A CASE STUDY OF WIDE DIAMETER CASING FOR GEOTHERMAL SYSTEMS

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Abstract

Three wells have been drilled in the central resistivity area of a geothermal field in the Taupo Volcanic Zone, New Zealand. Using a well bore simulator, WELL SIM V3.0, reservoir conditions and well characteristics are evaluated to determine the increase in output by increasing production casing diameters from either 8-5/8" OD or 9-5/8" OD. to 13-3/8" OD. Increases in well drilling costs are determined to provide a commentary on the economics. While open hole size is effectively doubled, well costs increase by 10% and, in this study, output increases by an average of 18%.

Introduction

After the completion of the initial exploration of geothermal resources, a developer has to determine the most appropriate well diameters for the production drilling phase.

A well consists of a number of casing strings, usually three or four, of decreasing diameters. The inner casing, known as the production casing, can have a direct impact on the maximum amount of steam that can be obtained, as it is the channel through which the steam reaches the surface. Smaller casing diameters can restrict the flow of geothermal fluids.

The remaining casing strings, external to the production casing exist to protect against blowout whilst drilling operations are being carried out, and may be used for locating the wellhead. To run a larger production casing, larger external casings must be run. The resulting well is generally more expensive than a standard well, due to increased material costs, longer drilling time, and additional non-standard equipment that is required to handle the larger casings.

The quantity of steam obtainable from any well is a function of both the production casing diameter and the reservoir conditions. The dollar value of this steam can be compared with the additional drilling costs, brought about by drilling the larger well, to determine the merits of wide diameter drilling.

This paper presents the results of a study which examines the viability of using wide diameter casings on three existing wells.

Situation

Three actual wells, named here as wells A, B and C, have been drilled in the Taupo Volcanic Zone, New Zealand. The characteristics each of these wells is tabulated in Table 1. Well profiles are shown in Figs. 1-3

	WELL A	WELL B	WELL C
Max. Discharge Pressure (bara)	62	45	68
Temperature (deg C)	310	290	320
Enthalpy (kJ/kg)	1650	1340	1450

Table 1. Well Characteristics.

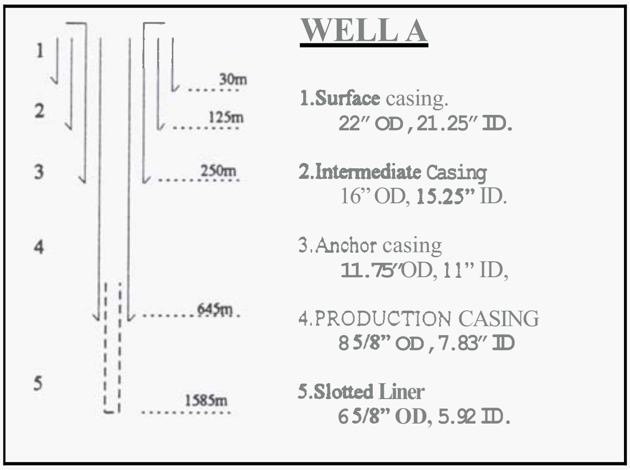

Figure 1

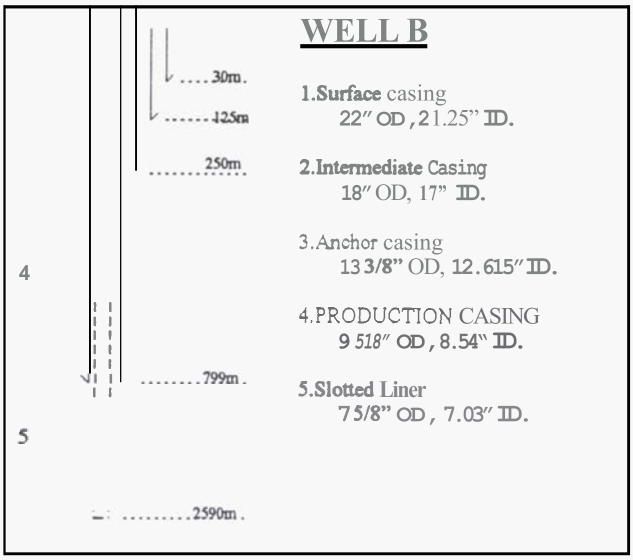

Figure 2

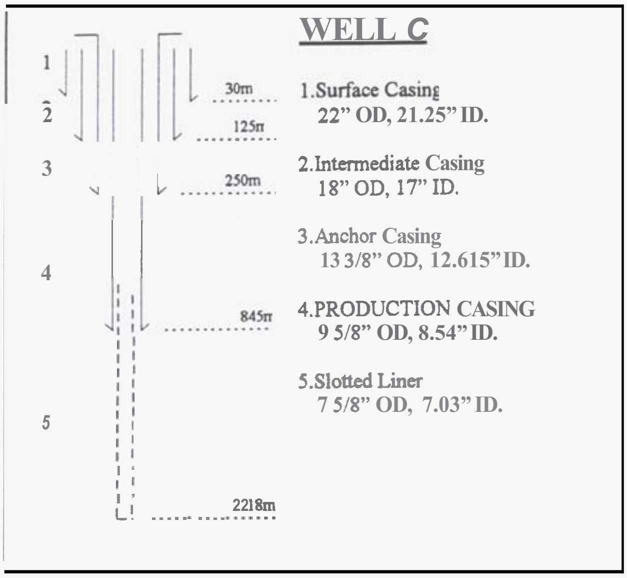

Figure 3.

Points that should be noted are

- The difference in the casing diameters between Well A and Wells B and C. (8 5/8" vs. 9 5/8")
- The differences in the lengths of casing and liner that are used, which contributes to differences in material costs.

Proposal

(Note: Production casing sizes are shown in bold).
Well A was constructed with 22" / 16" / 11$^3/_4$" / **8$^5/_8$"** / 6$^5/_8$" casings, which are not industry standard. Future wells would use 22" / 18" / 13$^3/_8$" / **9$^5/_8$"** / 7$^5/_8$" as the minimum casing sizes.
Two options exist to enlarge the size of the production casing. The first is to reduce the number of casings used by one, eliminating the smaller inner production casing, and to extend the depths of the remaining casings to allow for this. The second option is to use the same number of casings, sunk to the same depths, but to increase each of their diameters.
Any well design must comply with NZS 2403:1991 "Code of Practice for Deep Geothermal Wells". In the case of the three wells considered here, there is insufficient knowledge of formation temperatures and pressures down to depths of 800m to reduce the number of casings. If unexpected downhole conditions should arise during drilling operations, such as a shallow steam feed, a reduced casing well would be less safe due to the larger amount of open (uncased) hole exposed.
Accordingly, in order to construct wider diameter wells it is necessary to use casings consisting of the sizes 30" / 22" / 18" / 13$^3/_8$" / **9$^5/_8$"**.

Extra Costs Involved

Drilling these larger sizes will require the following additional drilling equipment:

- 30" Annular BOP
- 36" Hole Opener Assembly
- 36" Stabiliser

Drilling wider diameters will require additional drilling time.

For the purpose of this study the following costs have been assumed.

All Inclusive Drilling Rate		**$25,000/day**
Casing	30"× 158# 5LB/PE	$337/m
	22"× 87# 5LB/PE	$185/m
	18"× 93# 5LB/PE	$179/m
	16"×65# H40/BTC	$140/m
	13$^3/_8$"×61# N80/BTC	$142/m
	11$^3/_4$"×47# K55/BTC	$101/m
	9$^5/_8$" ×47# K55/BTC	$99/m
	9$^5/_8$" ×47# FJ Slotted	$125/m
	8$^5/_8$" ×36# K55/BTC	$76/m
	7$^5/_8$" ×30# FJ Slotted	$100/m
	6$^5/_8$" ×24# FJ Slotted	$81/m
Cement (incl. Additives)		**$263/tonne**
Hired Equipment		
	30" Annular BOP	$1000/day
	36" Hole Opener	$2817/well
	36" Stabiliser	$2785/well

The increased cost involved with increasing the diameter of the well casings has been calculated as shown in Table 2.

ITEM	WELL A		WELL B	WELL C
	9 5/8"	13 3/8"	13 3/8"	13 3/8"
Cement	$10,341	$44,292	$36,528	$39,045
Casing				
30"	n/a	$4,727	$4,286	$5,135
22"	$0	$5,657	$689	$689
18"	$4902	$19,679	$15,731	$15,479
13 3/8"	$10,344	$42,517	$34,366	$36,326
9 5/8"	$14,817	$42,843	$45,423	$35,068
7 5/8"	$18,500	n/a	n/a	n/a
30" BOP	n/a	$10,000	$10,000	$10,000
36" Stab	n/a	$2,785	$2,785	$2,785
36" H/O	n/a	$2,817	$2,817	$2,817
Rig Time	$25,000	$75,000	$100,000	$100,000
TOTAL	$83,904	$250,317	$252,625	$247,362

Table 2:
Incremental Costs of Wider Diameter Wells.
(Inclusive of establishment costs, water supply, consolidation grouting, drilling, well testing, the increase in cost is approximately 10%.)

Predicted Well Characteristics

Well modelling using a *WELLSIM* V3.00 WellBore Simulation and Analysis package was undertaken to predict the improved output from increased well profiles. This produced the following results.

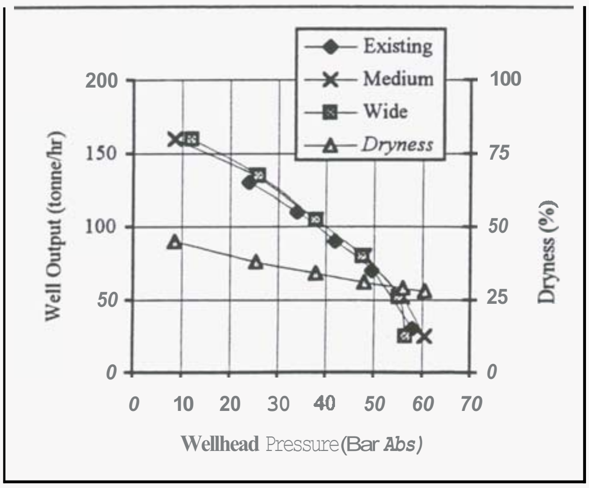

Figure 4 : Output Curves for Well A

In the above graph it can readily be seen that any increase in the size of the production casing will produce a negligible increase in the steam output of the well. Compare the graph with the one shown below.

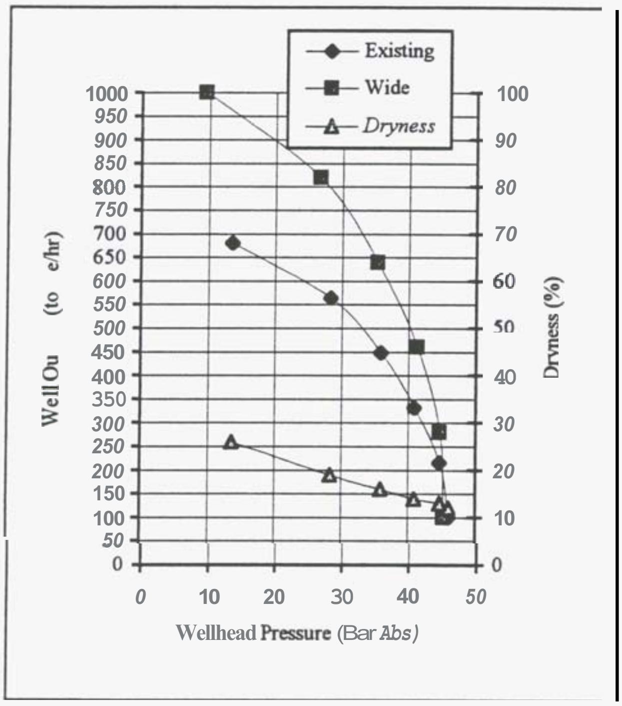

Figure 5 Output Curves for Well B

This well (B) would benefit greatly by increasing the production casing diameter. Another point to note is that although the change in total mass flowrate is relatively small for well A, it has a higher percentage of dry steam per tonne of output than either of the other two wells. This does not have any apparent impact upon the extra steam that can be obtained.

Examining these graphs further, it would appear that the biggest percentage gains are to be made by increasing the well diameter come from the wells that

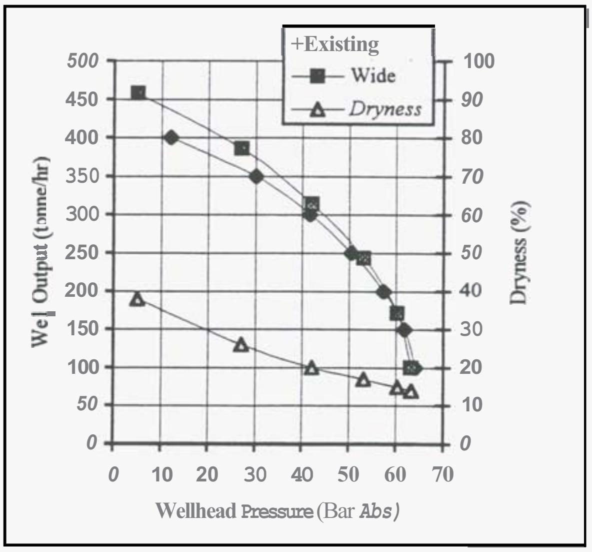

Figure 6: Output Curves for Well C

already have an initially high mass flowrate. This is a logical conclusion, as the higher the flowrate, the closer the discharge conditions are to choked flow.

The nature of the geothermal fluids, in particular the silica saturation temperature suggest that the optimum separation pressure is 12 bars absolute. The expected performance of these three wells at this pressure is shown in Table 3.

	WELL A		WELL B	WELL C
Size	9 5/8"	13 3/8"	13 3/8"	13 3/8"
MassFlow Initial (t/hr)	147	147	685	400
Massflow Predicted (t/hr)	155	160	975	435
ΔMassFlow (t/hr)	8	13	290	35
Percent Increase	5.4%	8.8%	42.3%	8.8%
Dryness %	43.6%	43.6%	27.7%	32.5%
Increased Dry Steam (t/hr)	**3.5**	**5.7**	**80.3**	**11.4**

Table 3: Predicted Well Performance

Benefits

Electricity is currently worth in the vicinity of 5 to 6 cents per kW-h. Based on: ...

- A 70:30 split in power plant to steamfield construction costs.

- **A** conversion rate of 6 tonne of ***steam*** for each MW of electricity produced.
- **A** higher return on investment (due to higher risk) in the steamfield in comparison to the powerplant.
- Consideration for the residual value of the hot water.
- The power-plant running for **8000** hours per year.

. . . the ***steam*** can be assessed to have a value of **$3 per** tonne.

	WELL A		WELL B	WELL C
	9 5/8"	13 3/8"	13 3/8"	13 3/8"
EXTRA COST	$83,904	$250,317	$252,625	$247,362
EXTRA DRY STEAM(t/hr)	3.5	5.7	80.3	11.4
STEAM VALUE ($/hr)	$10.50	$17.10	$240.90	$34.20
STEAM VALUE ($/Annum)	$84,000	$136,800	$1,927,200	$273,600
SIMPLE PAYBACK	365 days	668 days	48 days	330 days

Table 3 : Cost Analysis

Revised Casing Programme

For the costs assumed above, the savings in deleting one string of casing to achieve the wide diameter well show that there is ***cost*** savings of approximately **$200,000.**

These savings, using **22",18"** and **13-3/8"** casing, **(i.e.** deleting the **30"** casing), will require the consent of the statutory authorities due to the increased risk in drilling operations.

Conclusion

Due to the risks involved in developing and operating geothermal steamfields, a developer is generally looking at payback periods in the vicinity of 3 **years (1000** days). On the basis of the above analysis, wide diameter wells are economically justified. However, this **case** study shows that for these **three** wells increasing the following -

- production casing **from** **9-5/8"** to **13-3/8"**
- open hole from **8-1/2" to 12-1/4"** (a **100%** increase in well bore area).
- liner size from **7-5/8"** to **9-5/8"**

brings about an increase in ***steam*** production of **2.2 t/hr, 80.3 t/hr** and **11.4 t/hr** respectively or an average of 33 t/hr. This is an increase of 4%, 42% and 9% or an average increase of **18%.**

Further wells would be required to confirm the **18%** increase in this case study. However, **9-5/8"** OD wells of 700 t/hr mass flow are relatively rare and therefore it is probable that average increases would be less than **18%.**

Depending on the circumstances, including rig costs, equipment and material availability, and information from previous wells, the benefits of wide diameter well are not as great as one might expect, although they are still economically viable.

Acknowledmnents

The authors are grateful for the assistance of Auckland University in providing the use of the wellbore simulator used for this *case* study.