

EFFICIENT WELL TESTING AT ULUMBU FIELD, FLORES, INDONESIA

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ABSTRACT

Ulumbu field is a candidate for a mini-geothermal power project, to replace the existing diesel generation. Such a small project cannot support the drilling and testing programs involved with large developments.

After the successful drilling of a well, producing large flows of dry steam, a testing program covering a total of less than 9 days' discharge over a period of two months provided definition of the reservoir fluid state and permeability distribution.

The resource can support a larger discharge of dry steam from the currently drilled area than is needed for the present project, and it is indicated that drilling elsewhere will find greater resources of two-phase fluid.

INTRODUCTION

Ulumbu field is one of several geothermal prospects on the island of Flores in Indonesia. It is the most promising prospect on the island, and is the site of a mini-geothermal power project carried out by P.T. PLN (Suasdi 1996, Mahon et al 1992). The three wells were drilled deviated from a single pad. Figure 1 shows a plan view of the well tracks and figure 2 a cross section. The wells cover a spread of about half a kilometre at bottomhole. They thus give information from three wells within a single region of the field. There is sufficient distance and difference between the wells to give some indication of gradients within this area as well as conditions at one point.

Excellent permeability has been found and there is more than sufficient production for current plans. There are very strong indications that the resource is capable of supporting a considerably greater development, if there is demand for the electricity.

Due to limited water supplies it was not possible to carry out completion tests by injecting cold water. All three wells fill with steam in the upper part.

A mini project cannot support much overhead of drilling or testing. The program of well testing was designed and executed to determine reservoir parameters with minimum time and cost.

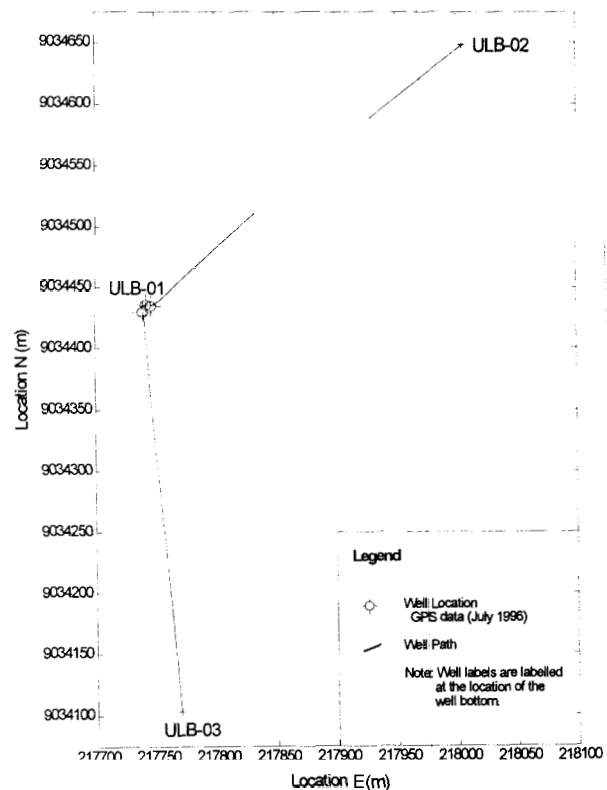


Figure 1. Plan view of wells ULB-01 to ULB-03, drilled from a single pad.

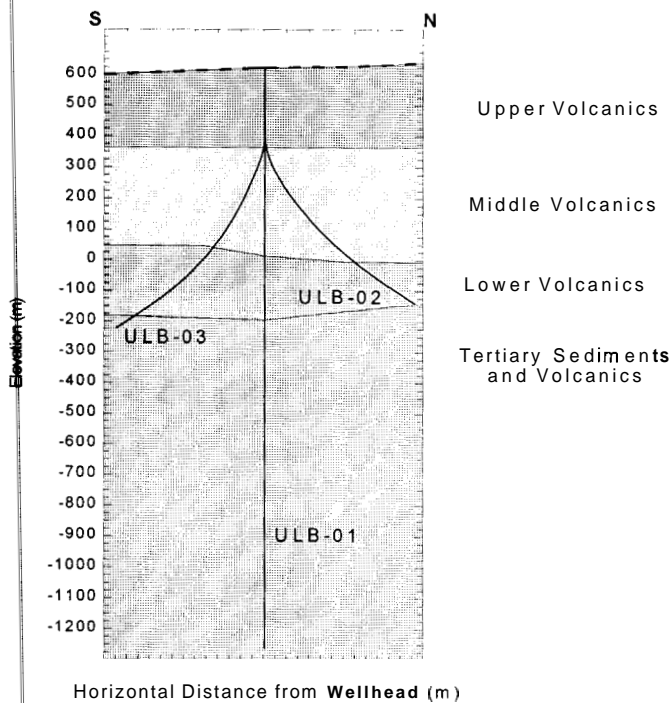


Figure 2. Cross section through the wells.

DOWNHOLE MEASUREMENTS

Temperatures and pressures

Measurements in all three wells show superficially similar results. Figures 3 & 4 show temperature and pressure profiles measured after the discharge testing of the wells.

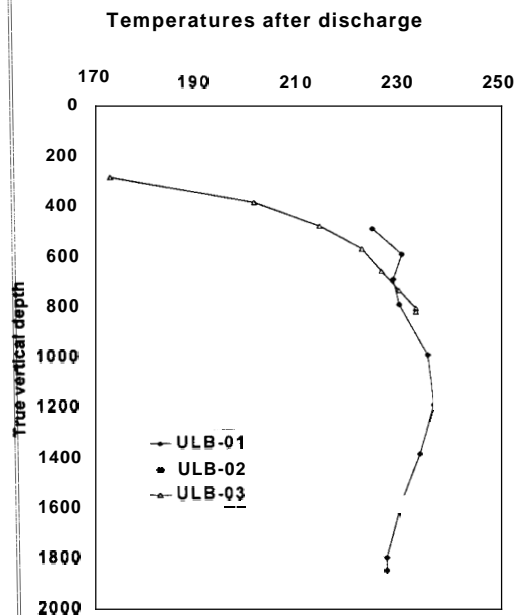


Figure 3. Downhole temperatures in wells ULB-01 to ULB-03, 11-13 July 1996.

All three wells show a stable wellhead pressure of around 30 bar. There is a column of steam in the wells

down to around sea level or somewhat lower. Beneath this there is liquid in the well.

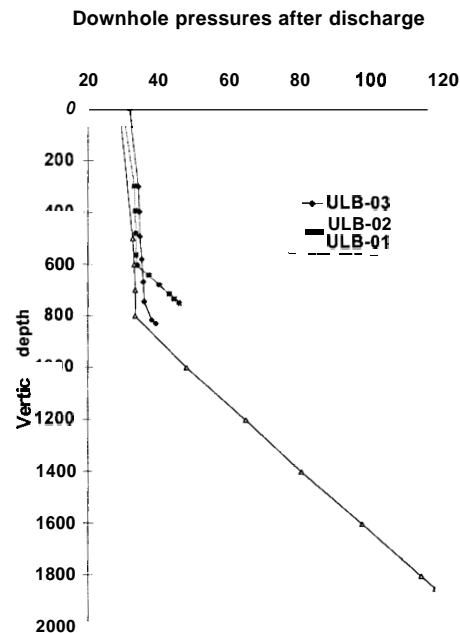


Figure 4. Downhole pressures in wells ULB-01 to -03, 11-13 July 1996.

In the steam column temperatures reach around 240°C. In the liquid zone measured temperatures are similar, or a little cooler. Earlier runs in ULB-01 showed a fairly constant profile with depth, suggesting a downflow. Stable temperatures in ULB-02 are very constant within the liquid column, also suggesting a downflow of water at 240°C.

The downhole pressure profile can be representative of reservoir conditions, ie corresponding a reservoir of liquid water with a vapour-dominated zone above. Alternatively the liquid columns could be accumulations of condensate and the reservoir entirely vapour-dominated. The presence of downflows within the liquid columns, and the discharge of liquid from ULB-01, demonstrates that the reservoir is liquid-dominated in the lower sections of the three wells.

DISCHARGE

Each well was discharged separately, and the discharge monitored. Wellhead pressures were monitored on all three wells throughout the test period.

The test was designed to achieve the maximum of results with minimum effort and environmental effort.

It was very economical of:

- reservoir fluid
- waste production
- testing effort.

One well was discharged for 8 days, flowing dry steam and hence producing no waste water. The other wells were flowed for periods of an hour to a few hours only. With this small test, excellent definition of significant reservoir parameters was obtained.

The test measured:

- the discharge performance of each well

In addition, depending on the nature of the well and the reservoir, the following may be measured (and were in some cases):

- well permeability from transient changes in pressure and/or flow
- reservoir permeability from interference

The test sequence proved to be a very efficient means of collecting an unusually wide range of measurements of reservoir parameters.

Normally instrumentation limitations or reservoir characteristics mean that considerably less interpreted information is available at such an early stage of field

development, with such a short test period. With the downhole conditions indicating a steam zone in the upper part of each well, and a liquid region beneath, a discharge may consist of dry steam from the upper zone, low-enthalpy fluid from the liquid zone or a mixture of the two. Which may be produced depends upon the permeability of the well in the two zones, and the wellhead pressure.

The water level in each well lies around sea level or somewhat below. Water cannot enter the discharge until the water level rises above the steam feed, which requires a downhole pressure drop of 10-20 bar. If there is high permeability in the steam zone its pressure will not drop by this much, and it will then be impossible to obtain any fluid from the liquid zone in the discharge, irrespective of the permeability there.

Conversely in a well with low permeability in the steam zone, liquid would be expected in the discharge except at high wellhead pressure. It should be possible to obtain a dry discharge in all wells at sufficiently small flow rates (high WHP) that there is little drawdown of the steam zone.

TEST HISTORY

Table 1 and figure 5 show the history of the discharge tests conducted over May-July 1996.

Table 1 *Ulumbu test history sequence*

Date	Time	Well	Action
25 May	11:20	ULB-02	Start output test
	14:35	ULB-02	Complete output test
6 June	15:28	ULB-02	Open
	15:40	ULB-02	Shut
	15:50	ULB-02	Open
14 June	16:20	ULB-02	Shut
5 July	11:25	ULB-01	Open 10" Lip pipe
	11:50	ULB-01	Discharge fails, well shut
6 July	15:27	ULB-01	Opened 6" lip pipe, throttled
	15:43	ULB-01	Full open
	16:43	ULB-01	Shut
10 July	11:58	ULB-03	Open 6" lip pipe
	14:50	ULB-03	Shut
21 July	11:24	ULB-02	Open for output test
	12:21	ULB-02	Shut

Flow of the Ulumbu wells

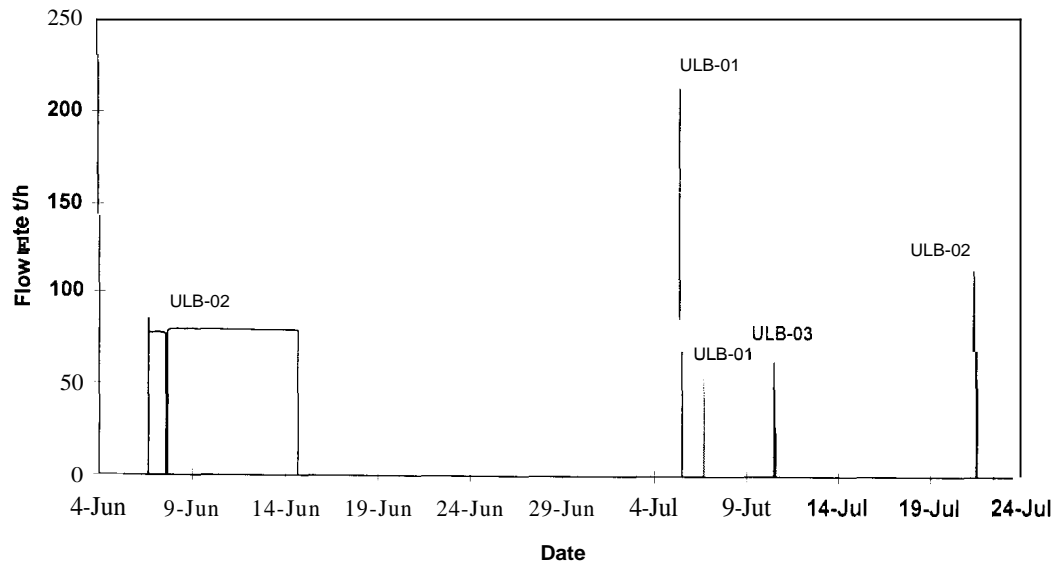


Figure 5. Test history

TEST RESULTS

Wellhead pressure was logged on all wells through the test. ULB-02 discharge a large flow of dry steam. The decline ULB-02 was monitored during its discharge, and the pressure buildup when the well was shut. In addition interference with ULB-01 was observed.

ULB-03 also discharged dry, while ULB-01 produced a low-enthalpy (1100 kJ/kg) discharge. For both of these wells a decline analysis of the discharge was used, and for ULB-03 also a buildup.

The following table summarises the results of the well testing:

Table 2. *kh* measurements for Ulumbu wells and reservoir

Well	liquid zone	steam zone
ULB-01	1.5	v. small
ULB-02	not meas.	150
ULB-03	v. small	0.7 - 1.6
Interference 02-01		230

RESERVOIR CHARACTERISTICS

Steam zone

The steam zone has high permeability, 100-250 dm. This permeability was intersected by ULB-02. ULB-03 intersected a smaller fracture. ULB-01, although

unproductive in the steam zone, lies sufficiently close to good permeability to respond to ULB-02

Drilling results indicate that a greater thickness of permeability was intersected in ULB-02 than ULB-01, consistent with a trend back toward the presumed centre of the field.

Gas correlations were used to estimate saturation of the steam zone, using the method of Grant et al. (1996), as extended by Grant & Hanano (1997). ULB-02 is extremely permeable and consequently there was little drawdown and hence little contrast in gas contents. No significant estimate was obtained.

Liquid zone

Wells in the liquid zone have found moderate to negligible permeability. Liquid pressures differ between ULB-01 and ULB-02, and between shallow and deeper zones of ULB-01, which indicates that permeability in this zone is not generally high.

If there is a larger development in the field it will need to draw on the liquid zone which is the bulk of the resource, rather than just produce from the steam zone. Well performance for liquid-fed wells is likely to be better elsewhere in the field where there will be higher temperatures. With production of 230-240°C water from an underpressured reservoir producing wellhead pressures will be low and will fall as reservoir pressure ultimately falls. Higher reservoir temperatures will give higher discharge enthalpies and better pressures at wellhead. The problem of an underpressured liquid resource is exacerbated by the poor liquid permeability, as was clearly shown by the failure of ULB-01 to sustain continued discharge at 10" lip pipe.

The liquid reservoir found in the area of the existing wells does not constitute an attractive resource, because of the poor performance expected of liquid-filled wells.

Reservoir conceptual model

The steam zone and liquid zone intersected by the three wells are both outflow zones from elsewhere in the field. In the upflow region there must be rising two-phase fluid from which steam and water flow laterally away. Temperatures in this upflow must therefore reach significantly higher temperatures than 240°C. This upflow zone is presumably located upslope from the existing wells.

ACKNOWLEDGMENT

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