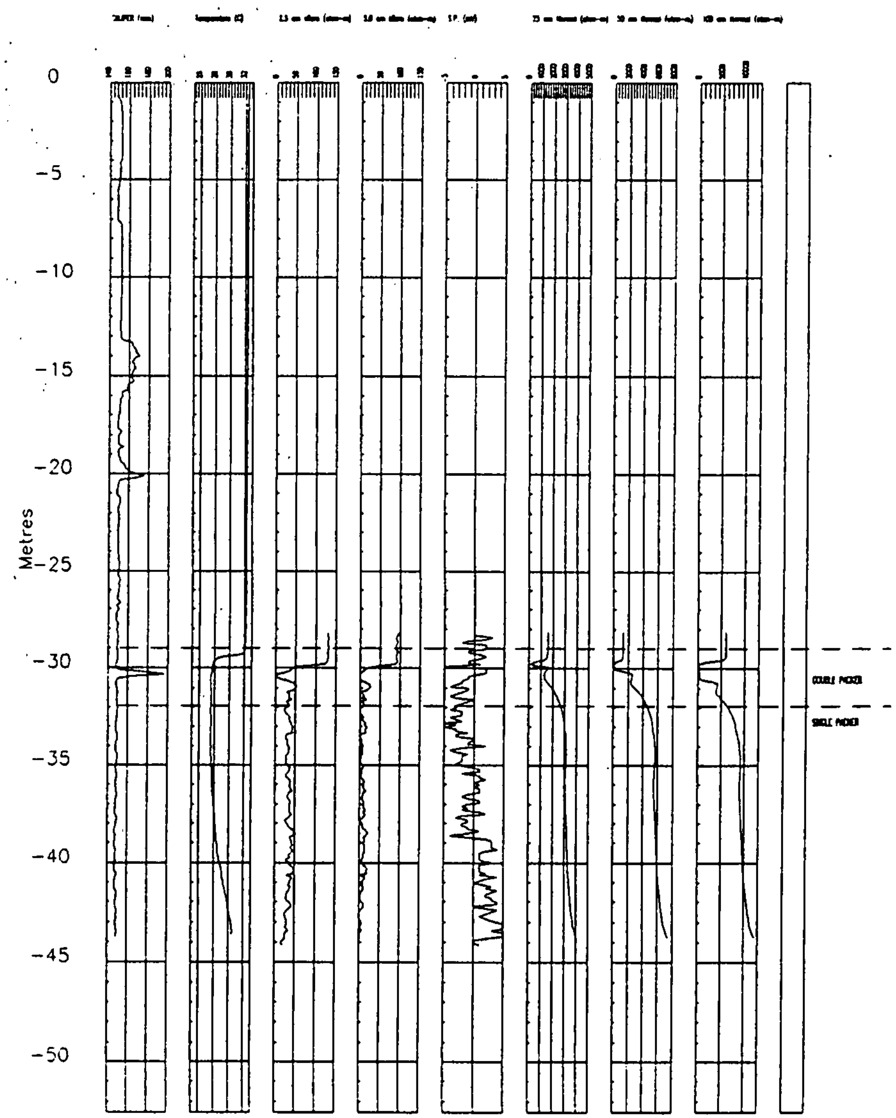
Pre pumptest water levels coincided with a large fracture at 30m, post pumptest levels however were above this fracture and thus were falling more rapidly than before. The analysis therefore shows that there has been a dramatic decrease in performance of this borehole which is probably not the case.

This borehole was relatively high yielding compared with the other sites visited.

Wellname
Filename CIKADZI1
Location
Elevation 0 Reference



Wellname
Filename CIKADZI2
Location
Elevation 0 Reference



PUMPING TEST - DRAWDOWN DATA

PROJECT: ZIMBABWE
LOCATION: CIKADZI SCHOOL
DATUM POINT: TOP OF CASING
PUMPING RATE: 0.0386 L/S
AQUIFER THICKNESS:
CONDITIONS: UNCONFINED

FILE NO.: BEFORE HF
WELL NO.: 8
ELEV. OF DATUM POINT:
STATIC WATER LEVEL: 29.805
R = ----- FROM
SCREEN INTERVAL: TO

TIME			ELAPSED TIME	WATER LEVEL	DRAWDOWN	(Q)
DY	HR	MN	t (MIN)	(m)	s (m)	(L/S)
29	7	30	0.00	29.805	0.000	0.0386
29	7	31	0.50	29.720	-0.085	0.0386
29	7	31	1.00	29.751	-0.054	0.0386
29	7	32	1.50	29.769	-0.036	0.0386
29	7	32	2.00	29.781	-0.024	0.0386
29	7	33	2.50	29.789	-0.016	0.0386
29	7	33	3.00	29.794	-0.011	0.0386
29	7	34	3.50	29.796	-0.009	0.0386
29	7	34	4.00	29.802	-0.003	0.0386
29	7	35	4.50	29.807	0.002	0.0386
29	7	35	5.00	29.810	0.005	0.0386
29	7	36	6.00	29.814	0.009	0.0386
29	7	37	7.00	29.819	0.014	0.0386
29	7	38	8.00	29.823	0.018	0.0386
29	7	39	9.00	29.828	0.023	0.0386
29	7	40	10.00	29.829	0.024	0.0386
29	7	42	12.00	29.832	0.027	0.0386
29	7	44	14.00	29.833	0.028	0.0386
29	7	46	16.00	29.838	0.033	0.0386
29	7	48	18.00	29.840	0.035	0.0386
29	7	50	20.00	29.841	0.036	0.0386
29	7	52	22.00	29.843	0.038	0.0386
29	7	54	24.00	29.848	0.043	0.0386
29	7	56	26.00	29.846	0.041	0.0386
29	7	58	28.00	29.849	0.044	0.0386
29	8	0	30.00	29.850	0.045	0.0386
29	8	2	32.00	29.851	0.046	0.0386
29	8	5	35.00	29.855	0.050	0.0386
29	8	10	40.00	29.860	0.055	0.0386
29	8	15	45.00	29.864	0.059	0.0386
29	8	20	50.00	29.871	0.066	0.0386
29	8	30	60.00	29.881	0.076	0.0386
29	8	40	70.00	29.892	0.087	0.0386
29	8	50	80.00	29.902	0.097	0.0386
29	9	0	90.00	29.911	0.106	0.0386
29	9	10	100.00	29.919	0.114	0.0386
29	9	30	120.00	29.930	0.125	0.0386
29	9	50	140.00	29.941	0.136	0.0386
29	10	10	160.00	29.953	0.148	0.0386
29	10	30	180.00	29.961	0.156	0.0386
29	10	50	200.00	29.969	0.164	0.0386
29	11	10	220.00	29.980	0.175	0.0386
29	11	30	240.00	29.989	0.184	0.0386
29	11	50	260.00	30.001	0.196	0.0386
29	12	10	280.00	30.012	0.207	0.0386
29	12	30	300.00	30.026	0.221	0.0386

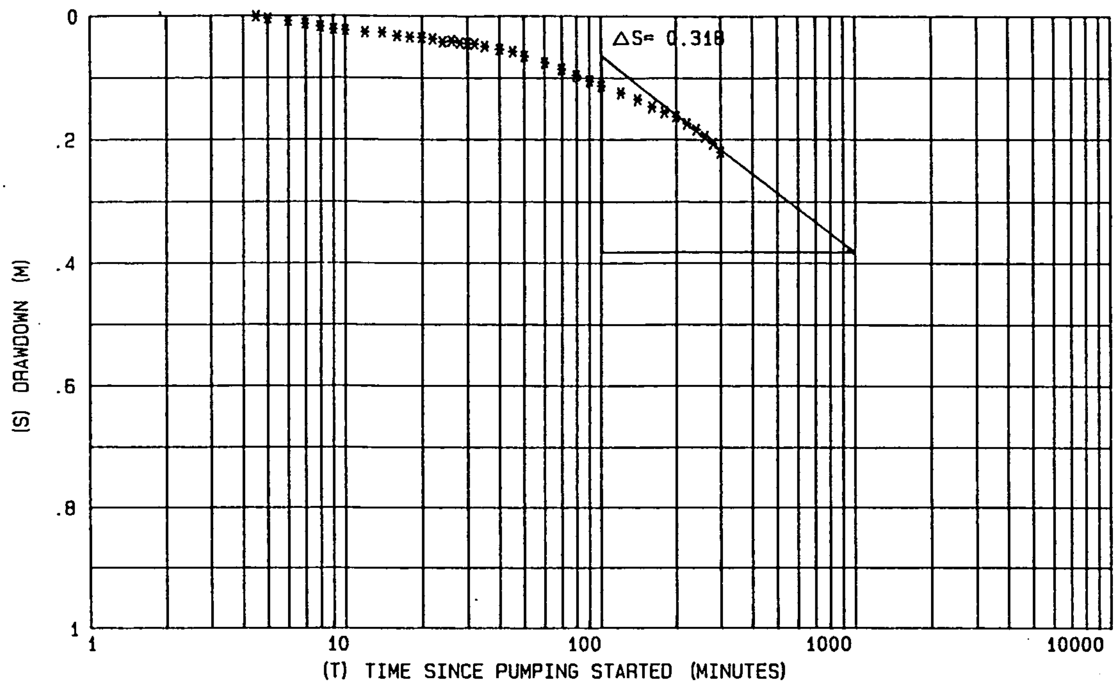
PUMPING TEST - DRAWDOWN DATA

PROJECT: ZIMBABWE
LOCATION: CIKADZI SCHOOL
DATUM POINT: TOP OF CASING
PUMPING RATE: 0.0301 L/S
AQUIFER THICKNESS:
CONDITIONS: UNCONFINED

FILE NO.: AFTER HF
WELL NO.: 8
ELEV. OF DATUM POINT:
STATIC WATER LEVEL: 29.009
R = ----- FROM
SCREEN INTERVAL: TO

TIME			ELAPSED TIME	WATER LEVEL	DRAWDOWN	(Q)
DY	HR	MN	t (MIN)	(m)	s (m)	(L/S)
30	8	0	0.00	29.009	0.000	0.0301
30	8	1	0.50	28.751	-0.258	0.0301
30	8	1	1.00	28.811	-0.198	0.0301
30	8	2	1.50	28.841	-0.168	0.0301
30	8	2	2.00	28.870	-0.139	0.0301
30	8	3	2.50	28.892	-0.117	0.0301
30	8	3	3.00	28.911	-0.098	0.0301
30	8	4	3.50	28.923	-0.086	0.0301
30	8	4	4.00	28.935	-0.074	0.0301
30	8	5	4.50	28.951	-0.058	0.0301
30	8	5	5.00	28.965	-0.044	0.0301
30	8	6	6.00	28.981	-0.028	0.0301
30	8	7	7.00	28.998	-0.011	0.0301
30	8	8	8.00	29.012	0.003	0.0301
30	8	9	9.00	29.035	0.026	0.0301
30	8	10	10.00	29.046	0.037	0.0301
30	8	12	12.00	29.064	0.055	0.0301
30	8	14	14.00	29.089	0.080	0.0301
30	8	16	16.00	29.107	0.098	0.0301
30	8	18	18.00	29.121	0.112	0.0301
30	8	20	20.00	29.149	0.140	0.0301
30	8	22	22.00	29.156	0.147	0.0301
30	8	24	24.00	29.170	0.161	0.0301
30	8	26	26.00	29.184	0.175	0.0301
30	8	28	28.00	29.192	0.183	0.0301
30	8	30	30.00	29.205	0.196	0.0301
30	8	32	32.00	29.214	0.205	0.0301
30	8	35	35.00	29.231	0.222	0.0301
30	8	40	40.00	29.259	0.250	0.0301
30	8	45	45.00	29.284	0.275	0.0301
30	8	50	50.00	29.309	0.300	0.0301
30	9	0	60.00	29.350	0.341	0.0301
30	9	10	70.00	29.378	0.369	0.0301
30	9	20	80.00	29.410	0.401	0.0301
30	9	30	90.00	29.430	0.421	0.0301
30	9	40	100.00	29.451	0.442	0.0301
30	10	0	120.00	29.485	0.476	0.0301
30	10	20	140.00	29.511	0.502	0.0301
30	10	40	160.00	29.532	0.523	0.0301
30	11	0	180.00	29.556	0.547	0.0301
30	11	20	200.00	29.581	0.572	0.0301
30	11	40	220.00	29.588	0.579	0.0301
30	12	0	240.00	29.600	0.591	0.0301
30	12	20	260.00	29.616	0.607	0.0301
30	12	40	280.00	29.631	0.622	0.0301
30	13	0	300.00	29.646	0.637	0.0301

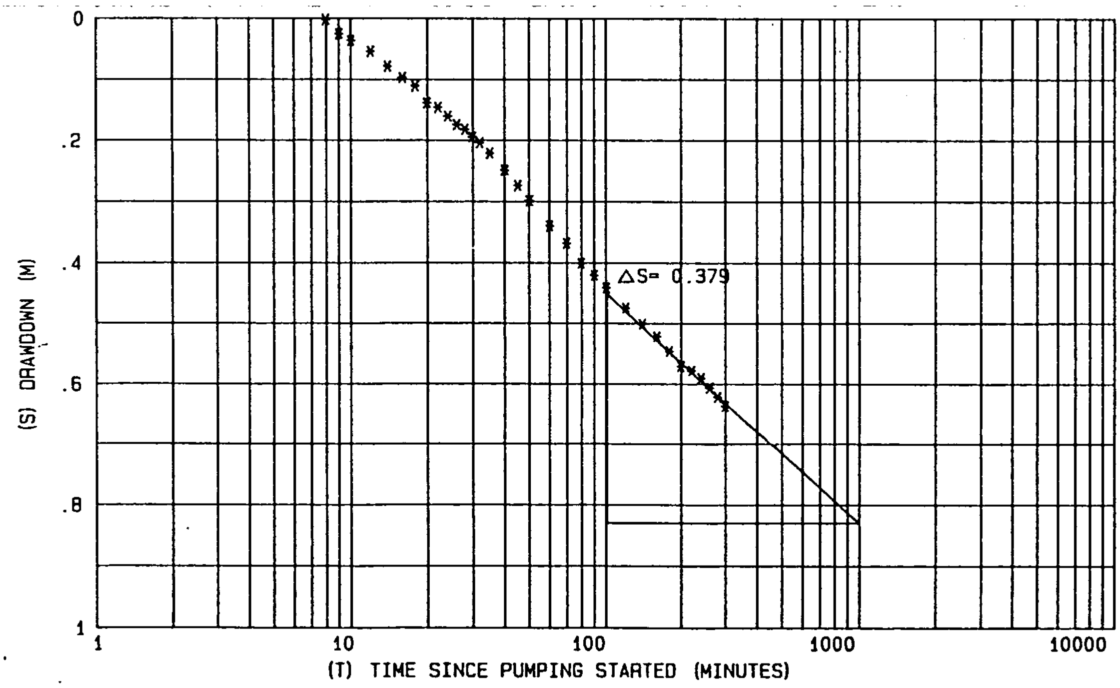
PUMPING TEST ANALYSIS STRAIGHT LINE APPROXIMATION METHOD



PROJECT: ZIMBABWE FILE: BEFORE HF LOCATION: CIKADZI SCHOOL	WELL NO.: 8 Q= .0386 L/S S.W.L.= 29.805	ΔS= 0.318 M T= 1.925 M2/DAY S=

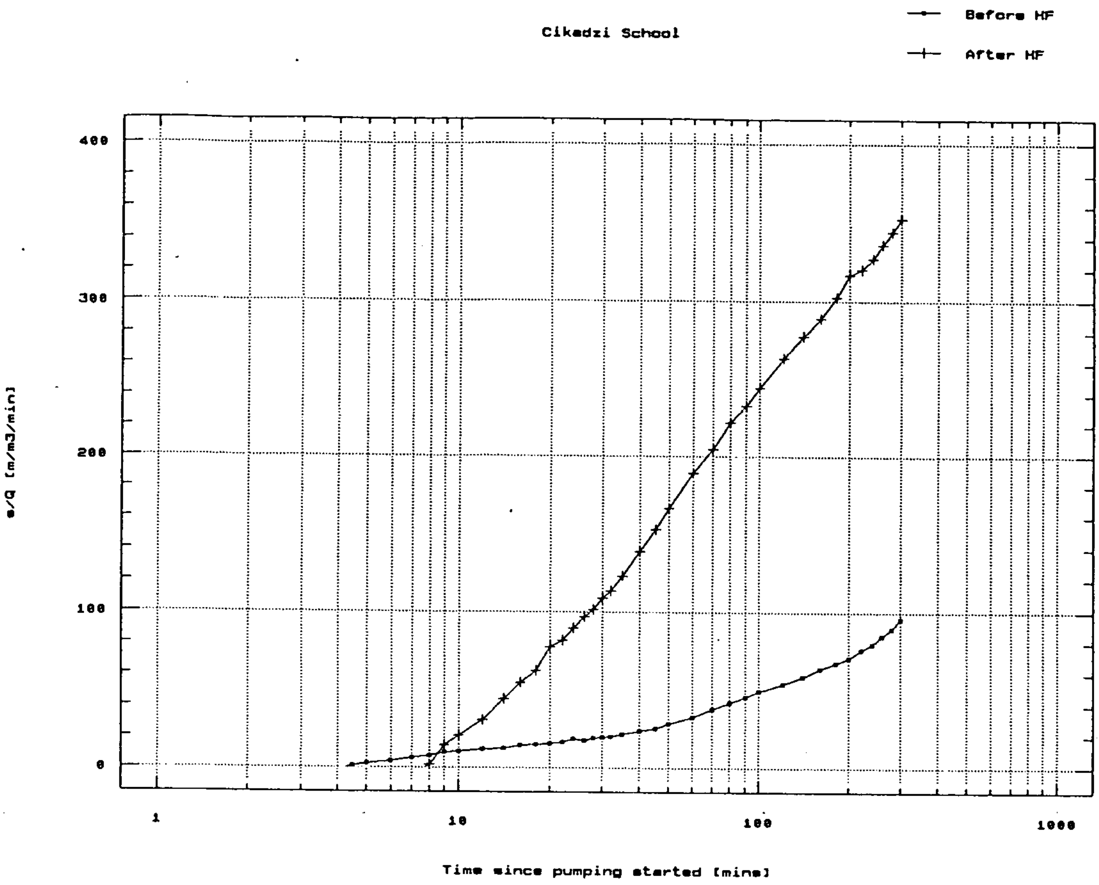
BRITISH GEOLOGICAL SURVEY — FIGURE

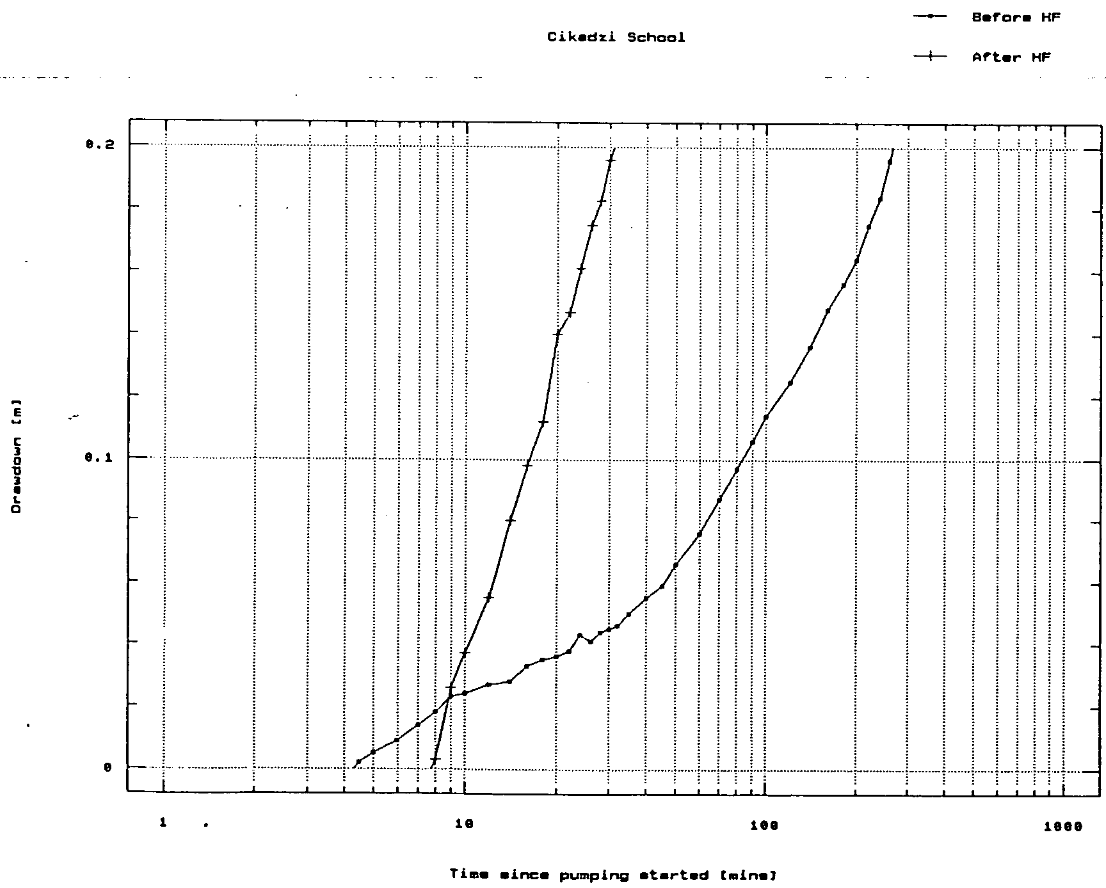
PUMPING TEST ANALYSIS STRAIGHT LINE APPROXIMATION METHOD



PROJECT: ZIMBABWE FILE: AFTER HF LOCATION: CIKADZI SCHOOL	WELL NO.: 8 Q= .0301 L/S S.W.L.= 29.009	ΔS= 0.379 M T= 1.259 M2/DAY S=

BRITISH GEOLOGICAL SURVEY — FIGURE


Cikedzi School
Before HF
After HF
400
300
200
100
0
s/Q [m/m3/min]
1
10
100
1000
Time since pumping started [mins]


Cikedzi School
Before HF
After HF
0.2
0.1
0
Drawdown [m]
1
10
100
1000
Time since pumping started [mins]

Site :-
Kuwirirana School

Grid Ref. :-
TM 482646

Sequence of Events :-

01/10/90 Bushpump removed
Borehole logging
Test pump installed

02/10/90 Pumptest
Test pump removed
Hydrofracturing

03/10/90 Hydrofracturing
Borehole logging
Test pump installed

04/10/90 Pumptest
Test pump removed
Bushpump replaced

Notes :-

Virtually dry, with 1 bucket of water after 30 minutes pumping indicated that the pump was broken. Have a nearby saline borehole but they walk 3-4 km to Mashava for their water. A water tank is filled occasionally in the school yard. Borehole was drilled about 2 years ago. Bushpump suction was at 46m and was replaced at 52m with a new cylinder. Water level on the morning of the 1st was 39.350m. School was revisited 09/10/90 as the pump had broken again, the pump was mended and the headmaster said that they now got 15 buckets of water before the borehole dried up.

Logging Results :-

Depth of borehole is 53.5m. Base of weathering is at about 28m. Fractures can be seen to occur at 37.5m and 49m before HF. After HF there is a new fracture visible at about 45m.

Hydrofracturing Results :-

Single packer used with 95mm rubbers set at 30m. Pressure did not build up beyond 10 bar. Packer set at 36m and again pressure did not build up beyond 10 bar. At this point a full tank of water had been pumped into the borehole and so the HF unit was removed back to base to refill. Next morning single packer set at 42m pressure peaked at 130 bar and the packer slipped. Packer set at 41m and the pressure did not build up. Packer set at 42m and the pressure peaked at 80 bar, the formation cracked and the running pressure was 30 bar. In total 1.25 tanks of water had been pumped into the borehole.

Water Quality :-

Water before hydrofracturing EC = 1330 µS/cm
Water from tank injected EC = 1240 µS/cm
Water after hydrofracturing EC = 1205 µS/cm

Pumptest Results :-

Submersible pump suction set at 49m. Pre pumptest lasted for 80 minutes with a total drawdown of 10.195m at a pumping rate of 0.0329 l/s. Post pumptest lasted 265 minutes with a total drawdown of 22.257m at a pumping rate of 0.0367 l/s. Water level was 13.078m higher after HF.

Transmissivity values were 0.020 m^2/day before HF and 0.045 m^2/day after HF (using same log cycle), an improvement of 125%.

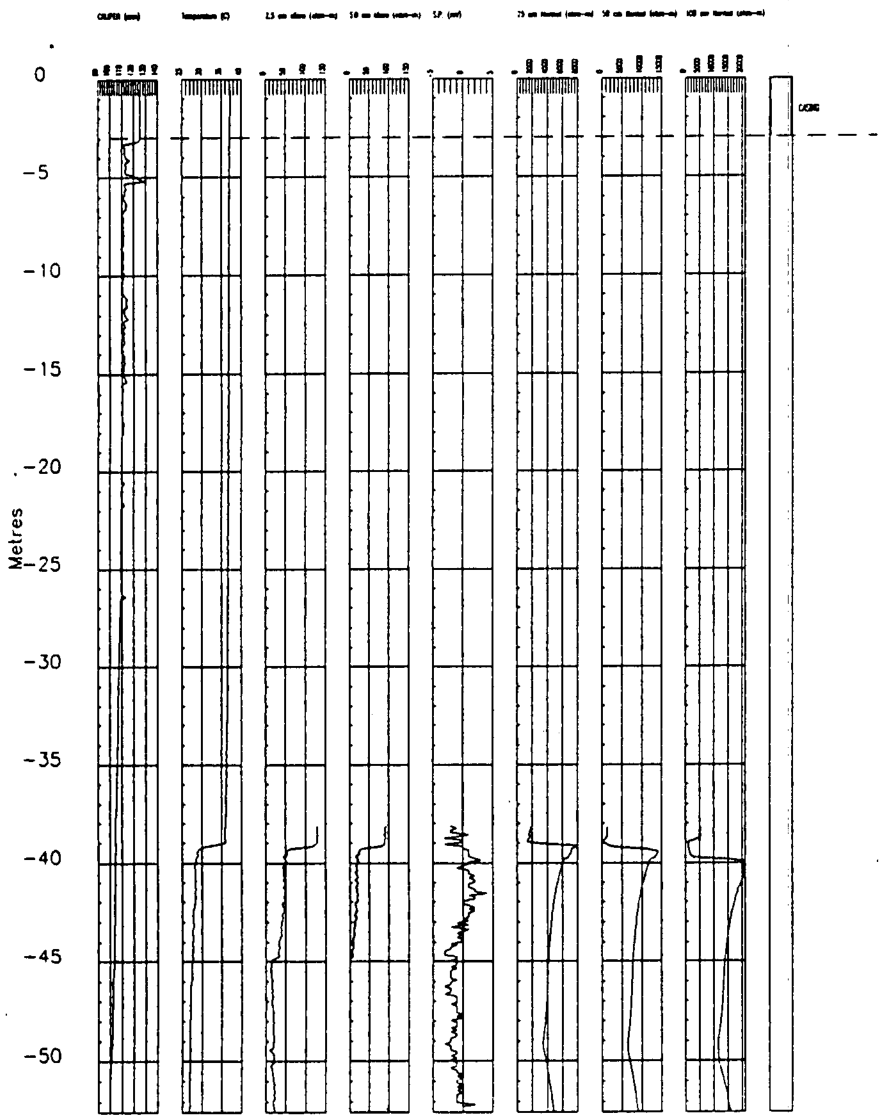
Specific capacity values after 80 minutes pumping were 0.279 m^3/day/m before HF and 0.603 m^3/day/m after HF, an improvement of 116%.

Predicted time to reach the pump suction (49m) before HF is 94 minutes giving a volume of 186 litres, and after HF was 288 minutes giving a volume of 634 litres, an improvement of 241%.

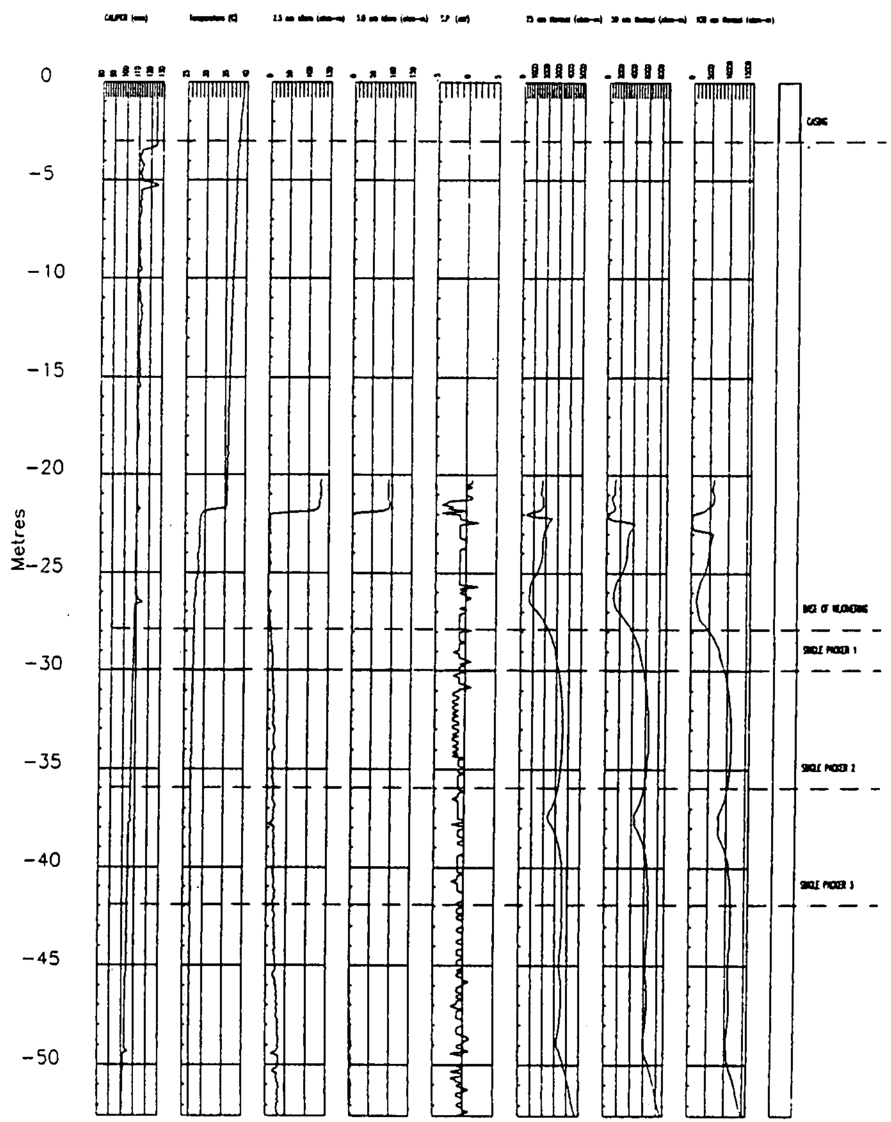
Special Remarks :-

If s/Q values were made equal at beginning of tests, the improvement would be even greater than that shown above.

Wellname Kuwirirana School
Filename KUWIRIR1
Location TM 482646 Zimbabwe
Elevation 0 Reference



Wellname Kuwirirana School
Filename KUWIRIR2
Location TM 482646 Zimbabwe
Elevation 0 Reference



PUMPING TEST - DRAWDOWN DATA

PROJECT: ZIMBABWE
LOCATION: KUWIRIRANA SCHOOL
DATUM POINT: TOP OF CASING
PUMPING RATE: 0.0329 L/S
AQUIFER THICKNESS:
CONDITIONS: UNCONFINED

FILE NO.: BEFORE HF
WELL NO.: 9
ELEV. OF DATUM POINT:
STATIC WATER LEVEL: 36.706
R = ----- FROM
SCREEN INTERVAL: TO

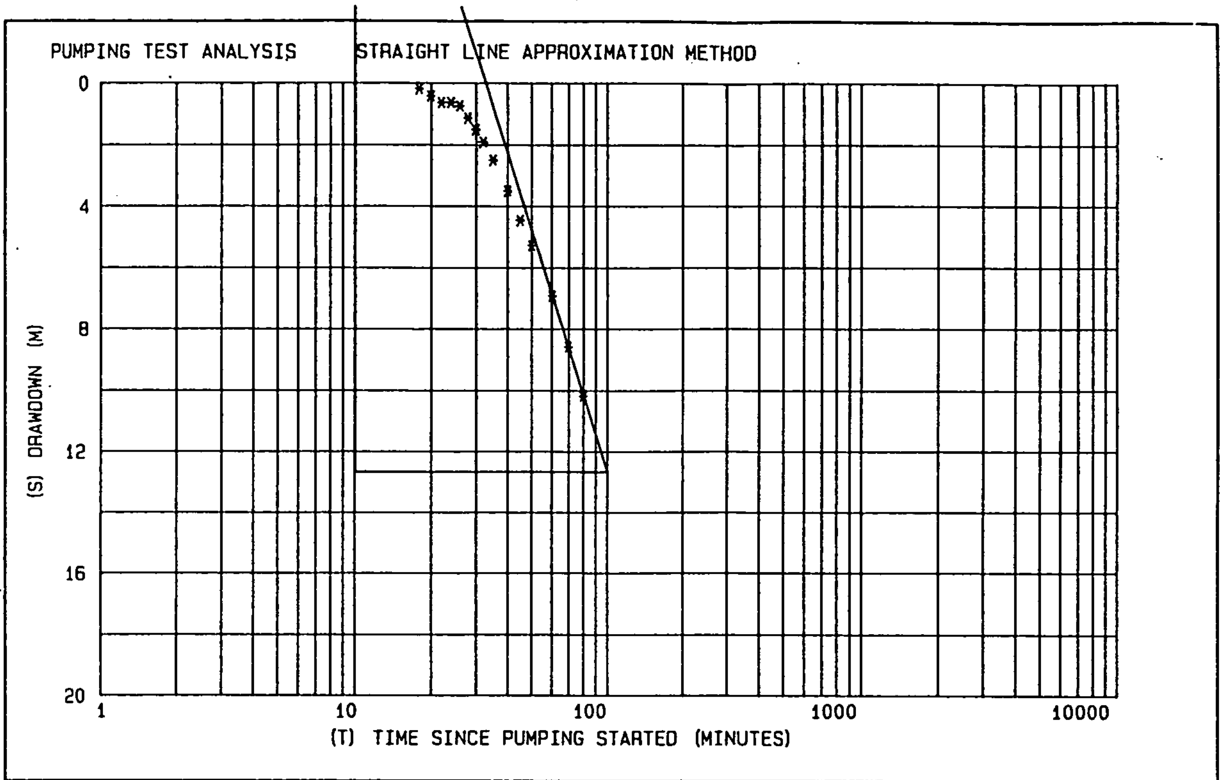
TIME			ELAPSED TIME	WATER LEVEL	DRAWDOWN	(Q)
DY	HR	MN	t (MIN)	(m)	s (m)	(L/S)
2	8	10	0.00	36.706	0.000	0.0329
2	8	11	0.50	34.192	-2.514	0.0329
2	8	11	1.00	34.161	-2.545	0.0329
2	8	12	1.50	34.231	-2.475	0.0329
2	8	12	2.00	34.331	-2.375	0.0329
2	8	13	2.50	34.426	-2.280	0.0329
2	8	13	3.00	34.520	-2.186	0.0329
2	8	14	3.50	34.624	-2.082	0.0329
2	8	14	4.00	34.716	-1.990	0.0329
2	8	15	4.50	34.805	-1.901	0.0329
2	8	15	5.00	34.896	-1.810	0.0329
2	8	16	6.00	35.080	-1.626	0.0329
2	8	17	7.00	35.252	-1.454	0.0329
2	8	18	8.00	35.412	-1.294	0.0329
2	8	19	9.00	35.590	-1.116	0.0329
2	8	20	10.00	35.754	-0.952	0.0329
2	8	22	12.00	36.059	-0.647	0.0329
2	8	24	14.00	36.360	-0.346	0.0329
2	8	26	16.00	36.641	-0.065	0.0329
2	8	28	18.00	36.908	0.202	0.0329
2	8	30	20.00	37.141	0.435	0.0329
2	8	32	22.00	37.352	0.646	0.0329
2	8	34	24.00	37.361	0.655	0.0329
2	8	36	26.00	37.470	0.764	0.0329
2	8	38	28.00	37.858	1.152	0.0329
2	8	40	30.00	38.240	1.534	0.0329
2	8	42	32.00	38.631	1.925	0.0329
2	8	45	35.00	39.213	2.507	0.0329
2	8	50	40.00	40.218	3.512	0.0329
2	8	55	45.00	41.179	4.473	0.0329
2	9	0	50.00	42.001	5.295	0.0329
2	9	10	60.00	43.641	6.935	0.0329
2	9	20	70.00	45.303	8.597	0.0329
2	9	30	80.00	46.901	10.195	0.0329

PUMPING TEST - DRAWDOWN DATA

PROJECT: ZIMBABWE
LOCATION: KUWIRIRANA SCHOOL
DATUM POINT: TOP OF CASING
PUMPING RATE: 0.0367 L/S
AQUIFER THICKNESS:
CONDITIONS: UNCONFINED

FILE NO.: AFTER HF
WELL NO.: 9
ELEV. OF DATUM POINT:
STATIC WATER LEVEL: 23.628
R = ----- FROM
SCREEN INTERVAL: TO

TIME			ELAPSED TIME	WATER LEVEL	DRAWDOWN	(Q)
DY	HR	MN	t (MIN)	(m)	s (m)	(L/S)
4	8	5	0.00	23.628	0.000	0.0367
4	8	6	1.00	22.738	-0.890	0.0367
4	8	7	1.50	22.910	-0.718	0.0367
4	8	7	2.00	23.025	-0.603	0.0367
4	8	8	2.50	23.145	-0.483	0.0367
4	8	8	3.00	23.248	-0.380	0.0367
4	8	9	3.50	23.343	-0.285	0.0367
4	8	9	4.00	23.425	-0.203	0.0367
4	8	10	4.50	23.516	-0.112	0.0367
4	8	10	5.00	23.582	-0.046	0.0367
4	8	11	6.00	23.729	0.101	0.0367
4	8	12	7.00	23.842	0.214	0.0367
4	8	13	8.00	23.955	0.327	0.0367
4	8	14	9.00	24.060	0.432	0.0367
4	8	15	10.00	24.162	0.534	0.0367
4	8	17	12.00	24.348	0.720	0.0367
4	8	19	14.00	24.509	0.881	0.0367
4	8	21	16.00	24.660	1.032	0.0367
4	8	23	18.00	24.816	1.188	0.0367
4	8	25	20.00	24.947	1.319	0.0367
4	8	27	22.00	25.076	1.448	0.0367
4	8	29	24.00	25.202	1.574	0.0367
4	8	31	26.00	25.330	1.702	0.0367
4	8	33	28.00	25.443	1.815	0.0367
4	8	35	30.00	25.558	1.930	0.0367
4	8	37	32.00	25.678	2.050	0.0367
4	8	40	35.00	25.850	2.222	0.0367
4	8	45	40.00	26.128	2.500	0.0367
4	8	50	45.00	26.413	2.785	0.0367
4	8	55	50.00	26.730	3.102	0.0367
4	9	5	60.00	27.430	3.802	0.0367
4	9	15	70.00	28.170	4.542	0.0367
4	9	25	80.00	28.886	5.258	0.0367
4	9	35	90.00	29.600	5.972	0.0367
4	9	45	100.00	30.299	6.671	0.0367
4	10	5	120.00	31.564	7.936	0.0367
4	10	25	140.00	33.303	9.675	0.0367
4	10	45	160.00	35.440	11.812	0.0367
4	11	5	180.00	37.371	13.743	0.0367
4	11	25	200.00	39.043	15.415	0.0367
4	11	45	220.00	41.271	17.643	0.0367
4	12	5	240.00	43.478	19.850	0.0367
4	12	25	260.00	45.885	22.257	0.0367



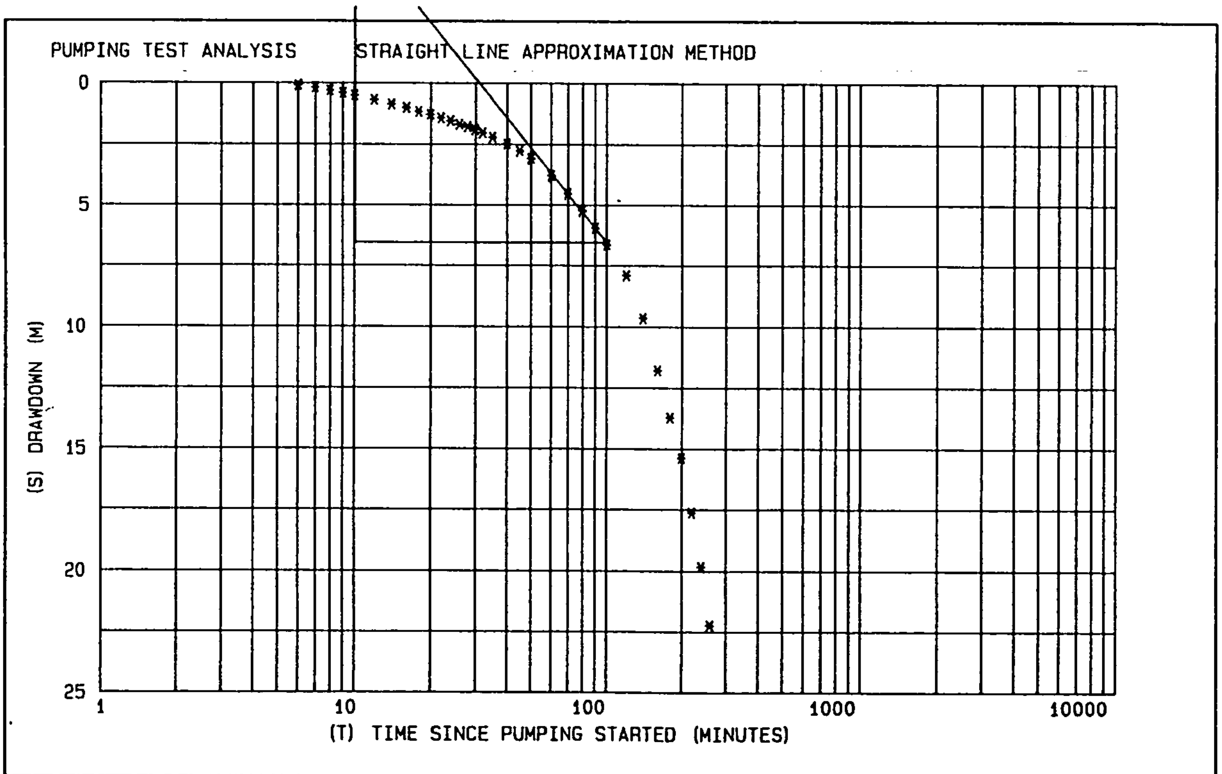
PROJECT: ZIMBABWE
FILE: BEFORE HF
LOCATION: KUWIRIRANA SCHOOL

WELL NO.: 9
Q= .0329 L/S
S.W.L.= 36.706

ΔS= 26.060 M
T= .020 M2/DAY
S=

BRITISH GEOLOGICAL SURVEY

FIGURE



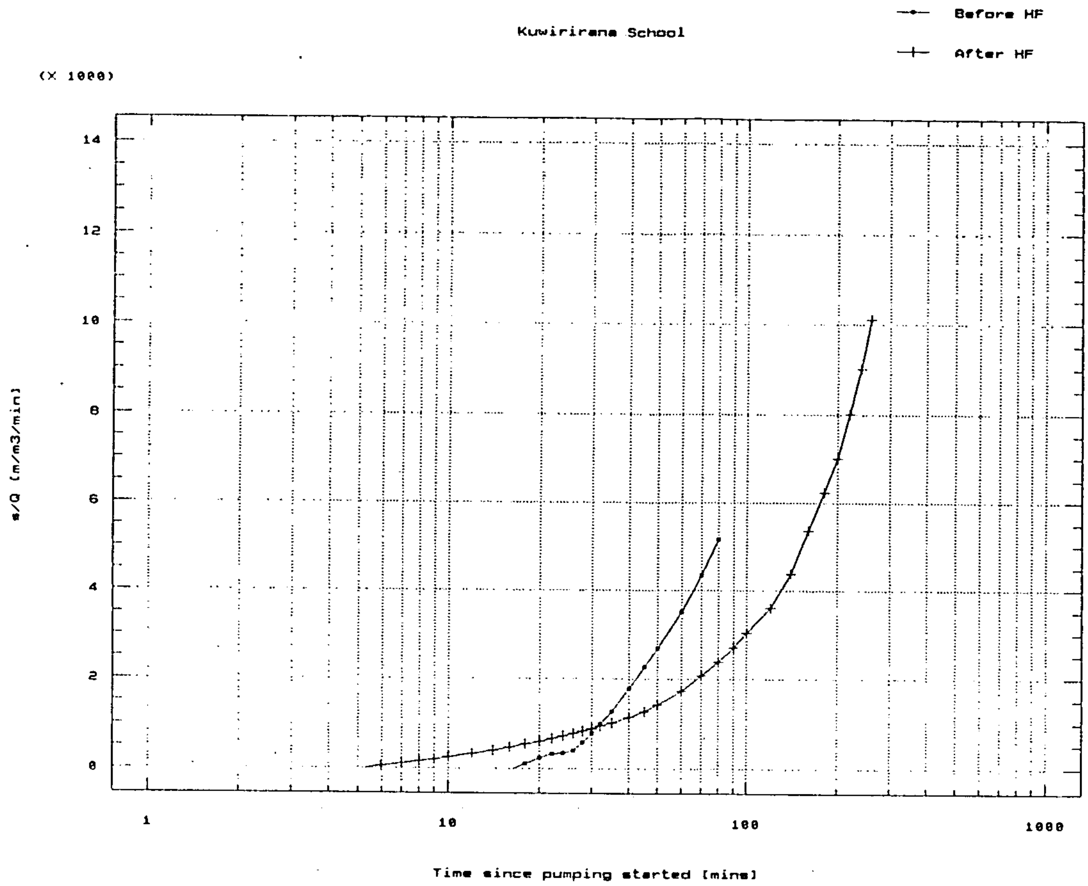
PROJECT: ZIMBABWE
FILE: AFTER HF
LOCATION: KUWIRIRANA SCHOOL

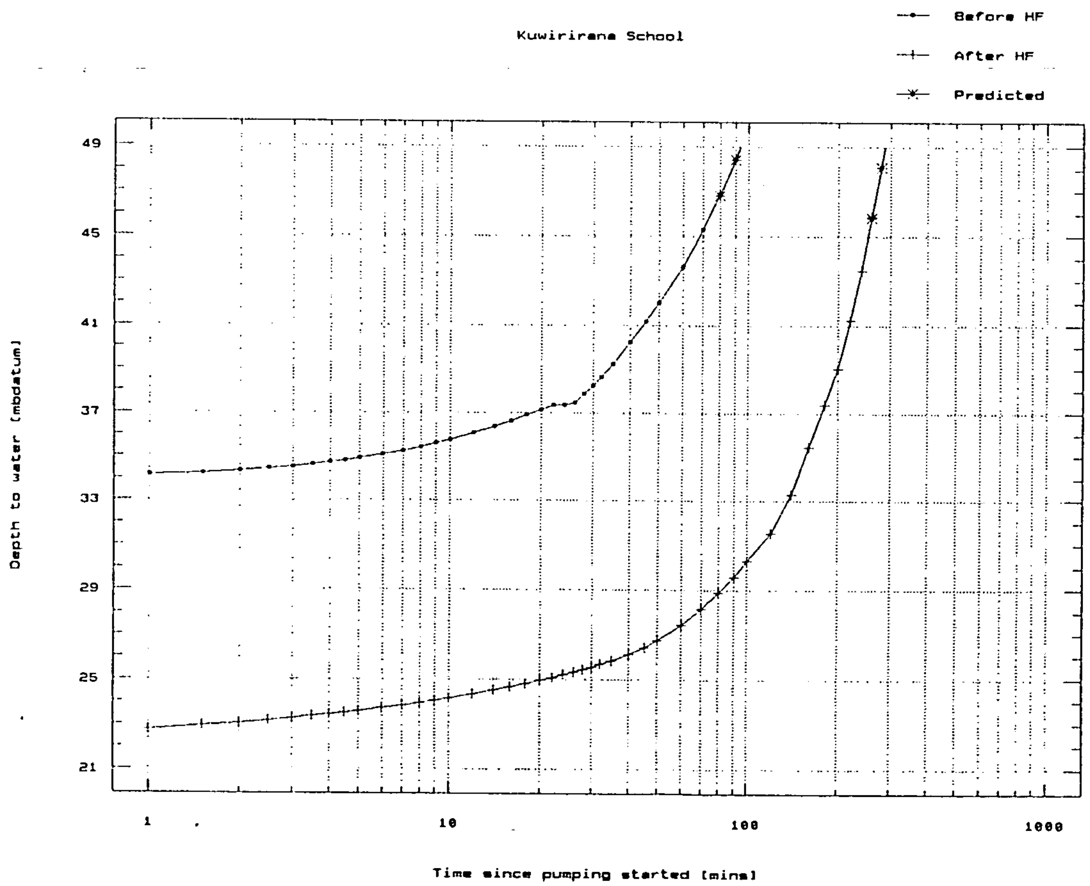
WELL NO.: 9
Q= .0367 L/S
S.W.L.= 23.628

ΔS= 12.902 M
T= .045 M2/DAY
S=

BRITISH GEOLOGICAL SURVEY

FIGURE


Kuwirirana School
Before HF
After HF
(X 1000)
14
12
10
8
6
4
2
0
s/Q (m/m3/min)
1
10
100
1000
Time since pumping started (mins)


Kuwirirana School
Before HF
After HF
Predicted
49
45
41
37
33
29
25
21
Depth to water (mbdatum)
1
10
100
1000
Time since pumping started (mins)

Site :-
Mashava Clinic

Grid Ref. :-
TM 489675

Sequence of Events :-
05/10/90 Bushpump removed
Borehole logging
Hydrofracturing
Borehole logging
Bushpump replaced

Notes :-
Bushpump has been broken since 1988 and borehole is not used, when it was working were able to get one bucket before borehole dried up. A new borehole was drilled two weeks previously near here but it was dry and was not cased, and it has collapsed. Bushpump suction set at 24.5m and water level at 24.45m.

Logging Results :-
Only calliper logs done because the hole is virtually dry. Depth of borehole is 24.9m. No major differences in the calliper logs are visible below where the packer was set.

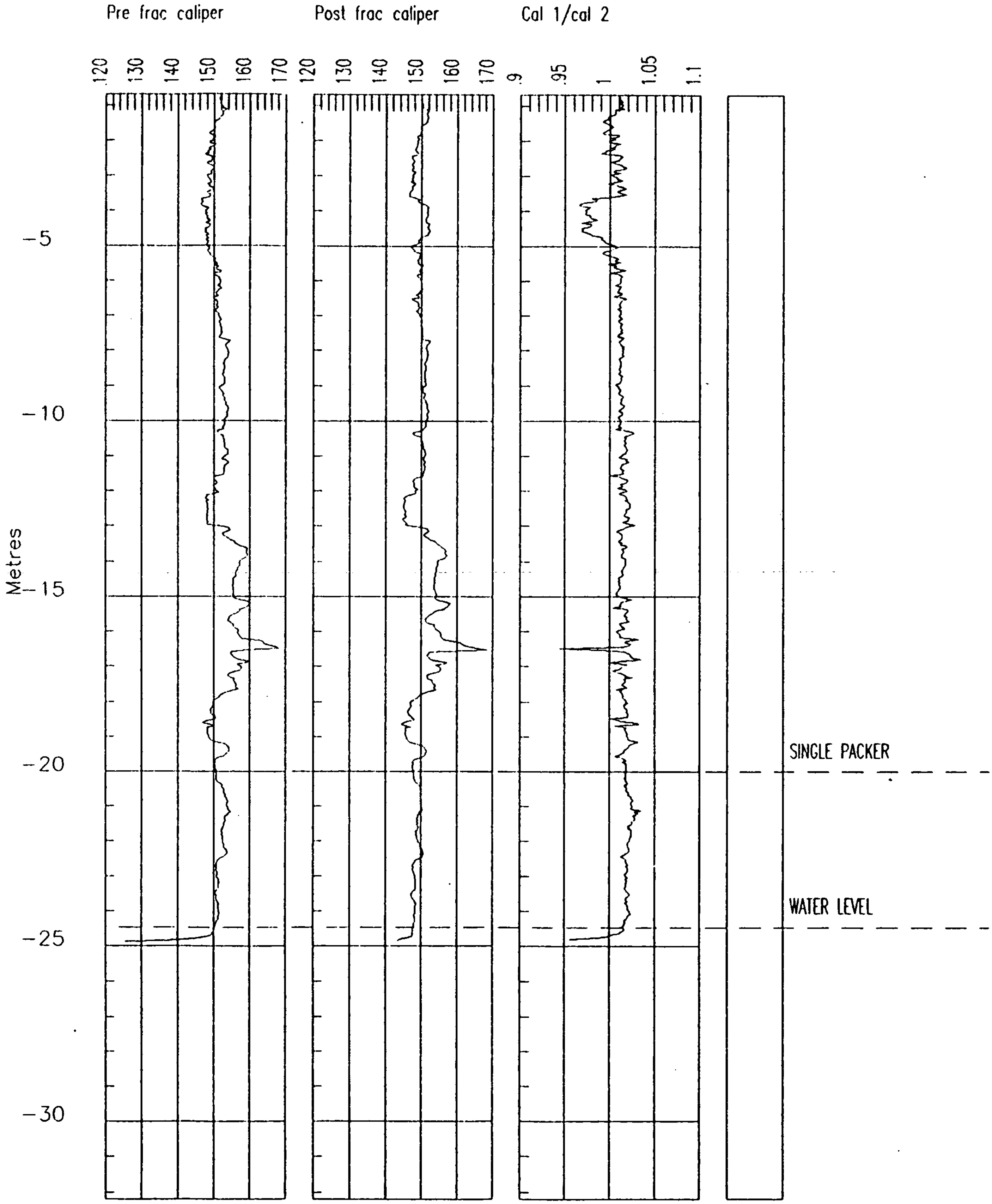
Hydrofracturing Results :-
Single packer with 145mm rubbers set at 20m where the pressure peaked at 50 bar and was running at 30 bar.

Water Quality :-
No sample able to be taken.

Pumptest Results :-
Insufficient water to perform pumptests.

Special Remarks :-
Clinic revisited on 9th October and pump now works but still only able to get one bucket of water. Have to wait one hour before they can get another.

Wellname Mashava Clinic
Filename MASHAVA
Location TM 489675 Zimbabwe
Elevation 0 Reference



Site :-
Sarahuru Secondary School

Grid Ref. :-
TM 455771

Sequence of Events :-

06/10/90 Bushpump removed
Borehole logging
Test pump installed

07/10/90 Pumptest
Test pump removed
Hydrofracturing
Test pump installed

08/10/90 Pumptest
Test pump removed
Borehole logging
Bushpump replaced

Notes :-

Less than 20 buckets from this borehole. Whole area has very deep weathering and several nearby older boreholes have silted up to the bottom of the casing. One drilled 1.5km away from this site was lined to the bottom. Bushpump suction was at 42.5m and was replaced at 48m.

Logging Results :-

Depth of borehole is about 53m with apparently at least 2m of silt at the bottom. Base of weathering is difficult to pinpoint possibly because the borehole is weathered completely to the base as suggested by other nearby boreholes. Fractures are however visible at 39m, 50m and 54m.

Hydrofracturing Results :-

Single packer with 145mm rubbers set at 45m the deepest the hydraulic line would allow. Pressure would not build up beyond 30 bar.

Water Quality :-

Water before hydrofracturing EC = 925 µS/cm
Water from tank injected EC = 1235 µS/cm
Water after hydrofracturing EC = 950 µS/cm

Pumptest Results :-

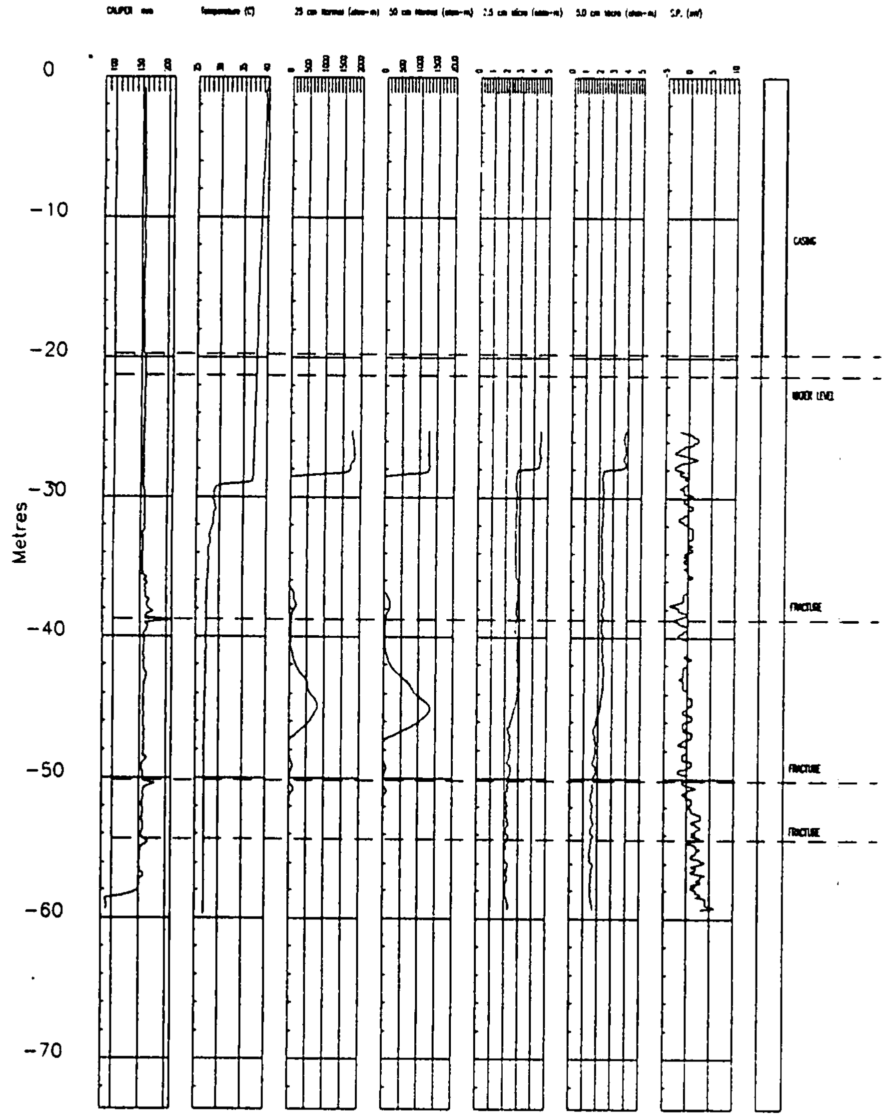
Submersible pump suction set at 43m. Pre pumptest lasted the full 300 minutes with a total drawdown of 3.335m at a pumping rate of 0.0350 l/s. Post pumptest lasted the full 300 minutes with a total drawdown of 3.041m at a pumping rate of 0.0347 l/s.

Transmissivity values were 0.179 m^2/day before HF and 0.194 m^2/day after HF, an improvement of 8%.

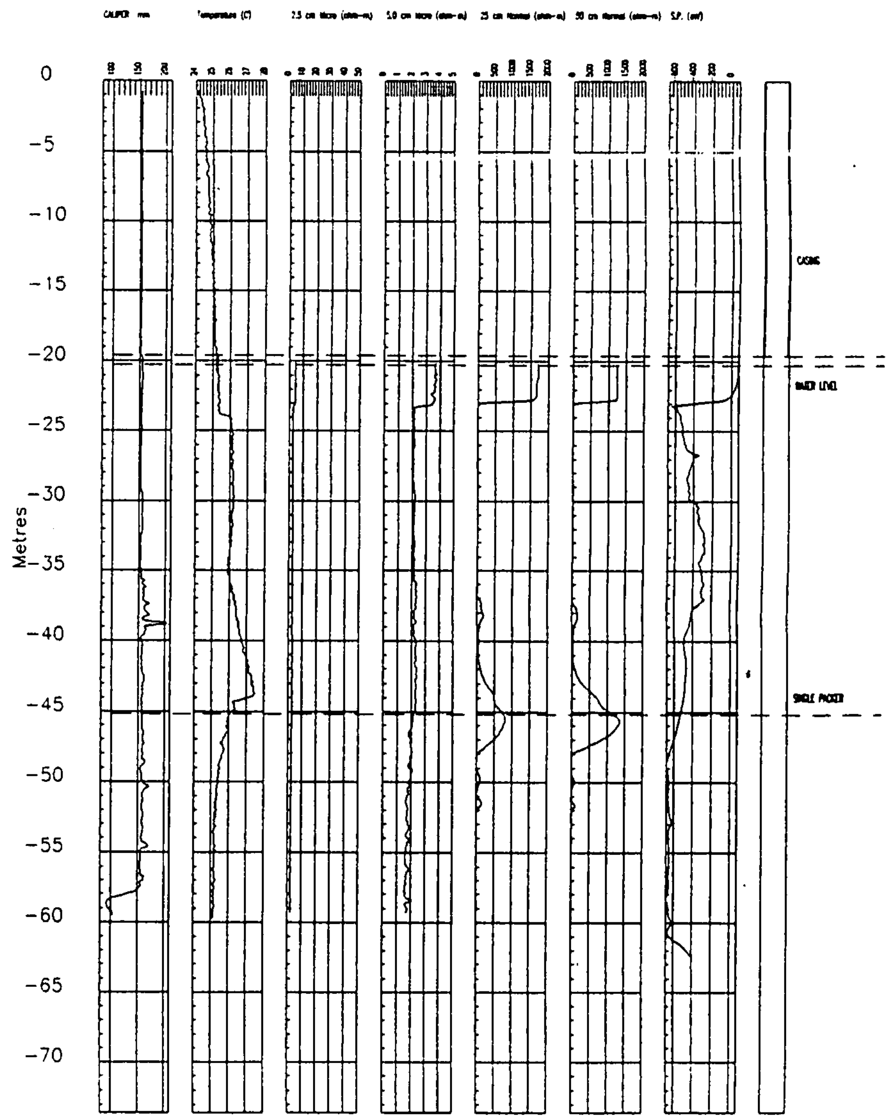
Specific capacity values after 300 minutes pumping were 0.907 m^3/day/m before HF and 0.986 m^3/day/m after HF, an improvement of 9%.

Predicted time for 3.5m drawdown before HF is 336 minutes giving a pumped volume of 706 litres and after HF is 421 minutes giving a pumped volume of 876 litres, an improvement of 24%.

Wellname SARAHURU SECONDARY SCHOOL
Filename SARAHUR1
Location Zimbabwe TM 455771
Elevation 0 Reference



Wellname SARAHURU SECONDARY SCHOOL
Filename SARAHUR2
Location Zimbabwe TM 455771
Elevation 0 Reference



72

PUMPING TEST - DRAWDOWN DATA

PROJECT: ZIMBABWE
LOCATION: SARAHURU SCHOOL
DATUM POINT: TOP OF CASING
PUMPING RATE: 0.0350 L/S
AQUIFER THICKNESS:
CONDITIONS: UNCONFINED

FILE NO.: BEFORE HF
WELL NO.: 11
ELEV. OF DATUM POINT:
STATIC WATER LEVEL: 21.396
R = ----- FROM
SCREEN INTERVAL: TO

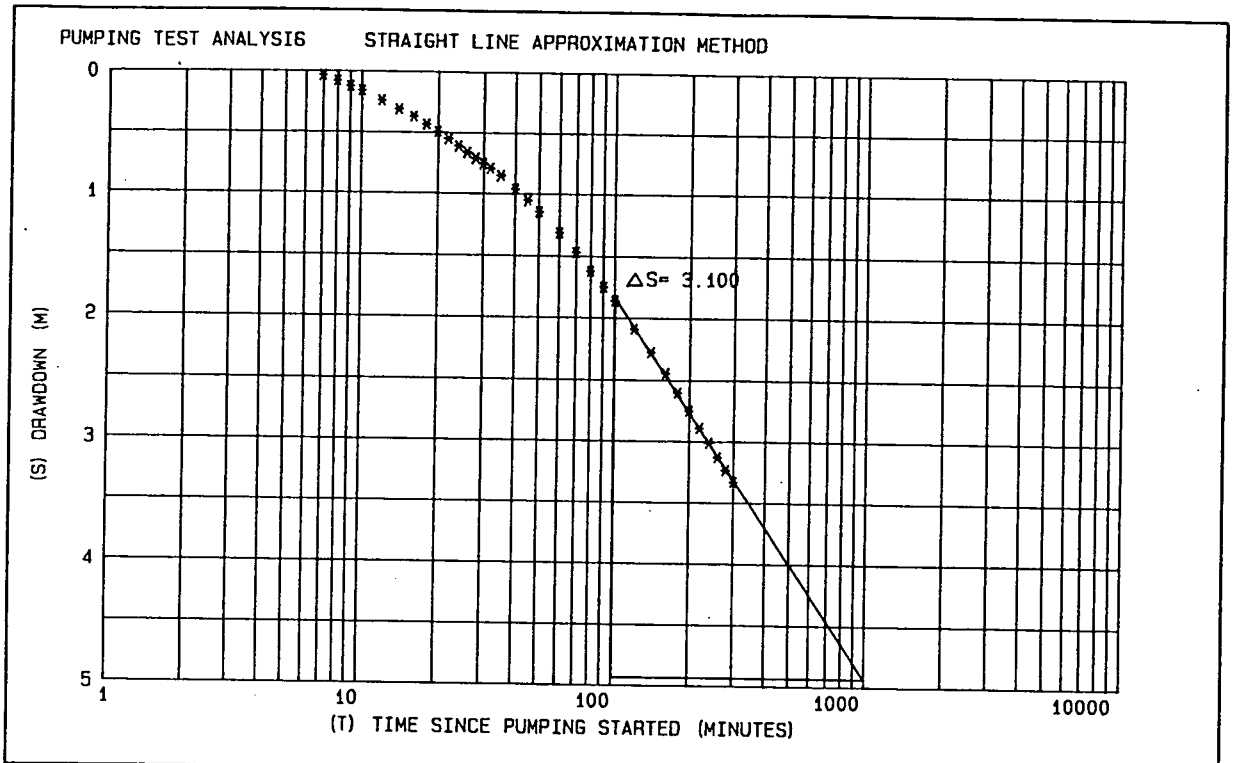
TIME			ELAPSED TIME	WATER LEVEL	DRAWDOWN	(Q)
DY	HR	MN	t (MIN)	(m)	s (m)	(L/S)
7	8	10	0.00	21.396	0.000	0.0350
7	8	11	0.50	21.139	-0.257	0.0350
7	8	11	1.00	21.160	-0.236	0.0350
7	8	12	1.50	21.185	-0.211	0.0350
7	8	12	2.00	21.211	-0.185	0.0350
7	8	13	2.50	21.239	-0.157	0.0350
7	8	13	3.00	21.261	-0.135	0.0350
7	8	14	3.50	21.284	-0.112	0.0350
7	8	14	4.00	21.303	-0.093	0.0350
7	8	15	4.50	21.327	-0.069	0.0350
7	8	15	5.00	21.352	-0.044	0.0350
7	8	16	6.00	21.391	-0.005	0.0350
7	8	17	7.00	21.435	0.039	0.0350
7	8	18	8.00	21.479	0.083	0.0350
7	8	19	9.00	21.521	0.125	0.0350
7	8	20	10.00	21.560	0.164	0.0350
7	8	22	12.00	21.639	0.243	0.0350
7	8	24	14.00	21.708	0.312	0.0350
7	8	26	16.00	21.770	0.374	0.0350
7	8	28	18.00	21.834	0.438	0.0350
7	8	30	20.00	21.894	0.498	0.0350
7	8	32	22.00	21.952	0.556	0.0350
7	8	34	24.00	22.010	0.614	0.0350
7	8	36	26.00	22.061	0.665	0.0350
7	8	38	28.00	22.109	0.713	0.0350
7	8	40	30.00	22.153	0.757	0.0350
7	8	42	32.00	22.190	0.794	0.0350
7	8	45	35.00	22.251	0.855	0.0350
7	8	50	40.00	22.360	0.964	0.0350
7	8	55	45.00	22.456	1.060	0.0350
7	9	0	50.00	22.547	1.151	0.0350
7	9	10	60.00	22.712	1.316	0.0350
7	9	20	70.00	22.872	1.476	0.0350
7	9	30	80.00	23.022	1.626	0.0350
7	9	40	90.00	23.148	1.752	0.0350
7	9	50	100.00	23.262	1.866	0.0350
7	10	10	120.00	23.489	2.093	0.0350
7	10	30	140.00	23.676	2.280	0.0350
7	10	50	160.00	23.846	2.450	0.0350
7	11	10	180.00	24.003	2.607	0.0350
7	11	30	200.00	24.150	2.754	0.0350
7	11	50	220.00	24.288	2.892	0.0350
7	12	10	240.00	24.410	3.014	0.0350
7	12	30	260.00	24.529	3.133	0.0350
7	12	50	280.00	24.636	3.240	0.0350
7	13	10	300.00	24.731	3.335	0.0350

PUMPING TEST - DRAWDOWN DATA

PROJECT: ZIMBABWE
LOCATION: SARAHURU SCHOOL
DATUM POINT: TOP OF CASING
PUMPING RATE: 0.0347 L/S
AQUIFER THICKNESS:
CONDITIONS: UNCONFINED

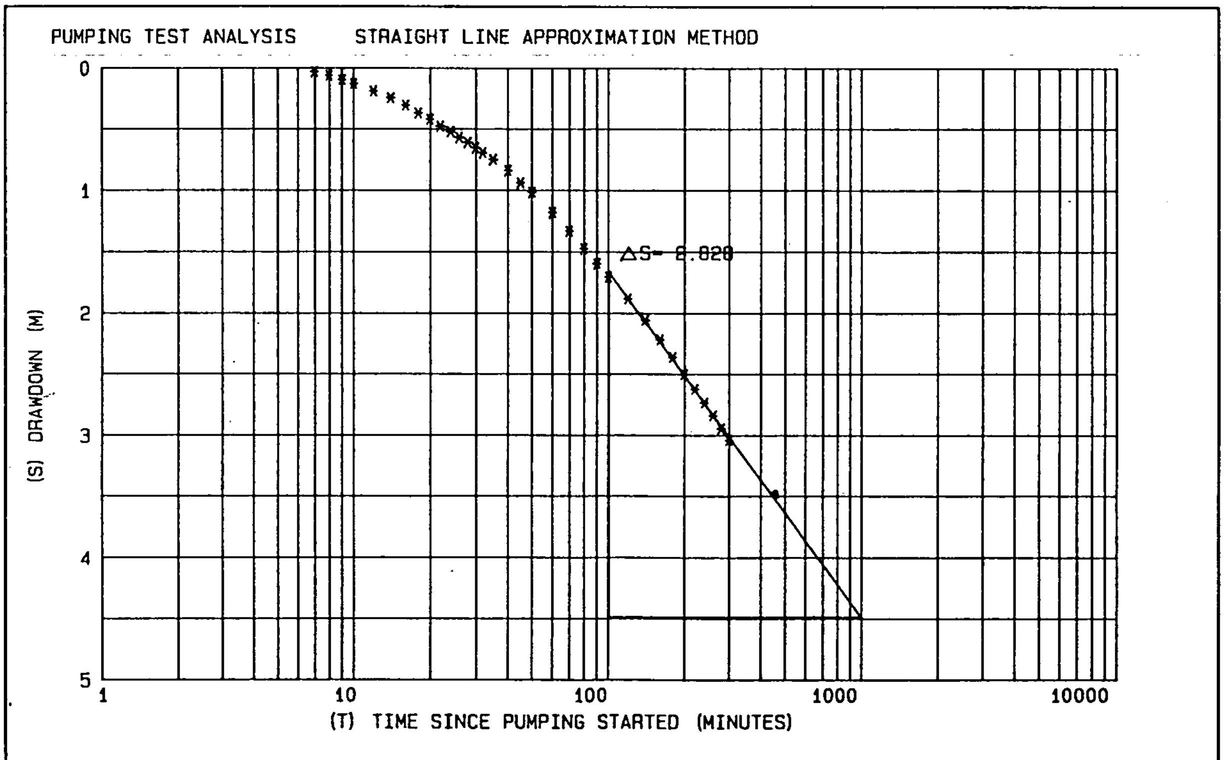
FILE NO.: AFTER HF
WELL NO.: 11
ELEV. OF DATUM POINT:
STATIC WATER LEVEL: 20.324
R = ----- FROM
SCREEN INTERVAL: TO

TIME			ELAPSED TIME	WATER LEVEL	DRAWDOWN	(Q)
DY	HR	MN	t (MIN)	(m)	s (m)	(L/S)
8	8	0	0.00	20.324	0.000	0.0347
8	8	1	0.50	20.079	-0.245	0.0347
8	8	1	1.00	20.102	-0.222	0.0347
8	8	2	1.50	20.130	-0.194	0.0347
8	8	2	2.00	20.155	-0.169	0.0347
8	8	3	2.50	20.178	-0.146	0.0347
8	8	3	3.00	20.201	-0.123	0.0347
8	8	4	3.50	20.228	-0.096	0.0347
8	8	4	4.00	20.245	-0.079	0.0347
8	8	5	4.50	20.264	-0.060	0.0347
8	8	5	5.00	20.286	-0.038	0.0347
8	8	6	6.00	20.320	-0.004	0.0347
8	8	7	7.00	20.358	0.034	0.0347
8	8	8	8.00	20.390	0.066	0.0347
8	8	9	9.00	20.424	0.100	0.0347
8	8	10	10.00	20.457	0.133	0.0347
8	8	12	12.00	20.519	0.195	0.0347
8	8	14	14.00	20.575	0.251	0.0347
8	8	16	16.00	20.635	0.311	0.0347
8	8	18	18.00	20.697	0.373	0.0347
8	8	20	20.00	20.750	0.426	0.0347
8	8	22	22.00	20.806	0.482	0.0347
8	8	24	24.00	20.848	0.524	0.0347
8	8	26	26.00	20.898	0.574	0.0347
8	8	28	28.00	20.939	0.615	0.0347
8	8	30	30.00	20.981	0.657	0.0347
8	8	32	32.00	21.020	0.696	0.0347
8	8	35	35.00	21.076	0.752	0.0347
8	8	40	40.00	21.168	0.844	0.0347
8	8	45	45.00	21.264	0.940	0.0347
8	8	50	50.00	21.340	1.016	0.0347
8	9	0	60.00	21.505	1.181	0.0347
8	9	10	70.00	21.659	1.335	0.0347
8	9	20	80.00	21.801	1.477	0.0347
8	9	30	90.00	21.924	1.600	0.0347
8	9	40	100.00	22.033	1.709	0.0347
8	10	0	120.00	22.210	1.886	0.0347
8	10	20	140.00	22.384	2.060	0.0347
8	10	40	160.00	22.545	2.221	0.0347
8	11	0	180.00	22.689	2.365	0.0347
8	11	20	200.00	22.829	2.505	0.0347
8	11	40	220.00	22.949	2.625	0.0347
8	12	0	240.00	23.062	2.738	0.0347
8	12	20	260.00	23.165	2.841	0.0347
8	12	40	280.00	23.269	2.945	0.0347
8	13	0	300.00	23.365	3.041	0.0347



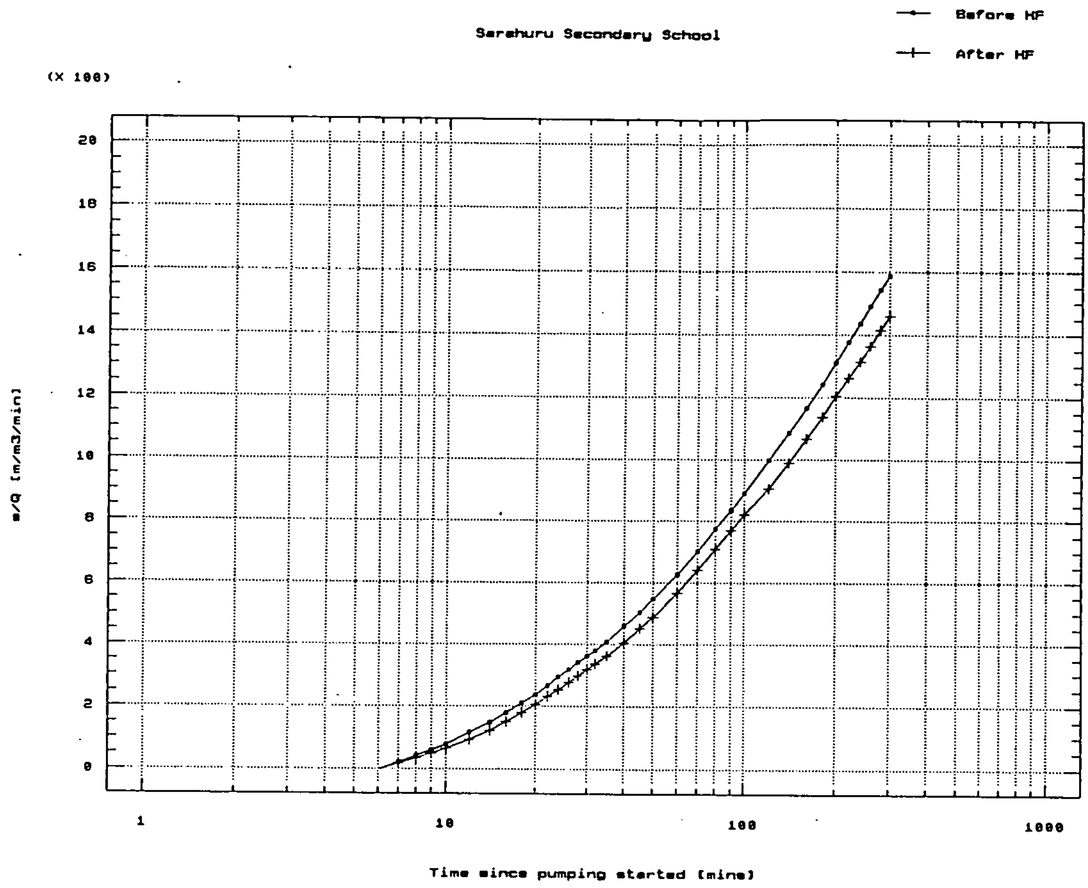
PROJECT: ZIMBABWE FILE: BEFORE HF LOCATION: SARAHURU SCHOOL	WELL NO.: 11 Q= .035 L/S S.W.L.= 21.396	ΔS= 3.100 M T= .179 M2/DAY S=

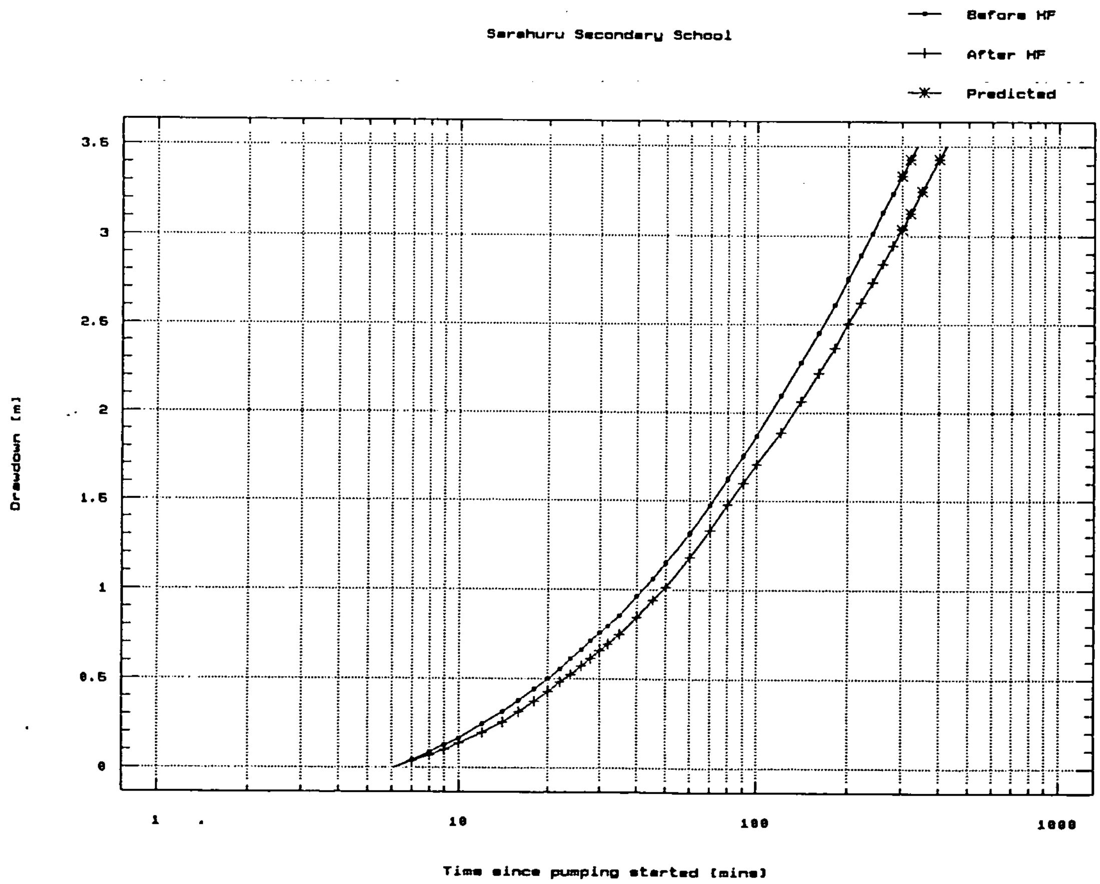
BRITISH GEOLOGICAL SURVEY — FIGURE



PROJECT: ZIMBABWE FILE: AFTER HF LOCATION: SARAHURU SCHOOL	WELL NO.: 11 Q= .0347 L/S S.W.L.= 20.324	ΔS= 2.828 M T= .194 M2/DAY S=

BRITISH GEOLOGICAL SURVEY — FIGURE


Sarehuru Secondary School
Before HP
After HP
(X 100)
s/Q [m/m3/min]
20
18
16
14
12
10
8
6
4
2
0
1
10
100
1000
Time since pumping started [mins]


Sarehuru Secondary School
Before HP
After HP
Predicted
Drawdown [m]
3.5
3
2.5
2
1.5
1
0.5
0
1
10
100
1000
Time since pumping started [mins]

Site :-
Chimbudzi Clinic

Grid Ref. :-
TM 408824

Sequence of Events :-
11/10/90 Bushpump removed
Borehole logging
Test pump installed
Test pump removed
Hydrofracturing
Bushpump replaced

Notes :-
Able to get 2 buckets of water in the morning before borehole dries up. Bushpump suction set at 57m.

Logging Results :-
Only calliper log before HF done. Depth of borehole is 62.4m.

Hydrofracturing Results :-
Single packer with 145mm rubbers set at 45m as deep as the hydraulic line would allow. Pressure would not build up at all, no more than 20 bar, half a tank of water pumped in.

Water Quality :-
Before hydrofracturing EC = 2750 µS/cm

Pumptest Results :-
Insufficient water to do the pumptests.

Site :-
Masogwe

Grid Ref. :-
TM 605833

Sequence of Events :-

12/10/90 Bushpump removed
Borehole logging
Test pump installed

13/10/90 Pumptest
Test pump removed
Hydrofracturing
Borehole logging
Test pump installed

14/10/90 Pumptest
Test pump removed
Bushpump replaced

Notes :-
Used by the local community who get 15 buckets initially then a further 2 buckets for every 10 minutes waiting. Drilled last year. Pump was mended earlier in the year and a 3m length of rising main was removed. Bushpump suction was at 37m replaced at 39.5m.

Logging Results :-
Depth of borehole is 39.9m. The base of weathering is at approximately 30m depth.

Hydrofracturing Results :-
Single packer with 145mm rubbers set at 35m the pressure peaked at 70 bar but formation did not crack. Packer set at 37m pressure did not build up beyond 30 bar water being pumped into aquifer.

Water Quality :-

Water before hydrofracturing EC = 590 µS/cm
Water from tank injected EC = 1190 µS/cm
Water after hydrofracturing EC = 980 µS/cm

Pumptest Results :-
Submersible pump suction set at 37m. Pre pumptest lasted full 300 minutes with a total drawdown of 10.722m at a pumping rate of 0.0367 l/s. Post pumptest lasted 135 minutes with a total drawdown of 9.469m at a pumping rate of 0.0609 l/s.

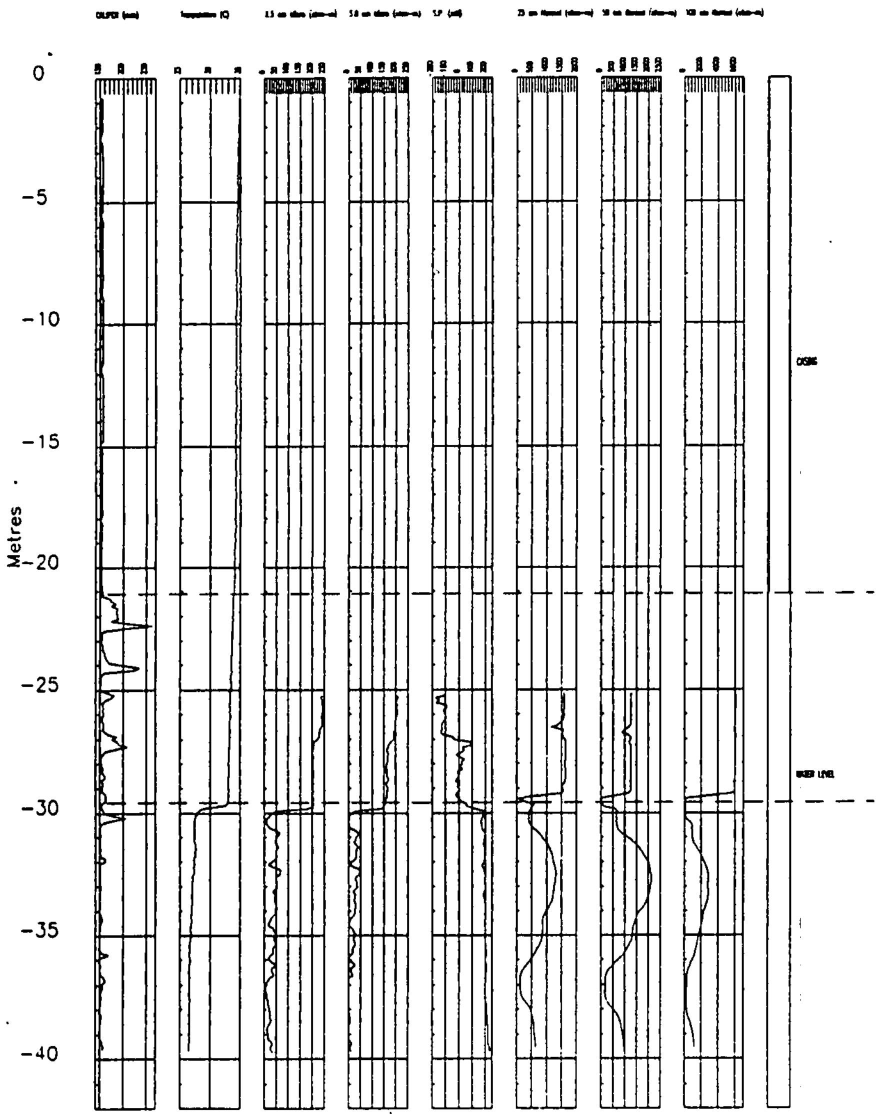
Transmissivity values were 0.035 m^2/day before HF and 0.042 m^2/day after HF, an improvement of 20%.

Specific capacity values after 120 minutes pumping were 0.769 m^3/day/m before HF and 0.556 m^3/day/m after HF, a decrease of 38%.

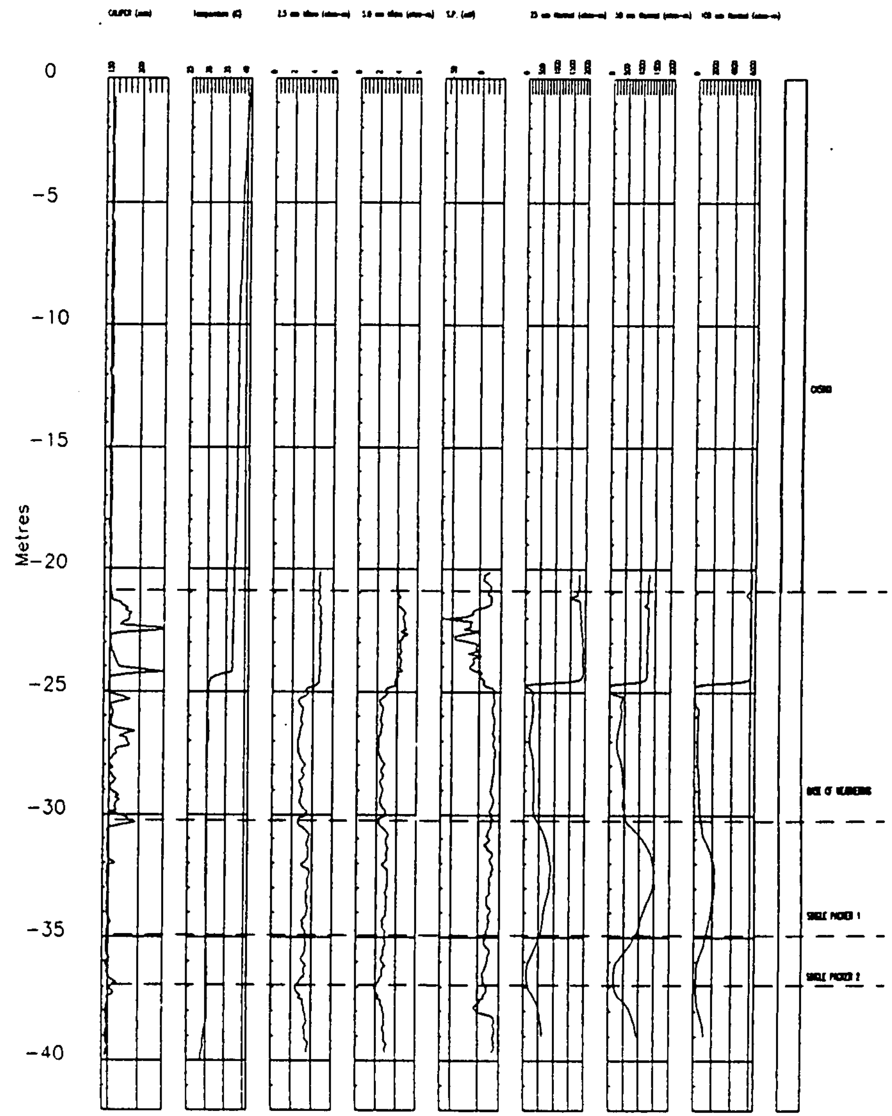
Predicted time to reach pump suction (37m) before HF is 312 minutes giving a volume pumped of 687 litres and after HF is 140 minutes giving a volume pumped of 512 litres, a decrease of 34%.

Special Remarks :-
This borehole has very ambiguous results which are difficult if not impossible to interpret accurately.

Wellname Masogwe
Filename MASOGWE1
Location TM 605833 Zimbabwe
Elevation 0 Reference



Wellname Masogwe
Filename MASOGWE2
Location TM 605833 Zimbabwe
Elevation 0 Reference



PUMPING TEST - DRAWDOWN DATA

PROJECT: ZIMBABWE
LOCATION: MASOGWE
DATUM POINT: TOP OF CASING
PUMPING RATE: 0.0367 L/S
AQUIFER THICKNESS:
CONDITIONS: UNCONFINED

FILE NO.: BEFORE HF
WELL NO.: 15
ELEV. OF DATUM POINT:
STATIC WATER LEVEL: 26.070
R = ----- FROM
SCREEN INTERVAL: TO

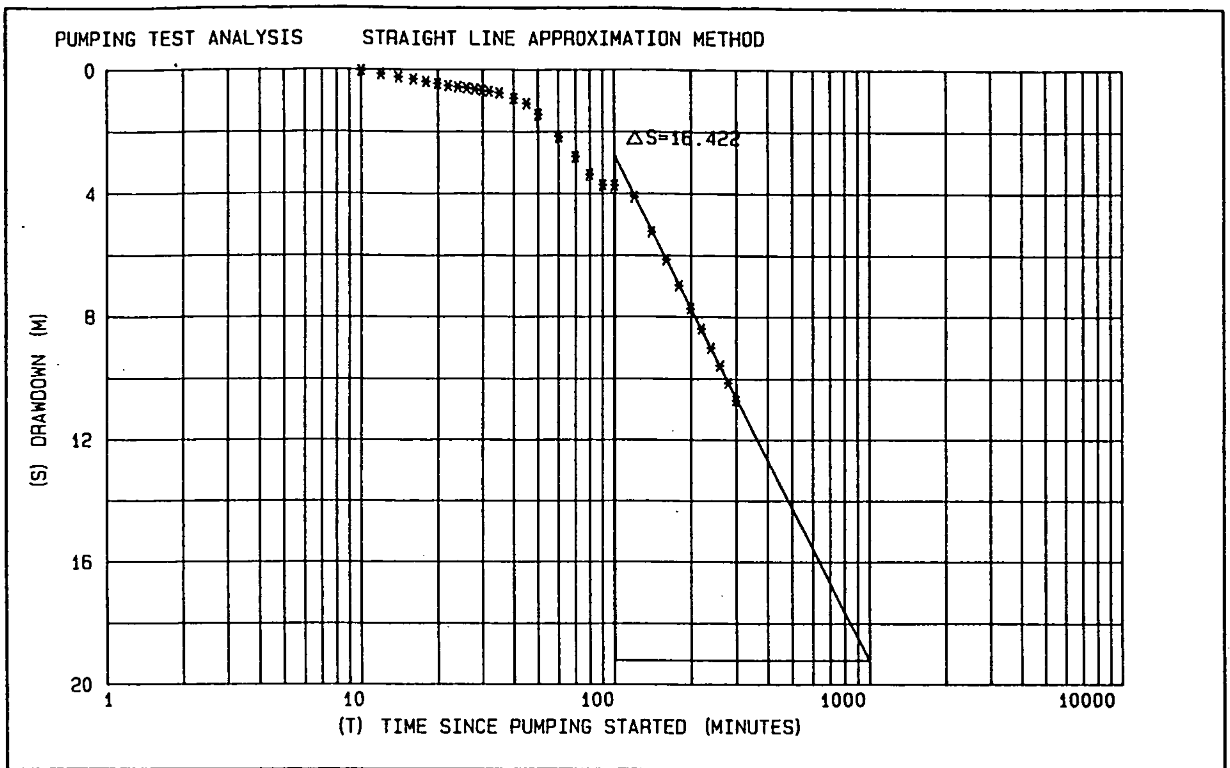
TIME			ELAPSED TIME	WATER LEVEL	DRAWDOWN	(Q)
DY	HR	MN	t (MIN)	(m)	s (m)	(L/S)
13	7	55	0.00	26.070	0.000	0.0367
13	7	56	0.50	25.325	-0.745	0.0367
13	7	56	1.00	25.391	-0.679	0.0367
13	7	57	1.50	25.424	-0.646	0.0367
13	7	57	2.00	25.480	-0.590	0.0367
13	7	58	2.50	25.538	-0.532	0.0367
13	7	58	3.00	25.571	-0.499	0.0367
13	7	59	3.50	25.605	-0.465	0.0367
13	7	59	4.00	25.636	-0.434	0.0367
13	7	60	4.50	25.669	-0.401	0.0367
13	8	0	5.00	25.700	-0.370	0.0367
13	8	1	6.00	25.746	-0.324	0.0367
13	8	2	7.00	25.878	-0.192	0.0367
13	8	3	8.00	25.980	-0.090	0.0367
13	8	4	9.00	26.042	-0.028	0.0367
13	8	5	10.00	26.128	0.058	0.0367
13	8	7	12.00	26.231	0.161	0.0367
13	8	9	14.00	26.331	0.261	0.0367
13	8	11	16.00	26.400	0.330	0.0367
13	8	13	18.00	26.476	0.406	0.0367
13	8	15	20.00	26.549	0.479	0.0367
13	8	17	22.00	26.605	0.535	0.0367
13	8	19	24.00	26.649	0.579	0.0367
13	8	21	26.00	26.686	0.616	0.0367
13	8	23	28.00	26.721	0.651	0.0367
13	8	25	30.00	26.759	0.689	0.0367
13	8	27	32.00	26.796	0.726	0.0367
13	8	30	35.00	26.849	0.779	0.0367
13	8	35	40.00	27.029	0.959	0.0367
13	8	40	45.00	27.179	1.109	0.0367
13	8	45	50.00	27.528	1.458	0.0367
13	8	55	60.00	28.249	2.179	0.0367
13	9	5	70.00	28.896	2.826	0.0367
13	9	15	80.00	29.463	3.393	0.0367
13	9	25	90.00	29.811	3.741	0.0367
13	9	35	100.00	29.818	3.748	0.0367
13	9	55	120.00	30.192	4.122	0.0367
13	10	15	140.00	31.323	5.253	0.0367
13	10	35	160.00	32.220	6.150	0.0367
13	10	55	180.00	33.078	7.008	0.0367
13	11	15	200.00	33.821	7.751	0.0367
13	11	35	220.00	34.482	8.412	0.0367
13	11	55	240.00	35.099	9.029	0.0367
13	12	15	260.00	35.670	9.600	0.0367
13	12	35	280.00	36.229	10.159	0.0367
13	12	55	300.00	36.792	10.722	0.0367

PUMPING TEST - DRAWDOWN DATA

PROJECT: ZIMBABWE
LOCATION: MASOGWE
DATUM POINT: TOP OF CASING
PUMPING RATE: 0.0609 L/S
AQUIFER THICKNESS:
CONDITIONS: UNCONFINED

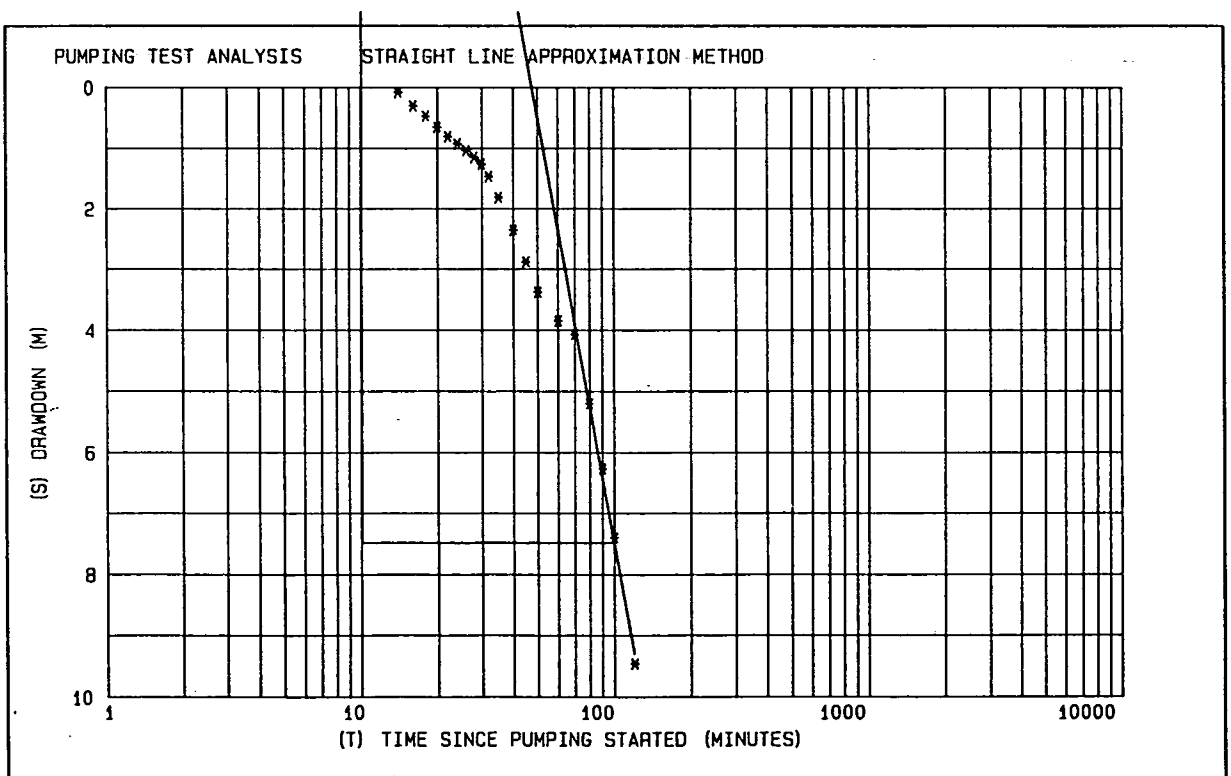
FILE NO.: AFTER HF
WELL NO.: 15
ELEV. OF DATUM POINT:
STATIC WATER LEVEL: 25.962
R = ----- FROM
SCREEN INTERVAL: TO

TIME			ELAPSED TIME	WATER LEVEL	DRAWDOWN	(Q)
DY	HR	MN	t (MIN)	(m)	s (m)	(L/S)
14	7	50	0.00	25.962	0.000	0.0609
14	7	51	0.50	25.251	-0.711	0.0609
14	7	51	1.00	25.320	-0.642	0.0609
14	7	52	1.50	25.346	-0.616	0.0609
14	7	52	2.00	25.389	-0.573	0.0609
14	7	53	2.50	25.416	-0.546	0.0609
14	7	53	3.00	25.439	-0.523	0.0609
14	7	54	3.50	25.461	-0.501	0.0609
14	7	54	4.00	25.480	-0.482	0.0609
14	7	55	4.50	25.500	-0.462	0.0609
14	7	55	5.00	25.512	-0.450	0.0609
14	7	56	6.00	25.542	-0.420	0.0609
14	7	57	7.00	25.563	-0.399	0.0609
14	7	58	8.00	25.580	-0.382	0.0609
14	7	59	9.00	25.601	-0.361	0.0609
14	8	0	10.00	25.614	-0.348	0.0609
14	8	2	12.00	25.635	-0.327	0.0609
14	8	4	14.00	26.043	0.081	0.0609
14	8	6	16.00	26.273	0.311	0.0609
14	8	8	18.00	26.441	0.479	0.0609
14	8	10	20.00	26.623	0.661	0.0609
14	8	12	22.00	26.770	0.808	0.0609
14	8	14	24.00	26.893	0.931	0.0609
14	8	16	26.00	27.005	1.043	0.0609
14	8	18	28.00	27.119	1.157	0.0609
14	8	20	30.00	27.230	1.268	0.0609
14	8	22	32.00	27.439	1.477	0.0609
14	8	25	35.00	27.782	1.820	0.0609
14	8	30	40.00	28.326	2.364	0.0609
14	8	35	45.00	28.853	2.891	0.0609
14	8	40	50.00	29.348	3.386	0.0609
14	8	50	60.00	29.812	3.850	0.0609
14	9	0	70.00	30.041	4.079	0.0609
14	9	10	80.00	31.170	5.208	0.0609
14	9	20	90.00	32.240	6.278	0.0609
14	9	30	100.00	33.367	7.405	0.0609
14	9	50	120.00	35.431	9.469	0.0609



PROJECT: ZIMBABWE FILE: BEFORE HF LOCATION: MASOGWE	WELL NO.: 15 Q= .0367 L/S S.W.L.= 26.070	△S= 16.422 M T= .035 M2/DAY S=

BRITISH GEOLOGICAL SURVEY — FIGURE



PROJECT: ZIMBABWE FILE: AFTER HF LOCATION: MASOGWE	WELL NO.: 15 Q= .0609 L/S S.W.L.= 25.962	△S= 23.060 M T= .042 M2/DAY S=

BRITISH GEOLOGICAL SURVEY — FIGURE

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