COSTING OF GEOTHERMAL WELLS

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ABSTRACT

Well cost forms a major cost component of the total cost of developing any geothermal development project. Due to this fact, it becomes a key consideration in the determination of the economic viability of a geothermal field. Well costs are generally categorized into two components; Tangible and intangible drilling costs. Tangible drilling costs are mainly cost of equipment that become a permanent part of the well and include Well Casings, Wellhead Equipment and Casing Setting Equipment, while intangible costs refer to money spent primarily for services. In addition, one formula of cost monitoring, during drilling, has been suggested. This formula can be a useful tool in ensuring that acceptable variation in the actual drilling costs and planned drilling costs. It can be deduced that well costing is of vital importance since it can help quantify the substantial cost associated with development of any geothermal project thus enabling adequate budgeting/financing. It can also help investigate the costs of drilling and completion of wells and relate those costs to the economic viability of the geothermal project. In addition, since well costs usually contribute a big percentage of the total project cost, determination of the selling price of energy produced will be easy if the well cost is accurate. From well costing records, it is possible to carry out analysis using drilling-costs-with-depth for various regions and couple them with energy-recovery-with-depth as they relate to various regions. Obviously, areas with relatively low drilling costs will have greater return on investment.

INTRODUCTION

Costing of geothermal wells help quantify the substantial cost associated with development of any geothermal project. It will also help to investigate the costs of drilling and completing of wells and relate those costs to the economic viability of the geothermal project. In addition, well costs contribute a big percentage in determination of the selling price of energy produced. From well costing records, it is possible to carry out analysis using drilling-costs-with-depth for various regions and couple them with energy-recovery-with-depth as they relate to various regions. Obviously, areas with relatively low drilling costs will have greater return on investment.

The objective of drilling is to reach the target depth or pay zone at the lowest cost, highest degree of safety, and minimal degree of damage to formation. To achieve this, two requirements must be satisfied. The first is proper design of the well program, which includes evaluating the formation, coring and testing. The second is proper choice of a drilling rig, which includes the ability to reach the target depth rapidly and economically with the highest degree of safety. The well program is 40 percent of the well costs. The remainder of the cost is proportional to the time for drilling, which includes rig day rate, rental tools, etc.

Proper well planning is key to optimizing operations and minimizing expenditures. To minimize the cost of drilling, it is imperative to gather sufficient information of the area to be drilled, such as:

- Cost of surrounding wells
- Geology to be encountered to reach target depth
- Casing requirements – Surface casing depth, Production casing
- Objective of the well – Hole Size
- Other well activities such as well logging, Cores and well testing.

Some information sources like bit records and rig inventory can be very useful in determining cost-effective procedures in drilling a well.

GENERAL OVERVIEW OF GEOTHERMAL WELL DRILLING IN KENYA

Geothermal wells in Kenya are drilledto a depth of about 3000m, vertical and directional (depending on a geothermal prospect) and temperatures of over 300^0C are encountered. High capacity drilling rigs (2000HP) are used in order to reach the target depth.

The planned drilling duration is approximated at 60 days to complete a well and the average cost of drilling is about 6.5 MUSD (using a drilling contractor), however, if own rigs are used, the drilling cost can be much less.

With directional drilling technology many wells (3-5) can be drilled on one platform (same pad). In addition, directional drilling intercepts as many structures as possible thus enhancing permeability. The kick off point

(KOP), where deviation starts, is normally 400m. The maximum deviation angle is 20 degrees built at a rate of 3 degrees per 30m.Deviationsurvey is done at KOP and after every single drilled during angle build up.

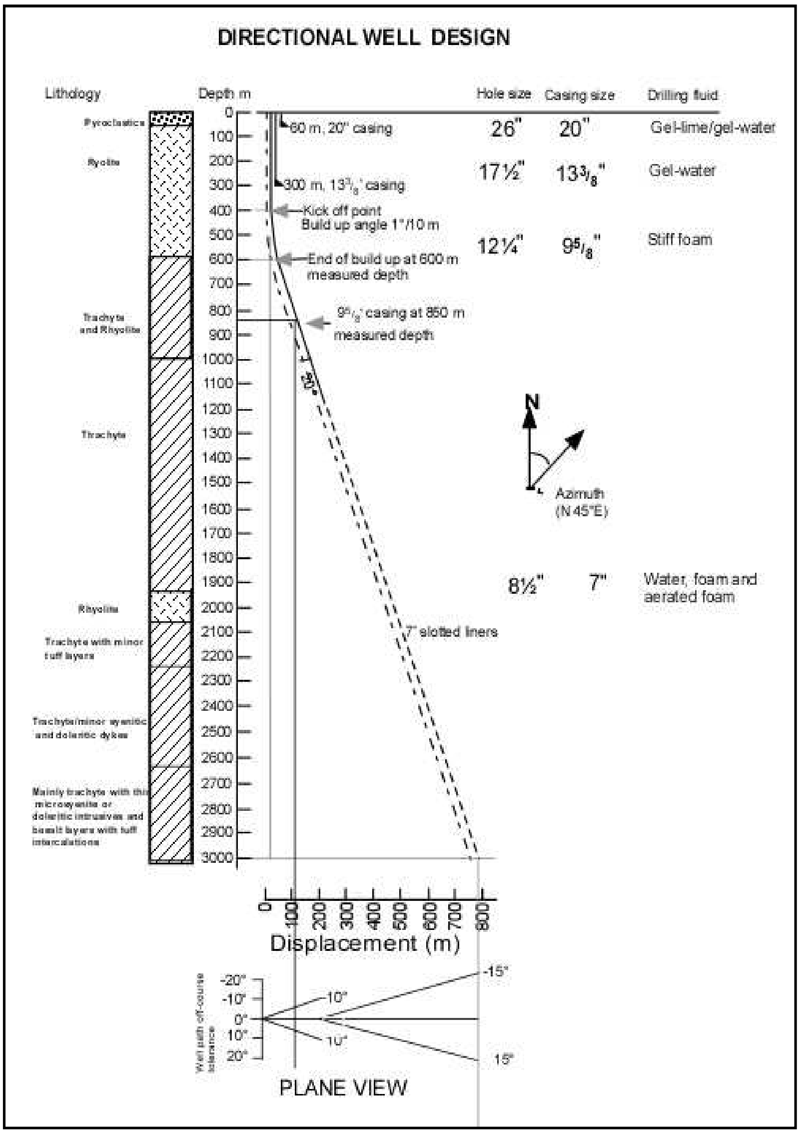
Coring is done only where the stratigraphy of the area is not known, but for well-known areas, it is done only if need arises or at the request of the Rig Geologist.

Cuttings samples are collected at 2 m interval, half a liter sample of both inflowing and out flowing drilling fluids are collected after every 50 m interval. Geo-sweeps are carried out with the request of the Rig Geologist if mixing of the cuttings is suspected.

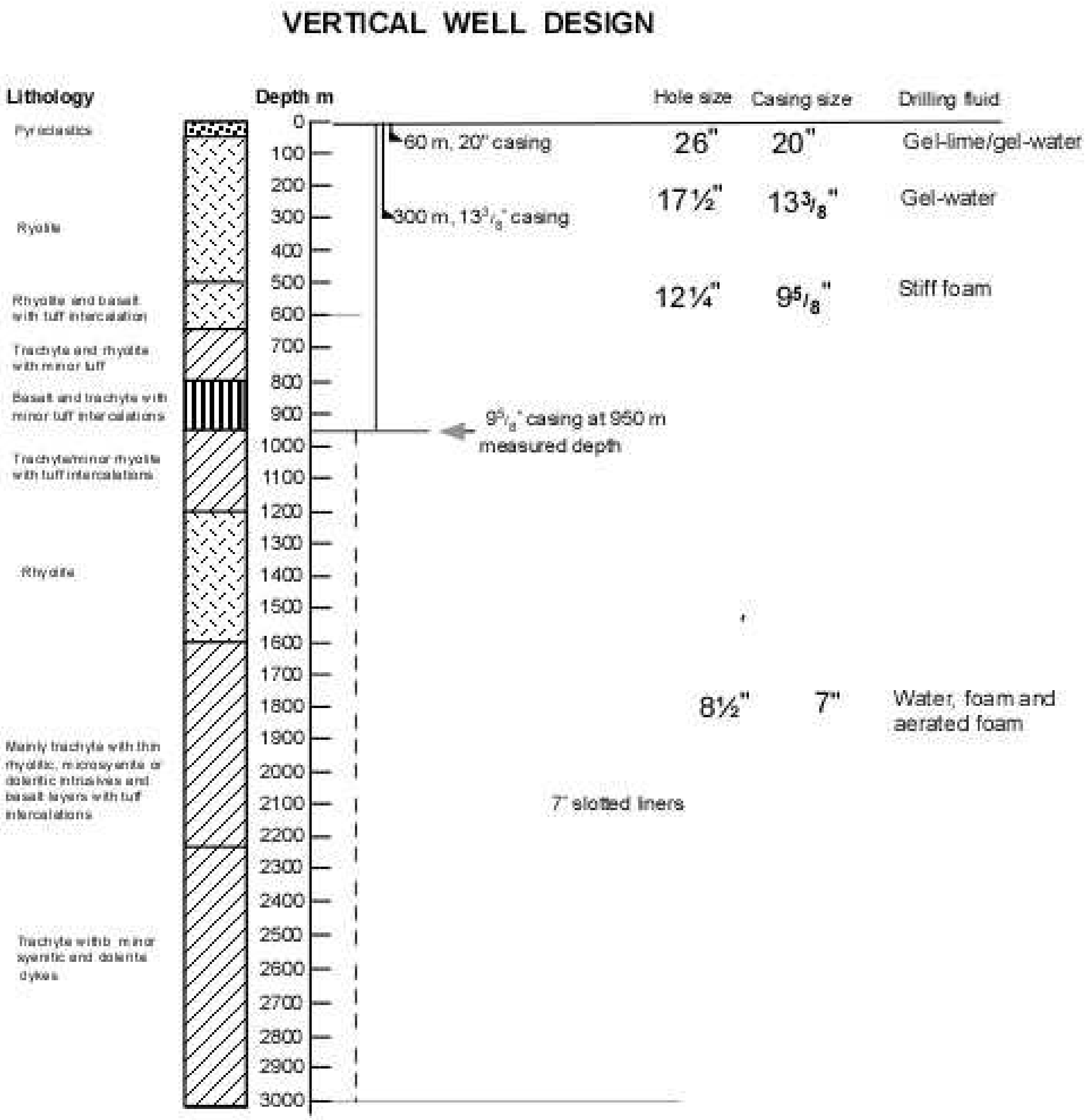
Anticipated drilling problems at various hole sections are usually tackled using advanced drilling techniques and adopting practices from past experiences. Problems like cave in(s), lost circulation, Washouts, are normally comprehensively addressed in the drilling program and possible solutions techniques recommended.

TYPICAL GEOTHERMAL WELL DESIGNS

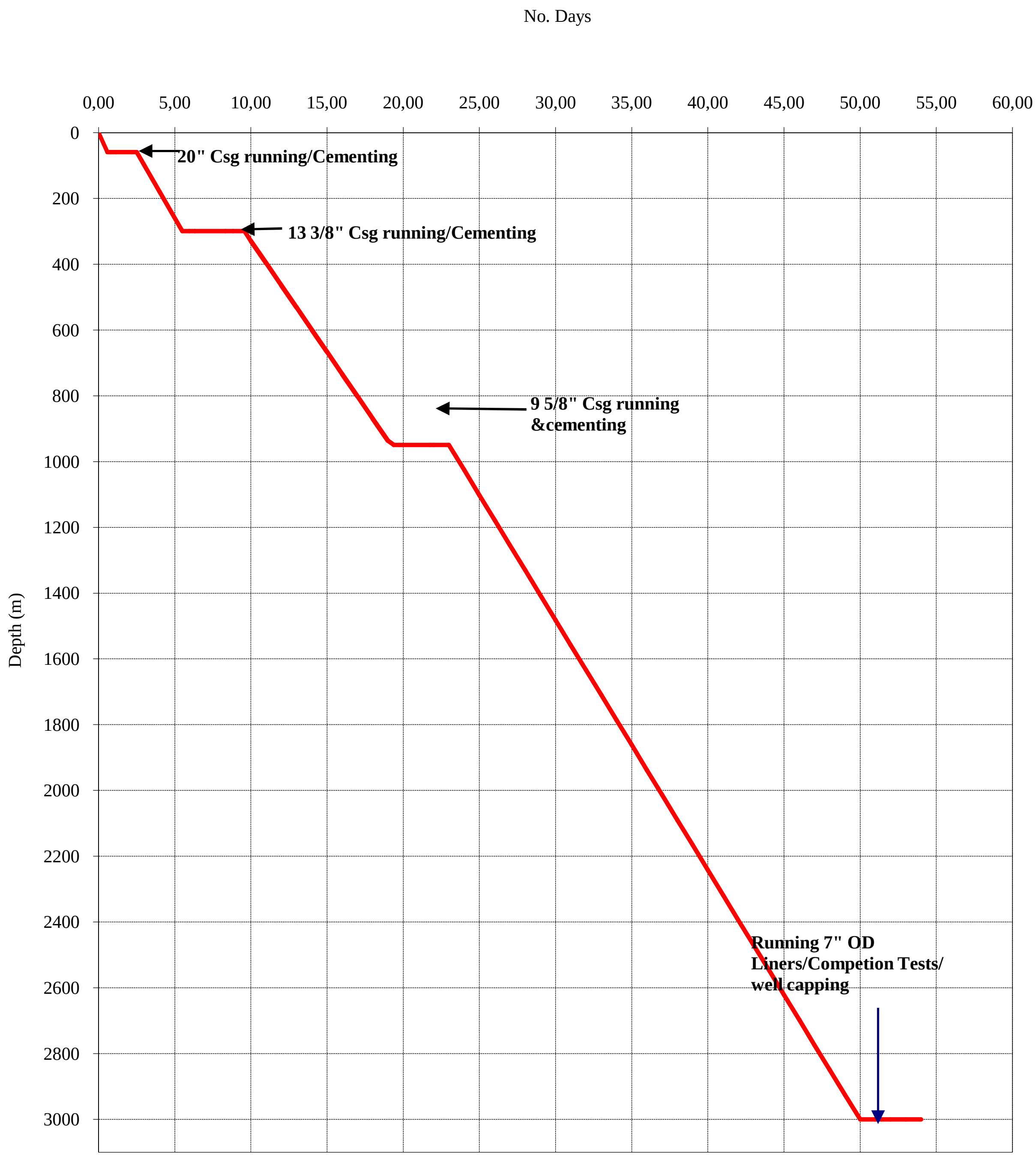
Directional well design



Vertical well design



Planned Drilled Depth Vs Drilling Days



GEOTHERMAL WELL COSTING

Well costs are generally categorized into two components; Tangible and intangible drilling costs. Tangible drilling costs are mainly cost of equipment that become a permanent part of the well while intangible costs refer to money spent primarily for services.

Tangible Drilling Costs (TDC)

These are expenditures for property that has salvage value and generally is equipment or capital costs.

Examples of such expenditures include:

- Well Casings;Surface Casing, Anchor Casing, Production Casing & Slotted Liners
- Wellhead Equipment; Casing Head Flange (CHF), Master Valve, Side Valves
- Casing Setting Equipment; Guide shoe, Casing Hangers, Centralizers, Stop collars.

Intangible Drilling Costs (IDC)

These are expenditures for items that are not tangible. By far the most significant factor in estimating intangibles is drilling time. Interpretation of offset well data yields a depth –versus - days drilling time curve. In addition to day-work charges, some of the most prominent intangible costs are wages, mud, bits, cement, fuel, repairs, hauling and supplies necessary for the drilling and recompletion of the well and the preparation of such well for production.

Other Examples of such costs include:

- ground clearing, drainage construction, location work, road making, temporary roads and ponds, surveying and geological works;
- drilling, completion, logging, cementing of wells;
- hauling mud and water, perforating and supervision overhead;
- Legal cost, damages, insurance;
- Directional drilling services,Plugging
- Environmental costs;
- Logging, coring and wireline services;
- Rig Mobilization and de-mobilization, Transport;
- Contract Labour & Services
- Tools services

Authorisation For Expenditure (AFE)

The authorization for expenditure (AFE) is an estimate of the total cost of drilling a well. It is normally the first steps in drilling a well so that the approximate cost of drilling the well can be known even before the drilling of the well begins. It is however paramount to note that there is no guarantee that the cost of well the drilled will be close to the estimated cost in the AFE. Nevertheless, drilling companies or operators are obligated to provide themselves, investors and all potential stakeholders with a reasonable estimate of the well cost, hence the need for the AFE. If, for some reason, during the drilling of a specific well the operator knows that the total cost of a well is going to exceed the estimated cost in the AFE, it is considered good practice to issue a supplementary AFE, for approval from investors or stakeholders. On some wells there may be several supplementary AFEs.

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WELL COSTING

WELL NO: …………..

INTERNAL ORDER:……………….

FIELD NAME: …………………..

COST CENTRE:……………………

AREA: ....

WELL LOCATION: ………………………

DATE SPUD: ....

ELAVATION:……………….*masl*

DATE COMPLETE: ………………

TARGET:

DRILLING DAYS: ………………….

DEPTH: ………..*m*

CONTRACTOR: ………………

RIG: ……………….

PROJECT:…………………………

TANGIBLE WELL COSTS

	ITEM DESCRIPTION		QTY	UNIT	UNIT COST (USD)	TOTAL (USD)
1	20 " CASING	20" Casing	54.00	m	452.00	24,408.00
		Casing Shoe	1.00	pc	687.00	687.00
2	13⅜ "CASING	13⅜ " 68 lb/ft Casing	22.04	M	227.00	5,003.08
		13⅜ " 54.5 lb/ft Casing	286.38	M	195.00	55,844.10
		Casing Shoe	1.00	Pc	287.00	287.00
		Float collar	1.00	Pc	642.30	642.30
		Top plug	1.00	Pc	385.00	385.00
		Centralizer	8.00	Pc	101.00	808.00
		Stop collar	8.00	Pc	25.25	202.00
3	9⅝ " CASING	9⅝ " 47 lb/ft Casing	1,192.99	M	156.00	186,106.44
		Casing Shoe	1.00	Pc	227.30	227.30
		Float collar	1.00	Pc	502.40	502.40
		Top plug	1.00	Pc	198.00	198.00
		Centralizer	27.00	Pc	90.30	2,438.10
		Stop collar	27.00	Pc	22.58	609.53

	ITEM DESCRIPTION		QTY	UNIT	UNIT COST (USD)	TOTAL (USD)
4	7"Liners	7" 26 lb/ft Casing-Plain		M		
		7" 26 lb/ft Casing-Slotted		M		
5	Wellhead Equipment	Casing Head Flange, 13 3/8"	1.00	Pc	7,988.00	7,988.00
		10" Class 600 Master Valve	1.00	Pc	28,583.00	28,583.00
		10" Class 900 Master Valve		Pc	-	-
		Adaptor Flange, API 6A	1.00	Pc	3,820.00	3,820.00
		2 1/16" Side Valve, 5000 psi	2.00	Pc	7,640.00	7,640.00
		R-57 Ring Gasket C600	1.00	Pc	120.00	120.00
		R-53 Ring Gasket C600	1.00	Pc	120.00	120.00
		R-24 Ring Gasket	2.00	Pc	70.00	70.00
TOTAL TANGIBLE COSTS						

This is a case study where all tangible costs of a well are recorded in a simple spreadsheet.

INTANGIBLE WELL COSTS

	ITEM DESCRIPTION		QTY	UNIT	UNIT COST (USD/KSHS)	TOTAL (USD/KSH)
1	MUD & MUD	Drilling Bentonite	32.50	Ton	653.00	21,222.50
		Lime: Ca(OH)2	-	Ton	1,200.00	-
		Starch	1.50	Ton	1,834.20	

	ITEM DESCRIPTION		QTY	UNIT	UNIT COST (USD)	TOTAL (USD)
	MATERIALS					2,751.30
		Caustic Soda	3.50	Ton	1,341.00	4,693.50
		Calcium Chloride	-	Ton	540.00	-
		Sodium Chloride	-	Ton		-
		CMC		Ton	3,067.00	-
2	LCM MATERIALS	Walnut Shells		Ton	757.40	
		Mica-Flakes		Ton	1,088.50	
		Total Cement for 20" Csg	18.00	Ton	13,189.20	237,405.60
		Blended Cement	18.0	Ton		
		Neat Cement	-	Ton		
		Wyoming (2% BWOC)	0.4	Ton	1,088.50	391.86
		Mica Flakes (3% BWOC)	0.5	Ton	1,088.50	587.79
		Total Cement for 13-3/8" Csg	38.16	Ton	13,189.20	503,299.87
		Blended Cement	21.40	Ton		
		Neat Cement	16.76	Ton		
		Wyoming (2% BWOC)	0.43	Ton	1,088.50	465.88

	ITEM DESCRIPTION		QTY	UNIT	UNIT COST (USD)	TOTAL (USD)
3	CEMENT & CMT ADDITIVES	Mica Flakes (3% BWOC)	0.64	Ton	1,088.50	698.82
		ITEM DESCRIPTION	**QTY**	**UNIT**	**UNIT COST (USD/KSHS)**	**TOTAL (USD/KSH)**
		Fluid Loss (0.65% BWOC)	0.14	Ton	11,515.50	1,601.81
		Friction Reducer (0.3% BWOC)	0.06	Ton	4,941.50	317.24
		Retarder (0.1% BWOC)	0.02	Ton	7,857.40	168.15
		Total Cement for 9-5/8" Csg	80.56	Ton	13,189.20	1,062,521.95
		Blended Cement	46.40	Ton		
		Neat Cement	34.16	Ton		
		Wyoming (2% BWOC)	0.93	Ton	1,088.50	1,010.13
		Mica Flakes (2% BWOC)	1.39	Ton	1,088.50	1,515.19
		Fluid Loss (0.65% BWOC)	0.30	Ton	11,515.50	3,473.07
		Friction Reducer (0.3% BWOC)	0.14	Ton	4,941.50	687.86
		Retarder (0.1% BWOC)	0.05	Ton	7,857.40	364.58
4	ROCK BITS	26" Bit	0.25	Pc	12,285.00	3,071.25
		17-1/2" Bit	0.00	Pc	16,330.00	-
		12-1/4"Bit	3.00	Pc	9,145.00	27,435.00
		8-1/2" Bit	10.00	Pc	5,700.00	57,000.00
5	DIESEL	DIESEL	468,000	Lts	83.56	39,106,080.00
6	OTHERS	Corrosion Inhibitor	drums	drums	710.90	
		Pipelax	drums	drums	700.00	

	ITEM DESCRIPTION		QTY	UNIT	UNIT COST (USD)	TOTAL (USD)
		Casing Dope13⅜ "Casing	1.00	Tin	120.75	120.75
		Baker Lock13⅜ "Casing	1.00	Tin	73.63	73.63
		Casing Dope9⅝ " Casing	1.00	Tin	120.75	120.75
		Baker Lock9⅝ " Casing	1.00	Tin	73.63	73.63
		Casing Dope 7” Liner		Tin		
		Rig mobilization and De-mobilisation				
		Survey and Permits				
		Well Services				
		Legal matters				
		Water Supply				
		Transport				
		Drilling operations (daily rates,)				
		Cementing Service				
		directional drilling Services				
		Insurance				
		Tools and Equipment Rent				
		Drilling Supervision				
		Contract Labour and Services				
TOTAL INTANGIBLE COSTS						

DISCUSSION

There is no guarantee that the estimated cost in the AFE will be anywhere close tothe actual cost of the drilled well. This is because during drilling, hole problems are encountered resulting to extend drilling times and thus increased drilling cost.

Daily drilling costs can be monitored so as to maintain the actual cost as close to the estimated cost as much as possible.Estimates of total drilling expenditures for each day can be recorded so that any abnormal variation in the daily estimates can be picked and investigated. The sum of the daily estimates of drilling expenditures over the drilling period should give the approximate cost of drilling the well.

The following equation can be used to determine estimates of drilling costs for any period considered appropriate, either hourly, daily or per bit basis.

$$C_t = \frac{B + C_r\,(t + T_r)}{F}$$

Where:

C_t = Total drilling cost, \$/ft.

B = Bit Cost, \$.

C_r = Rig cost, \$/hr.

t = Total on-bottom time, hr.

T_r = Round trip time, hr.

F = total ft. /bit

Bit cost B, is easy to estimate. The total on-bottom time, t, is the total time on-bottom with the bit, and includes string connection time. Round trip time, T_r, is the total time necessary to pull and rerun a bit.The total footage per bit, F, is easy to determine. The hourly rig operating costs, C_r, may be difficult to determine but can be estimated from:

- Daily maintenance expenditures
- Drilling practices i.e. Pump pressures, RPM, WOB etc.such practices will impact on rig operating costs (fuel, repairs etc.)
- Rig rental rate.

An accurate record of drilling expenditures of the tangible and intangible drilling costs will give the total well cost. Monitoring the daily drilling expenditures will ensure that the actual drilling costs compare favorably with the AFE costs.

SUMMARY AND CONCLUSION

Costing of geothermal wells can be a fairly simple task if one has a clear understanding of all activities and operations involved from well planning up to when it is completed. If that is the case, it will be possible to factor all costs associated with the drilling of a geothermal well to obtain an accurate figure of the well cost.

It is also imperative to note that proper and reliable record keeping is vital when doing well costing. Therefore this calls for systematized controls of all documents related to costs of items spent on the well so that determination of the well cost can be as accurate as possible.

The level of supervision by engineers, geologists, and operating personnel is also an important contributing factor to accurate well costing. This is because these personnel play a major role in data and record management processes.

Accurate well costing help quantify the substantial costs associated with development of geothermal projects. It will also help to investigate the costs of drilling and completing of wells and relate those costs to the economic viability of the geothermal project. In addition, well costs contribute a big percentage in determination of the selling price of energy produced. From well costing records, it is possible to carry out analysis using drilling-costs-with-depth for various regions and couple them with energy-recovery-with-depth as they relate to various regions.

REFERENCES

Moore L.Preston, (1986)Drilling Practices Manual, 2nd Ed, Pennwell Publishing Company.

2003 Joint Association Survey on Drilling Costs, 2005, American Petroleum Institute.

Chilingarian G., and R. Vorabutr 1983, Drilling and Drilling Fluids, Appendix G, New York, Amsterdam: Elsevier,