An Unconventional Directional Sidetrack of a Geothermal Well in Kenya: Menengai Well MW-15A

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Keywords

Directional Drilling, Geothermal, Sidetracking, Unconventional, Stuck Pipe, Back Off

ABSTRACT

Directional drilling, a key technology for exploration and exploitation of deep geothermal resources, offers a number of significant advantages: it maximises wellbore exposure through productive zones in the reservoir, enables drilling to inaccessible locations like built up areas or beneath mountainous areas, sidetracking, minimises environmental damage and is economical to drill several wells from a single well pad. Directional drilling techniques allow the wellbore to be deflected from the vertical and directed towards a desired direction in order to hit a predetermined target below the surface of the earth. Sidetracking directional drilling technique is applied in a number of situations such as to bypass fish or junk in the hole, sidetracking through casing, and to bypass an unusable section of the original wellbore.

This paper highlights an unconventional directional sidetrack performed during drilling of Menengai well MW-15A at a depth of 1335 metres to bypass a fish in the hole. The fish was left in hole after the drill string was backed off at 1567 metres as a result of stuck pipe at a total drilled depth of 1688 metres. After unsuccessful fishing, it was decided that the wellbore be filled with sand to a depth of 1400 metres, set a cement plug to 1200 metres and sidetrack. The procedure was successfully performed and the well was drilled to a final depth of 2340 metres achieving the desired horizontal departure of 600 metres.

1. Introduction

The Menengai Geothermal Field is located in the southern part of the Kenyan rift in Nakuru County. The Kenyan rift is part of the East African rift system, which runs from the Afar triple junction at the Gulf of Aden in the north to Mozambique in the south. The East African rift splits into two, the western rift and the eastern rift valley, with the Kenyan rift being a segment of the eastern rift valley. Geothermal activity is widely spread in many parts of the Kenyan rift and 14 major geothermal prospects have been identified. However, only a few prospects in the Kenyan rift have so far been drilled, namely Olkaria, Eburru,Longonot,Menengai and Paka currently being explored by Geothermal Development Company (GDC).

Exploration for geothermal resources in Kenya started in the 1950s with mainly geological investigations in the region between Olkaria and Lake Bogoria in the north rift. In the 1970s, exploration was concentrated in Olkaria and by 1976 six deep wells had been drilled. After evaluation of these initial wells, development was found to be feasible. Utilization of the geothermal resource began in 1981 when the first 15 MW generating unit located in Olkaria East was commissioned and operated by KenGen (Kahutu, 2016). Figure 1 shows the location of geothermal prospects in the Kenyan Rift valley system.

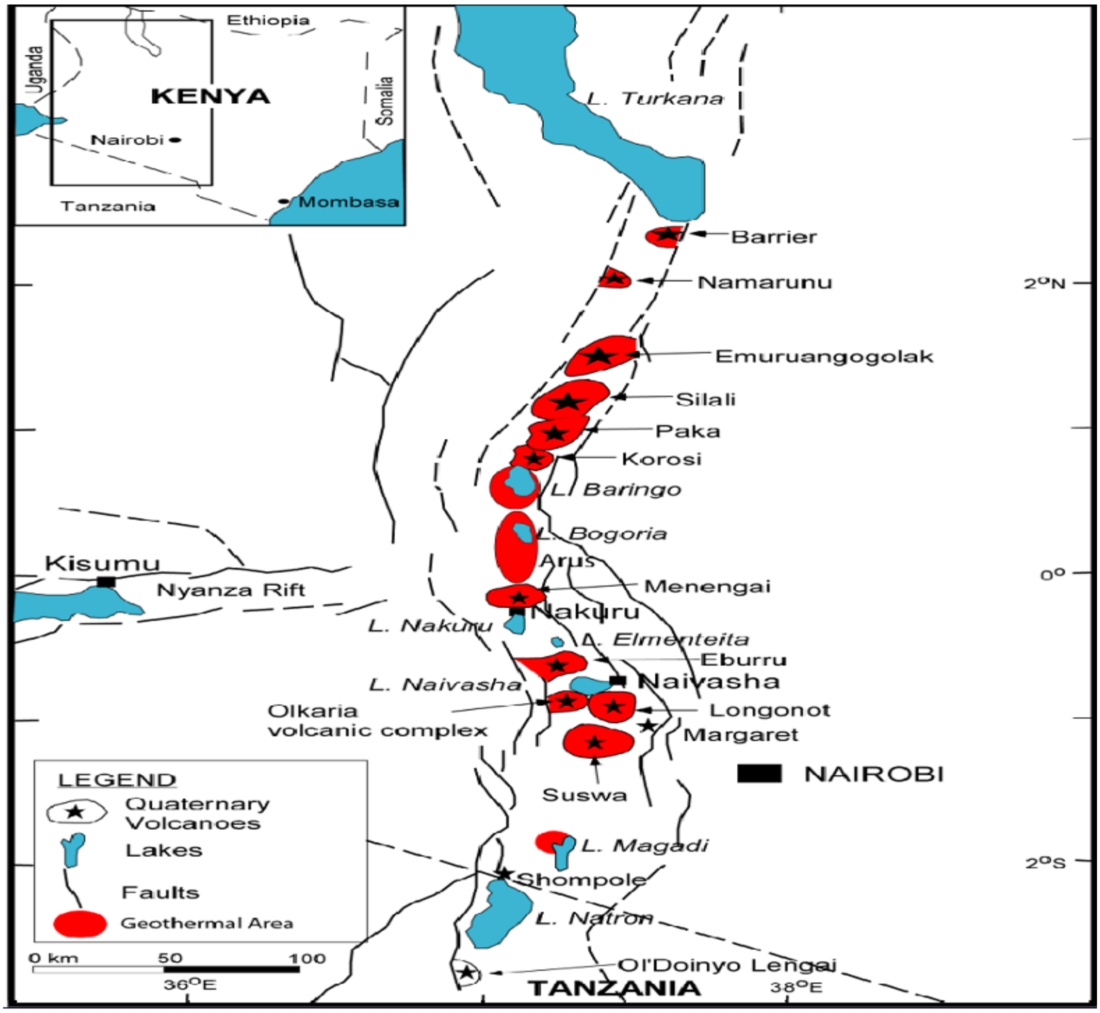

Figure 1: Locations of geothermal resources in Kenya.

Drilling in the Menengai geothermal field started in February 2011 with the aim of harnessing steam for electric power generation. Several wells have been completed and tested, and a temperature of more than 300°C has been recorded at 2000m (Ofwona et al.,2011).The first few exploration wells were drilled vertically in Menengai. Directional drilling was adopted after confirming the existence of the resource to take advantage of the benefits offered by directional drilling (Iglis, 1987). The success of directional wells drilled in the Olkaria field by Kengen (Theuri, 2014) provided further impetus to adopt the technology in the Menengai geothermal field.

2. Geological Well Prognosis, Design and Drilling of Menengai Well MW-15A

2.1 Geological Prognosis

This prognosis serves to give the specifications of well configuration aspects such as well type, direction, casing depths, drilling fluids, and sampling and measurement intervals among others, of MW-15A drilled in the Menengai Geothermal Field. It was based on anticipation of the geothermal system elements with depth, the understanding and prediction of which is derived from data from previously-drilled wells and updated models. Some of the parameters such as casing depths and target depths were revised depending on the drilling data gathered at the drill site by the geologist and the engineer.

2.1.1 Well Data

Table 1 gives the well location in the field and other design parameters for the well.

Table 1: Well data for MW-15A.

PROJECT	MENENGAI GEOTHERMAL PROJECT
FIELD	MENENGAI GEOTHERMAL FIELD
WELL IDENTITY	MW-15A
LOCATION	Easting: 175228.7 Northing: 9977474
ELEVATION	1,960m a.m.s.l
CONFIGURATION / WELL-TYPE	DIRECTIONAL/ S-TYPE
AZIMUTH	030˚NNE
SURFACE CASING SHOE	80m
ANCHOR CASING SHOE	355m
KICKOFF DEPTH	385m-400m
PRODUCTION CASING SHOE	950m
HORIZONTAL DEPARTURE AT PRODUCTION CASING SHOE DEPTH	≈300m
TARGET DEPTH (TD)	2300m -2700m
TOTAL SWEEP AT TD	600m

2.1.2 Well Objective

- Well MW-15A is a production well aimed at providing steam for the second phase (60MW) of Menengai Development Project.
- The well aided in appraising the nature and extend of the reservoir to the North and NNE of MW-15 and North of MW-18A.
- The well helped in exploration and appraisal of the resource to the NNE of well MW-15, by providing borehole geology data, such as lithology and mineralogy that will help in updating the Menengai litho-stratigraphic model and determine feed zones.
- It was also aimed at providing information on the nature and chemical characteristics of the resource.
- The well is an S-type directional well, directed at an azimuth of 030˚ NNE with a target depth of 2300m.The S-type well was chosen because a horizontal departure of 300 metres at the production casing point was required by the geologist.Futhermore, the well was designed to hit the target at some inclination angle.

2.1.3 Site geology

Well MW-15A is located on the eastern section of the dome area and is designed to tap the N-S trending faults at this area as shown in Figure 2. This area is encouragingly a potential resource area judging by the results of wells MW-15, MW-28A, and MW-18A. The regional N-S faults will provide a sufficient supply of steam at the production section of the well by increasing the surface area of the well in a fluid region, and high steam production is expected if permeability, temperature and fluids are found at the reservoir zones. The well was expected to have similar lithological units as those penetrated by wells MW-15, MW-28A and MW-18A.The expected lithostratigraphy for Menengai well MW-15A is highlighted in Figure 3

2.2 Well Design

The well was planned to be drilled at an azimuth of N30°E.The planned kick-off depth was 380m, at which inclination angle was progressively built to attain a horizontal departure of at least 300 m at the production casing depth. The bit was anticipated to bore along N-S fault structures but control was exercised to avoid severe doglegs.

2.2.1 Casing depths

The casing depths for the well are outlined below and in Figure 3. The formation at the proposed depths was anticipated to be competent enough for anchoring of the casings. Hydrothermal alteration coupled with Static Formation Temperature Tests (SFTT) were monitored to at least 950 m. The Wellsite Geologist advised on the appropriate production casing depth during actual drilling of the well.

Conductor Casing
The conductor casing is a meter-length cylindrical steel set at the surface (into the cellar bottom) of the well to prevent loose surface soil from slumping into the well during spud in.

Surface Casing
Surface casing is done to case off cold surface water and to provide stability for the proceeding section of the well. The surface casing shoe was planned to be set at 80m, being the intermediate point between a loss zone (probably a fracture or line of weakness) at 48-

64m, and a tuff formation (which by geological axiom is a soft formation) at 88-94m,information derivatived from MW-15.The surface casing for MW-15A was set at 69.5m.

Anchor Casing

From the word ‘anchor’ (sometimes called intermediate casing), this casing is meant to be a bulwark, providing support, or stability for the entire section of the well. The casing shoe for this section was planned to be at 355m, where it is assumed from MW-15 data to be competent. Anchor casing for MW-15A was set at 353m.

Production Casing

Production casing was set to case off cold waters in intermediate aquifers which may otherwise quench the well. This casing shoe was planned, informed by rock competence, casing of MW-15 (940m), and high temperature anticipation to be set between 950m and 1050m, depending on the data gathered while drilling the well. MW-15 mineralogy, like actinolite and chalcedony, suggests high temperatures from as shallow as 700m but marginal certainty was assumed at ≥900m. Pyrite and calcite encountered at MW-15 breeds confidence in permeability at this depth. This casing for MW-15A was set at 1172m TVD.

Figures 4 shows planned trajectory of the well using the average angle method of survey calculation (Nguyen and Gabolde, 1999), while Figure 5 shows the planned directional well profile.

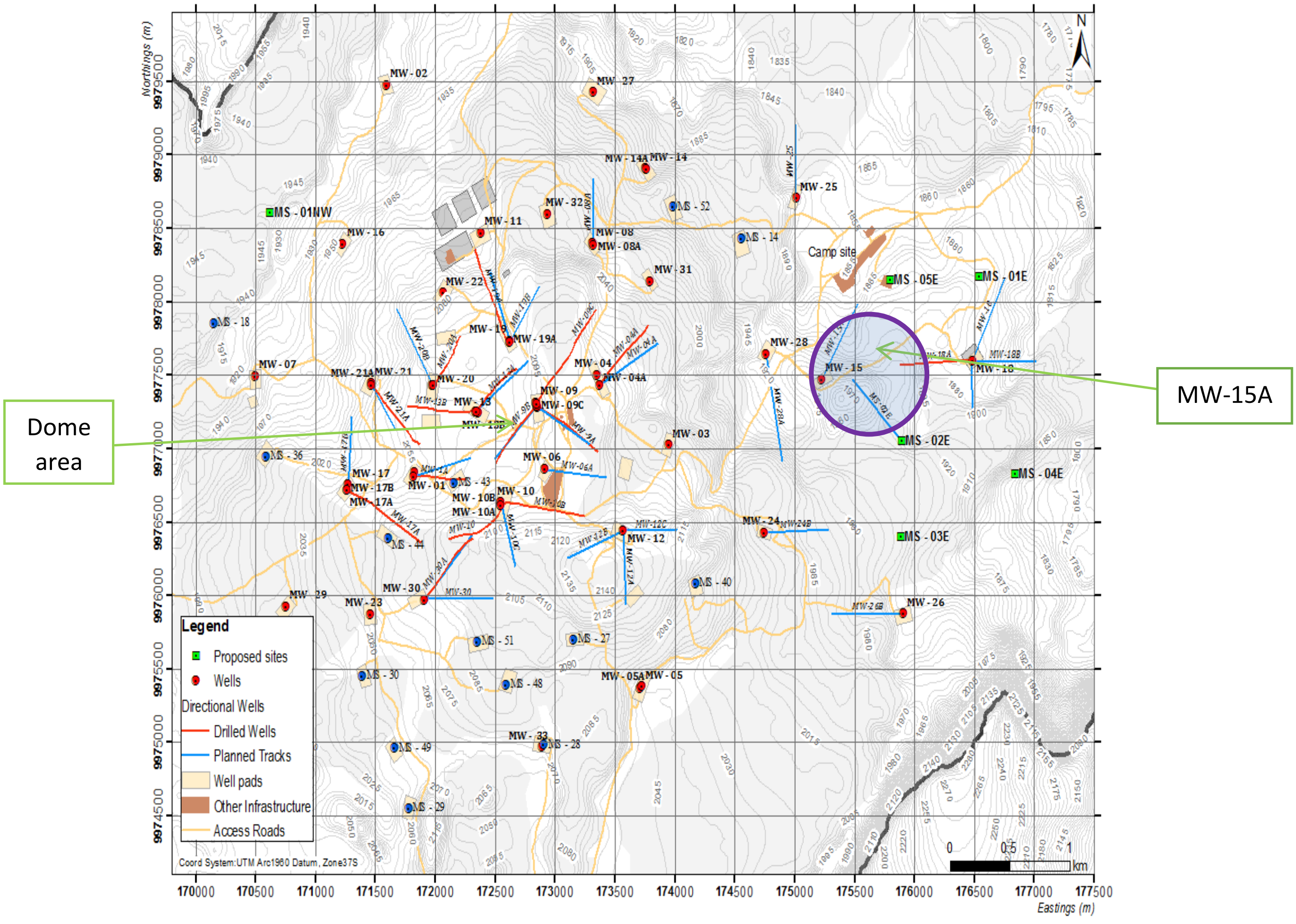

Figure 2: A map of Menengai Geothermal Field showing location and direction of MW15A

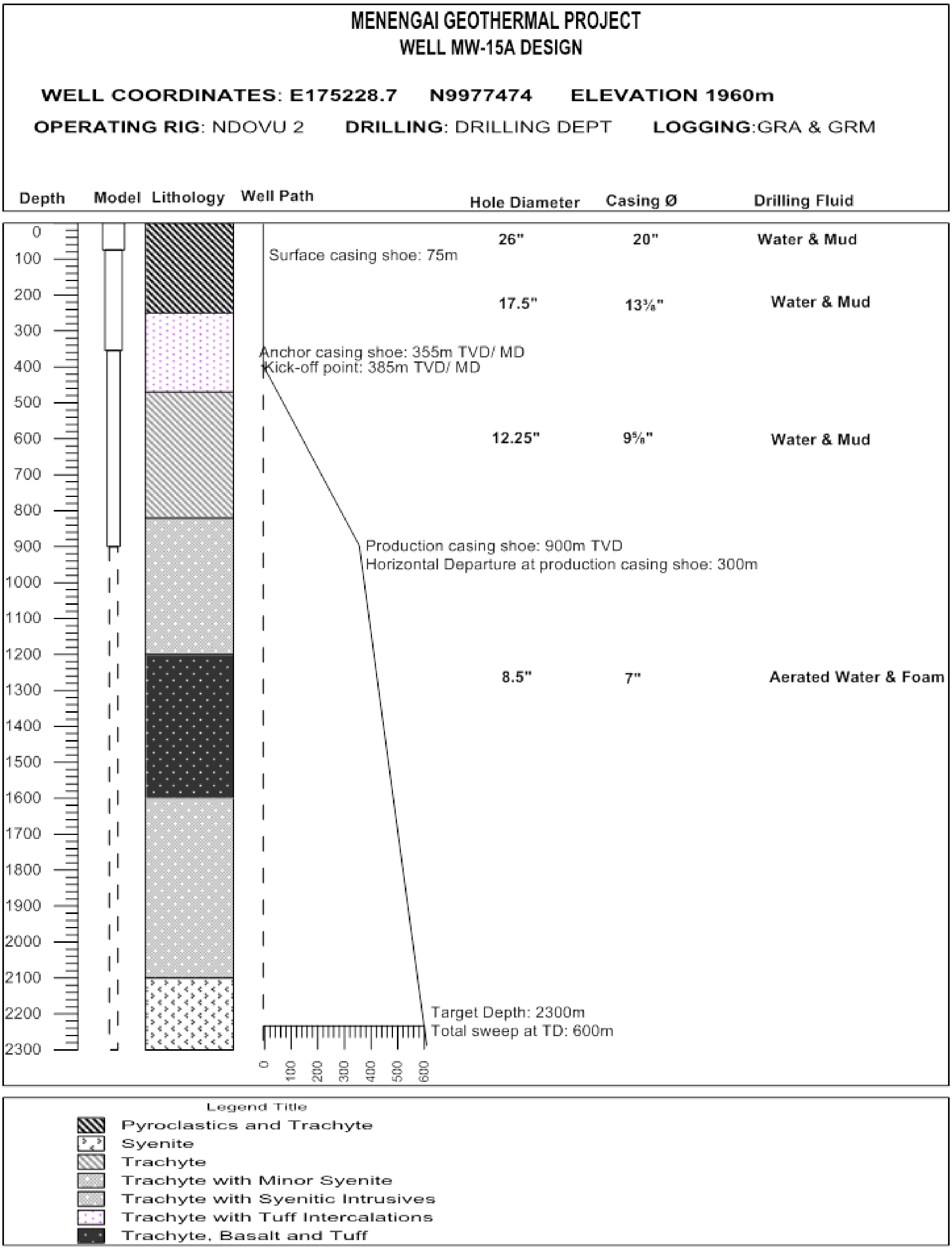

Figure 3: Expected lithostratigraphy of Menengai well MW-15A

MW15A **PLANNED** TRAJECTORY USING AVERAGE ANGLE METHOD																	
SS #	MD	I (°)	A (°)	ΔMD	A_{av}	A_{av}-c	ΔN	ΔE	ΔV	N	E	TVD (M)	D	θ (°)	VS	DL	DLS
0	0	0.00	0.0	0	0.000	0.000	0.000	0.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	379	0.00	0.0	379	0.000	0.000	0.000	0.000	379.0	0.0	0.0	379.0	0.0	0.0	0.0	0.0	0.0
2	388.5	0.95	30.0	9.5	15.000	15.000	0.076	0.020	9.5	0.1	0.0	388.5	0.1	15.0	0.1	0.9	10.0
3	398	1.90	30.0	9.5	30.000	30.000	0.205	0.118	9.5	0.3	0.1	398.0	0.3	3.7	0.3	0.9	10.0
4	407.5	2.85	30.0	9.5	30.000	30.000	0.341	0.197	9.5	0.6	0.3	407.5	0.7	1.6	0.7	0.9	10.0
5	417	3.80	30.0	9.5	30.000	30.000	0.477	0.275	9.5	1.1	0.6	417.0	1.3	0.9	1.3	0.9	10.0
6	426.5	4.75	30.0	9.5	30.000	30.000	0.613	0.354	9.5	1.7	1.0	426.4	2.0	0.6	2.0	0.9	10.0
7	436	5.70	30.0	9.5	30.000	30.000	0.749	0.433	9.5	2.5	1.4	435.9	2.8	0.4	2.8	0.9	10.0
8	445.5	6.65	30.0	9.5	30.000	30.000	0.885	0.511	9.4	3.3	1.9	445.4	3.9	0.3	3.9	0.9	10.0
9	455	7.60	30.0	9.5	30.000	30.000	1.020	0.589	9.4	4.4	2.5	454.8	5.0	0.2	5.0	0.9	10.0
10	464.5	8.55	30.0	9.5	30.000	30.000	1.156	0.667	9.4	5.5	3.2	464.2	6.4	0.2	6.4	0.9	10.0
11	474	9.50	30.0	9.5	30.000	30.000	1.291	0.745	9.4	6.8	3.9	473.6	7.9	0.1	7.9	0.9	10.0
12	483.5	10.45	30.0	9.5	30.000	30.000	1.425	0.823	9.4	8.2	4.7	482.9	9.5	0.1	9.5	0.9	10.0
13	493	11.40	30.0	9.5	30.000	30.000	1.559	0.900	9.3	9.8	5.6	492.3	11.3	0.1	11.3	0.9	10.0
14	502.5	12.35	30.0	9.5	30.000	30.000	1.693	0.977	9.3	11.5	6.6	501.5	13.3	0.1	13.3	0.9	10.0
15	512	13.30	30.0	9.5	30.000	30.000	1.826	1.054	9.3	13.3	7.7	510.8	15.4	0.1	15.4	0.9	10.0
16	521.5	14.25	30.0	9.5	30.000	30.000	1.959	1.131	9.2	15.3	8.8	520.0	17.6	0.1	17.6	0.9	10.0
17	531	15.20	30.0	9.5	30.000	30.000	2.091	1.207	9.2	17.4	10.0	529.2	20.0	0.1	20.0	0.9	10.0
18	540.5	16.15	30.0	9.5	30.000	30.000	2.223	1.283	9.1	19.6	11.3	538.4	22.6	0.0	22.6	0.9	10.0
19	550	17.10	30.0	9.5	30.000	30.000	2.354	1.359	9.1	21.9	12.6	547.5	25.3	0.0	25.3	0.9	10.0
20	559.5	18.05	30.0	9.5	30.000	30.000	2.484	1.434	9.1	24.4	14.1	556.5	28.2	0.0	28.2	0.9	10.0
21	569	19.00	30.0	9.5	30.000	30.000	2.614	1.509	9.0	27.0	15.6	565.5	31.2	0.0	31.2	0.9	10.0
22	600	22.10	30.0	31	30.000	30.000	9.424	5.441	29.0	36.5	21.0	594.6	42.1	0.0	42.1	3.1	10.0
23	609.5	23.05	30.0	9.5	30.000	30.000	3.158	1.823	8.8	39.6	22.9	603.3	45.7	0.0	45.7	0.9	10.0
24	619	24.00	30.0	9.5	30.000	30.000	3.284	1.896	8.7	42.9	24.7	612.0	49.5	0.0	49.5	0.9	10.0
25	649	27.00	30.0	30	30.000	30.000	11.185	6.458	27.1	54.1	31.2	639.1	62.4	0.0	62.4	3.0	10.0
26	679	30.00	30.0	30	30.000	30.000	12.397	7.157	26.4	66.5	38.4	665.5	76.8	0.0	76.8	3.0	10.0
27	709	30.00	30.0	30	30.000	30.000	12.990	7.500	26.0	79.5	45.9	691.5	91.8	0.0	91.8	0.0	0.0
28	739	30.00	30.0	30	30.000	30.000	12.990	7.500	26.0	92.5	53.4	717.5	106.8	0.0	106.8	0.0	0.0
29	769	30.00	30.0	30	30.000	30.000	12.990	7.500	26.0	105.5	60.9	743.4	121.8	0.0	121.8	0.0	0.0
30	799	30.00	30.0	30	30.000	30.000	12.990	7.500	26.0	118.5	68.4	769.4	136.8	0.0	136.8	0.0	0.0
31	829	30.00	30.0	30	30.000	30.000	12.990	7.500	26.0	131.4	75.9	795.4	151.8	0.0	151.8	0.0	0.0
32	859	30.00	30.0	30	30.000	30.000	12.990	7.500	26.0	144.4	83.4	821.4	166.8	0.0	166.8	0.0	0.0
33	889	30.00	30.0	30	30.000	30.000	12.990	7.500	26.0	157.4	90.9	847.4	181.8	0.0	181.8	0.0	0.0
34	919	30.00	30.0	30	30.000	30.000	12.990	7.500	26.0	170.4	98.4	873.3	196.8	0.0	196.8	0.0	0.0
35	949	30.00	30.0	30	30.000	30.000	12.990	7.500	26.0	183.4	105.9	899.3	211.8	0.0	211.8	0.0	0.0
36	979	30.00	30.0	30	30.000	30.000	12.990	7.500	26.0	196.4	113.4	925.3	226.8	0.0	226.8	0.0	0.0
37	1009	30.00	30.0	30	30.000	30.000	12.990	7.500	26.0	209.4	120.9	951.3	241.8	0.0	241.8	0.0	0.0
38	1039	30.00	30.0	30	30.000	30.000	12.990	7.500	26.0	222.4	128.4	977.3	256.8	0.0	256.8	0.0	0.0
39	1069	30.00	30.0	30	30.000	30.000	12.990	7.500	26.0	235.4	135.9	1003.2	271.8	0.0	271.8	0.0	0.0
40	1099	30.00	30.0	30	30.000	30.000	12.990	7.500	26.0	248.4	143.4	1029.2	286.8	0.0	286.8	0.0	0.0
41	1129	30.00	30.0	30	30.000	30.000	12.990	7.500	26.0	261.3	150.9	1055.2	301.8	0.0	301.8	0.0	0.0
42	1159	30.00	30.0	30	30.000	30.000	12.990	7.500	26.0	274.3	158.4	1081.2	316.8	0.0	316.8	0.0	0.0
43	1189	30.00	30.0	30	30.000	30.000	12.990	7.500	26.0	287.3	165.9	1107.2	331.8	0.0	331.8	0.0	0.0
44	1219	30.00	30.0	30	30.000	30.000	12.990	7.500	26.0	300.3	173.4	1133.1	346.8	0.0	346.8	0.0	0.0
45	1249	27.00	30.0	30	30.000	30.000	12.397	7.157	26.4	312.7	180.5	1159.5	361.1	0.0	361.1	3.0	10.0
46	1279	24.00	30.0	30	30.000	30.000	11.185	6.458	27.1	323.9	187.0	1186.6	374.0	0.0	374.0	3.0	10.0
47	1309	21.00	30.0	30	30.000	30.000	9.942	5.740	27.7	333.8	192.7	1214.3	385.5	0.0	385.5	3.0	10.0
48	1359	16.00	30.0	50	30.000	30.000	13.740	7.933	47.4	347.6	200.7	1261.7	401.3	0.0	401.3	5.0	10.0
49	1409	13.00	30.0	50	30.000	30.000	10.842	6.260	48.4	358.4	206.9	1310.1	413.9	0.0	413.9	3.0	6.0
50	1459	13.00	30.0	50	30.000	30.000	9.741	5.624	48.7	368.2	212.5	1358.8	425.1	0.0	425.1	0.0	0.0
51	1509	13.00	30.0	50	30.000	30.000	9.741	5.624	48.7	377.9	218.2	1407.6	436.4	0.0	436.4	0.0	0.0
52	1559	13.00	30.0	50	30.000	30.000	9.741	5.624	48.7	387.6	223.8	1456.3	447.6	0.0	447.6	0.0	0.0
53	1609	13.00	30.0	50	30.000	30.000	9.741	5.624	48.7	397.4	229.4	1505.0	458.8	0.0	458.8	0.0	0.0
54	1659	13.00	30.0	50	30.000	30.000	9.741	5.624	48.7	407.1	235.0	1553.7	470.1	0.0	470.1	0.0	0.0
55	1709	13.00	30.0	50	30.000	30.000	9.741	5.624	48.7	416.9	240.7	1602.4	481.3	0.0	481.3	0.0	0.0
56	1759	13.00	30.0	50	30.000	30.000	9.741	5.624	48.7	426.6	246.3	1651.2	492.6	0.0	492.6	0.0	0.0
57	1809	13.00	30.0	50	30.000	30.000	9.741	5.624	48.7	436.3	251.9	1699.9	503.8	0.0	503.8	0.0	0.0
58	1859	13.00	30.0	50	30.000	30.000	9.741	5.624	48.7	446.1	257.5	1748.6	515.1	0.0	515.1	0.0	0.0
59	1909	13.00	30.0	50	30.000	30.000	9.741	5.624	48.7	455.8	263.1	1797.3	526.3	0.0	526.3	0.0	0.0
60	1959	13.00	30.0	50	30.000	30.000	9.741	5.624	48.7	465.6	268.8	1846.0	537.6	0.0	537.6	0.0	0.0
61	2009	13.00	30.0	50	30.000	30.000	9.741	5.624	48.7	475.3	274.4	1894.7	548.8	0.0	548.8	0.0	0.0
62	2059	13.00	30.0	50	30.000	30.000	9.741	5.624	48.7	485.1	280.0	1943.5	560.1	0.0	560.1	0.0	0.0
63	2109	13.00	30.0	50	30.000	30.000	9.741	5.624	48.7	494.8	285.6	1992.2	571.3	0.0	571.3	0.0	0.0
64	2159	13.00	30.0	50	30.000	30.000	9.741	5.624	48.7	504.5	291.3	2040.9	582.6	0.0	582.6	0.0	0.0
65	2209	13.00	30.0	50	30.000	30.000	9.741	5.624	48.7	514.3	296.9	2089.6	593.8	0.0	593.8	0.0	0.0
66	2259	13.00	30.0	50	30.000	30.000	9.741	5.624	48.7	524.0	302.5	2138.3	605.1	0.0	605.1	0.0	0.0
67	2309	13.00	30.0	50	30.000	30.000	9.741	5.624	48.7	533.8	308.1	2187.1	616.3	0.0	616.3	0.0	0.0

Figure 4: Planned trajectory of Menengai well MW-15A using the average angle method.

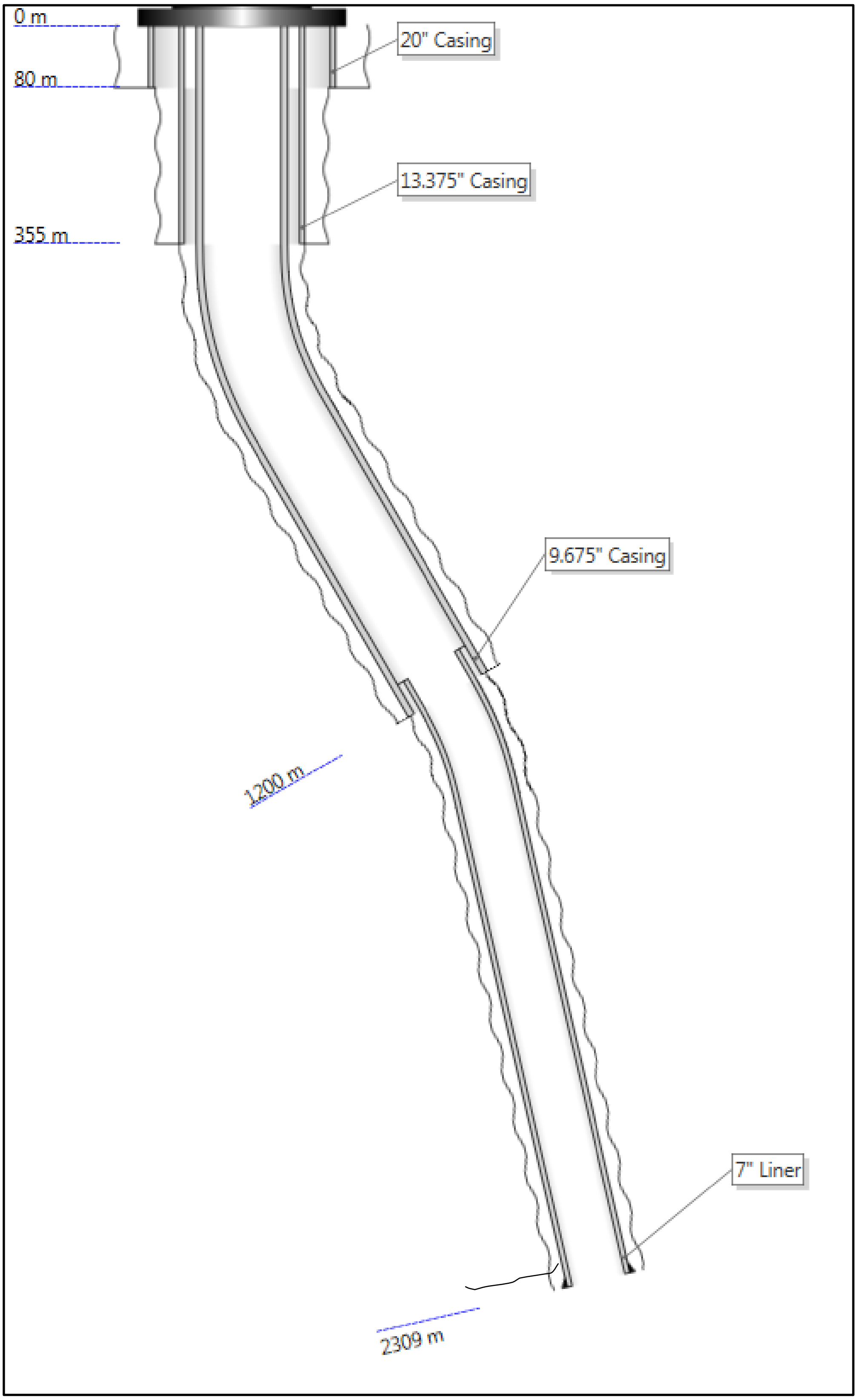

Figure 5: Planned directional well profile.

2.3 Drilling of Menengai Well MW-15A

The well was drilled vertically to a depth of 380 metres and then kicked off using a mud motor oriented to achieve an azimuth of 30 degrees. The surface and anchor casing were set at 70 metres and 353 metres respectively. The well was then drilled following the trajectory shown in Figure 6 and the production casing successfully set at 1209 metres measured depth. At a drilled depth of 1688m the drill string got stuck. Several attempts to free the string were futile, over a duration of two weeks, and it was decided that the string be backed off as low as possible in the BHA. The string was backed off at 1567 metres and pulled to surface, leaving a fish in the hole. After unsuccessful fishing, the well was sidetracked and drilling continued to a final depth of 2340 metres measured depth having achieved the required horizontal departure of 600 metres. Details of the sidetrack is given in Section 2.3.2.

MW15A ACTUAL TRAJECTORY USING AVERAGE ANGLE METHOD																	
SS #	MD	I (°)	A (°)	ΔMD	A_{av}	A_{av}-c	ΔN	ΔE	ΔV	N	E	TVD(m)	D	θ (°)	VS	DL	DLS
0	0	0.00	0.00	0	0.000	0.000	0.000	0.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	388	0.90	81.62	388	40.810	40.810	2.306	1.992	388.0	2.3	2.0	388.0	3.0	-10.8	3.0	0.9	0.2
2	397	1.59	85.26	9	83.440	83.440	0.022	0.194	9.0	2.3	2.2	397.0	3.2	-13.2	3.1	0.7	7.7
3	416	1.94	57.30	19	71.280	71.280	0.188	0.554	19.0	2.5	2.7	416.0	3.7	-17.4	3.5	0.9	4.8
4	436	3.27	36.60	20	46.950	46.950	0.621	0.664	20.0	3.1	3.4	436.0	4.6	-17.3	4.4	1.6	8.0
5	456	4.28	37.82	20	37.210	37.210	1.049	0.796	20.0	4.2	4.2	455.9	5.9	-15.1	5.7	1.0	5.1
6	475	4.89	18.25	19	28.035	28.035	1.341	0.714	18.9	5.5	4.9	474.9	7.4	-11.6	7.2	1.7	8.8
7	494	4.91	16.00	19	17.125	17.125	1.551	0.478	18.9	7.1	5.4	493.8	8.9	-7.3	8.8	0.2	1.0
8	502	5.68	9.09	8	12.545	12.545	0.721	0.160	8.0	7.8	5.6	501.7	9.6	-5.5	9.5	1.0	12.5
9	532	6.79	2.02	30	5.555	5.555	3.243	0.315	29.8	11.0	5.9	531.6	12.5	2.0	12.5	1.3	4.5
10	551	9.07	2.19	19	2.105	2.105	2.620	0.096	18.8	13.7	6.0	550.4	14.9	6.4	14.8	2.3	12.0
11	600	13.53	358.77	49	360.480	0.480	9.601	0.080	48.1	23.3	6.0	598.4	24.0	15.4	23.2	4.5	9.2
12	619	14.73	3.80	19	361.285	1.285	4.637	0.104	18.4	27.9	6.1	616.9	28.6	17.6	27.2	1.7	9.0
13	678	16.17	12.56	59	8.180	8.180	15.558	2.236	56.9	43.5	8.4	673.7	44.3	19.1	41.8	2.7	4.6
14	685	20.51	20.90	7	16.730	16.730	2.109	0.634	6.6	45.6	9.0	680.4	46.4	18.8	44.0	5.1	72.3
15	705	22.48	21.24	20	21.070	21.070	6.838	2.635	18.6	52.4	11.7	698.99	53.7	17.5	51.2	1.97	9.9
16	726	23.34	22.03	21	21.635	21.635	7.599	3.014	19.3	60.0	14.7	718.3	61.8	16.3	59.8	0.9	4.3
17	755	22.91	21.95	29	21.990	21.990	10.561	4.265	26.7	70.6	18.9	745.0	73.1	15.0	71.1	0.4	1.5
18	774	22.53	22.29	19	22.120	22.120	6.798	2.763	17.5	77.4	21.7	762.5	80.3	14.3	78.5	0.4	2.1
19	803	22.45	21.64	29	21.965	21.965	10.288	4.149	26.8	87.7	25.8	789.3	91.4	13.6	89.6	0.3	0.9
20	846	22.74	22.94	43	22.290	22.290	15.287	6.266	39.7	102.9	32.1	829.0	107.8	12.7	106.1	0.6	1.3
21	874	24.10	22.63	28	22.785	22.785	10.261	4.310	25.7	113.2	36.4	854.7	118.9	12.2	117.8	1.4	4.9
22	902	25.72	22.61	28	22.620	22.620	10.886	4.536	25.4	124.1	41.0	880.1	130.7	11.7	129.6	1.6	5.8
23	959	28.39	24.7	57	23.645	23.645	23.750	10.398	50.8	147.8	51.4	930.9	156.5	10.8	155.5	2.8	5.0
24	1014	30.77	24.4	55	24.520	24.520	24.702	11.268	47.8	172.5	62.6	978.7	183.5	10.0	182.6	2.4	4.3
25	1053	31.77	26.3	39	25.310	25.310	18.301	8.655	33.3	190.8	71.3	1012.0	203.7	9.5	202.8	1.4	3.6
26	1110	32.45	26.6	57	26.420	26.420	27.134	13.481	48.3	218.0	84.8	1060.3	233.9	8.7	233.0	0.7	1.2
27	1186	31.98	26.5	76	26.525	26.525	36.251	18.094	64.3	254.2	102.9	1124.6	274.2	8.0	274.0	0.5	0.6
28	1242	31.39	28.83	56	27.650	27.650	26.055	13.650	47.7	280.3	116.5	1172.27	303.5	7.4	303.0	1.37	2.5
29	1300	30.82	30.77	58	29.800	29.800	26.001	14.891	49.7	306.3	131.4	1221.93	333.3	6.8	333.0	1.15	2.0
29	1374	29.75	31.12	74	30.945	30.945	32.006	19.190	63.9	338.3	150.6	1285.83	370.3	6.0	370.0	1.08	1.5
30	1434	28.87	33.16	60	32.140	32.140	24.871	15.626	52.3	363.2	166.2	1338.15	399.4	5.4	399.0	1.33	2.2
32	1512	28.35	33.01	78	33.085	33.085	31.294	20.389	68.5	394.4	186.6	1406.63	436.4	4.7	436.0	0.52	0.7
33	1550	27.93	34.11	38	33.560	33.560	14.934	9.907	33.5	409.4	196.5	1440.14	454.1	4.4	454.0	0.67	1.8
34	1588	27.54	36.21	38	35.160	35.160	14.458	10.184	33.6	423.8	206.7	1473.77	471.6	4.0	471.0	1.05	2.8
35	1665	26.41	33.41	77	34.810	34.810	28.677	19.939	68.6	452.5	226.6	1542.39	506.1	3.4	506.0	1.70	2.2

Figure 6: Directional trajectory of well MW-15A before backing off drill string, plugging and side tracking.

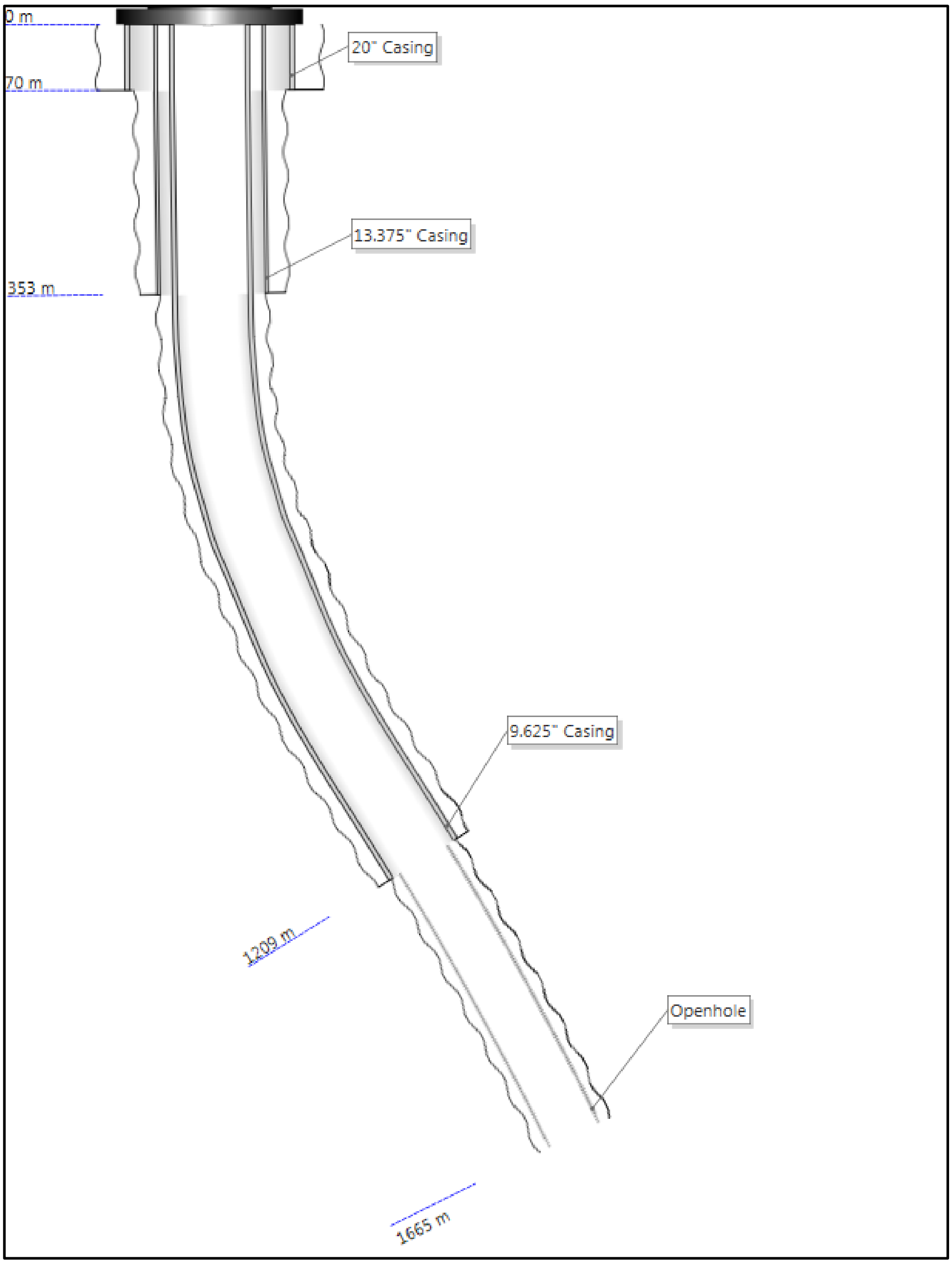

Figure 7: Directional well profile before sidetracking

2.3.1 Options considered before unconventional sidetracking

Following unsuccessful fishing, a number of options were considered to continue drilling of the well:

- Sidetracking using a whip stock. The time required to mobilize a contractor was lengthy, hence this option was dropped.

- Squeeze cement at 1567 metres and sidetrack. This option was not adopted because high temperature in the well at that depth could have possibly caused cement to harden fast and stick to the drill string before pulling of hole. The high temperature in the well at this depth would also have affected the available mud motor for sidetracking. Moreover, squeezed cement at this depth would have plugged the reservoir pores at the productive zone.
- Terminate the well at the current depth. This would have meant not exploring greater depths, otherwise considered a productive zone.
- Fill the well with sand from the back off depth of 1567m to about 1400m, set cement plug to 1200m, and sidetrack.

2.3.2 Description of the Unconventional Sidetrack

The last option was adopted because of the speed of execution and suitability of sand in protecting the reservoir from damage, compared to setting a cement plug at a greater depth considered a productive zone.

A total of 6.6 tons of sand was poured into the hole through the riser, and water was pumped to mobilise the sand. Sand was squeezed by closing the blind ram and pumping water at 30 SPM through the kill line for 10 hours. The top of sand was tagged at 1401 metres, indicating that sand filled a column of 166 metres from the top of the fish at 1567 metres to 1401metres. The well was then cooled by circulation with water before running open-ended drill pipe to 1358metres to set a cement plug. The cement plug was tagged at 1196 metres. The well set up before sidetracking is shown in Figure 8.The cement plug was then drilled with a slick BHA to 1316 metres, then pulled out of the hole and a mud motor assembly was run in the hole to sidetrack the well. The well inclination and azimuth at this sidetrack depth was 30.82° and 30.77°, respectively. Therefore, the high-side tool face was set at 180 degrees to sidetrack towards the low side of the well. After initiating the sidetrack from a depth of 1335 metres to 1389 metres, the mud motor assembly was pulled out of the hole. Thereafter, different BHA designs were used to steer the well to a final depth of 2340 metres, having achieved the desired horizontal departure of 600 metres. The completed sidetracked well profile is shown in figure 9 while the well trajectory viewed from different planes is shown in Figures 11-14.

This sidetrack was considered unconventional because most sidetracks in the Menengai geothermal field to bypass a fish in the hole had been carried out by setting only a cement plug and then running in the hole a mud motor to sidetrack the well. The idea of filling the wellbore with sand before setting a cement plug made this sidetrack unconventional.

5. Conclusion

Menengai well MW-15A was successfully sidetracked and its design objective achieved after drilling to a total depth of 2340 metres and attaining the required horizontal departure of 600 metres. Preparing the well for the sidetrack, up to start of the sidetracking took 5 days.Mobilising the whipstock to site by the contractor was projected to take at least 10 days. Therefore the unconventional option of filling the well with sand before setting a cement plug and sidetracking proved a viable option. This presented a huge cost saving compared to terminating the well at that depth before drilling through all the productive zones or waiting for the contractor to mobilise whipstock to sidetrack the well.

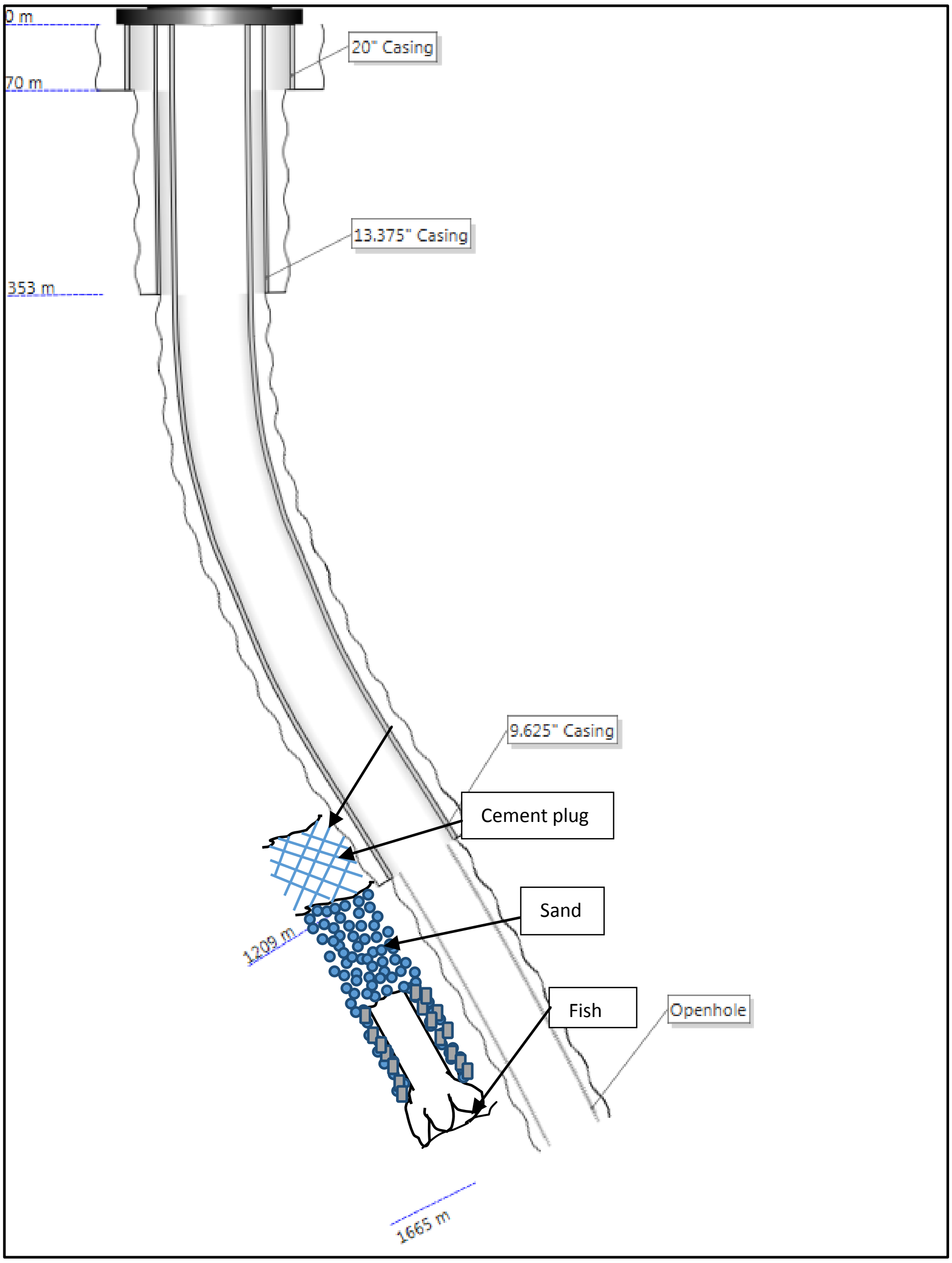

Figure 8: well set up before sidetracking

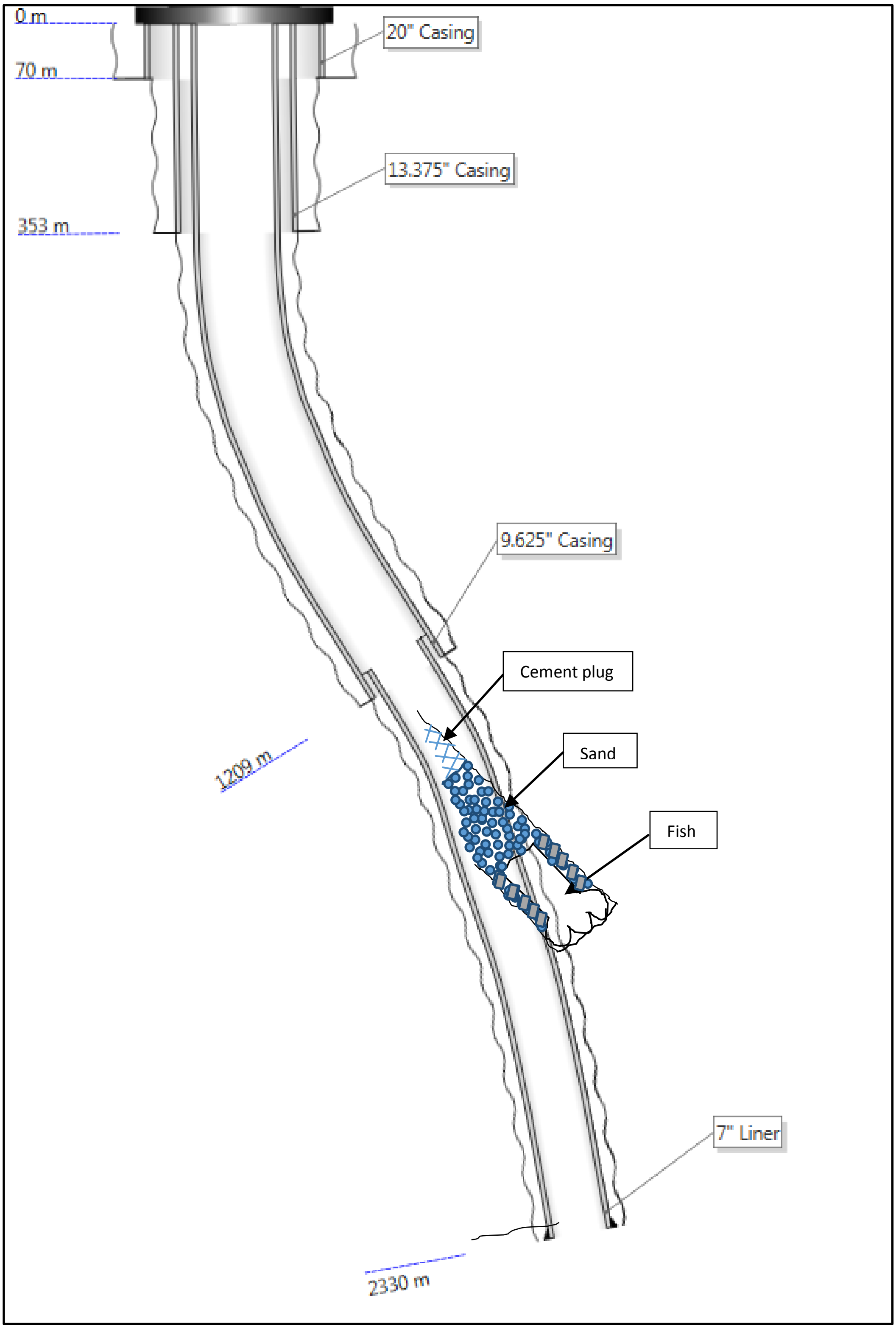

Figure 9: Complete sidetracked well

MW15A ACTUAL TRAJECTORY USING AVERAGE ANGLE METHOD																	
SS #	MD	I (°)	A (°)	ΔMD	A_{av}	A_{av}-c	ΔN	ΔE	ΔV	N	E	TVD(m)	D	θ (°)	VS	DL	DLS
0	0	0.00	0.00	0	0.000	0.000	0.000	0.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	388	0.90	81.62	388	40.810	40.810	2.306	1.992	388.0	2.3	2.0	388.0	3.0	-10.8	3.0	0.9	0.2
2	397	1.59	85.26	9	83.440	83.440	0.022	0.194	9.0	2.3	2.2	397.0	3.2	-13.2	3.1	0.7	7.7
3	416	1.94	57.30	19	71.280	71.280	0.188	0.554	19.0	2.5	2.7	416.0	3.7	-17.4	3.5	0.9	4.8
4	436	3.27	36.60	20	46.950	46.950	0.621	0.664	20.0	3.1	3.4	436.0	4.6	-17.3	4.4	1.6	8.0
5	456	4.28	37.82	20	37.210	37.210	1.049	0.796	20.0	4.2	4.2	455.9	5.9	-15.1	5.7	1.0	5.1
6	475	4.89	18.25	19	28.035	28.035	1.341	0.714	18.9	5.5	4.9	474.9	7.4	-11.6	7.2	1.7	8.8
7	494	4.91	16.00	19	17.125	17.125	1.551	0.478	18.9	7.1	5.4	493.8	8.9	-7.3	8.8	0.2	1.0
8	502	5.68	9.09	8	12.545	12.545	0.721	0.160	8.0	7.8	5.6	501.7	9.6	-5.5	9.5	1.0	12.5
9	532	6.79	2.02	30	5.555	5.555	3.243	0.315	29.8	11.0	5.9	531.6	12.5	2.0	12.5	1.3	4.5
10	551	9.07	2.19	19	2.105	2.105	2.620	0.096	18.8	13.7	6.0	550.4	14.9	6.4	14.8	2.3	12.0
11	600	13.53	358.77	49	360.480	0.480	9.601	0.080	48.1	23.3	6.0	598.4	24.0	15.4	23.2	4.5	9.2
12	619	14.73	3.80	19	361.285	1.285	4.637	0.104	18.4	27.9	6.1	616.9	28.6	17.6	27.2	1.7	9.0
13	678	16.17	12.56	59	8.180	8.180	15.558	2.236	56.9	43.5	8.4	673.7	44.3	19.1	41.8	2.7	4.6
14	685	20.51	20.90	7	16.730	16.730	2.109	0.634	6.6	45.6	9.0	680.4	46.4	18.8	44.0	5.1	72.3
15	705	22.48	21.24	20	21.070	21.070	6.838	2.635	18.6	52.4	11.7	698.99	53.7	17.5	51.2	1.97	9.9
16	726	23.34	22.03	21	21.635	21.635	7.599	3.014	19.3	60.0	14.7	718.3	61.8	16.3	59.8	0.9	4.3
17	755	22.91	21.95	29	21.990	21.990	10.561	4.265	26.7	70.6	18.9	745.0	73.1	15.0	71.1	0.4	1.5
18	774	22.53	22.29	19	22.120	22.120	6.798	2.763	17.5	77.4	21.7	762.5	80.3	14.3	78.5	0.4	2.1
19	803	22.45	21.64	29	21.965	21.965	10.288	4.149	26.8	87.7	25.8	789.3	91.4	13.6	89.6	0.3	0.9
20	846	22.74	22.94	43	22.290	22.290	15.287	6.266	39.7	102.9	32.1	829.0	107.8	12.7	106.1	0.6	1.3
21	874	24.10	22.63	28	22.785	22.785	10.261	4.310	25.7	113.2	36.4	854.7	118.9	12.2	117.8	1.4	4.9
22	902	25.72	22.61	28	22.620	22.620	10.886	4.536	25.4	124.1	41.0	880.1	130.7	11.7	129.6	1.6	5.8
23	959	28.39	24.7	57	23.645	23.645	23.750	10.398	50.8	147.8	51.4	930.9	156.5	10.8	155.5	2.8	5.0
24	1014	30.77	24.4	55	24.520	24.520	24.702	11.268	47.8	172.5	62.6	978.7	183.5	10.0	182.6	2.4	4.3
25	1053	31.77	26.3	39	25.310	25.310	18.301	8.655	33.3	190.8	71.3	1012.0	203.7	9.5	202.8	1.4	3.6
26	1110	32.45	26.6	57	26.420	26.420	27.134	13.481	48.3	218.0	84.8	1060.3	233.9	8.7	233.0	0.7	1.2
27	1186	31.98	26.5	76	26.525	26.525	36.251	18.094	64.3	254.2	102.9	1124.6	274.2	8.0	274.0	0.5	0.6
28	1242	31.39	28.83	56	27.650	27.650	26.055	13.650	47.7	280.3	116.5	1172.27	303.5	7.4	303.0	1.37	2.5
29	1300	30.82	30.77	58	29.800	29.800	26.001	14.891	49.7	306.3	131.4	1221.93	333.3	6.8	333.0	1.15	2.0
30	1351	29.74	30.29	51	30.530	30.530	22.150	13.063	44.0	328.4	144.5	1265.97	358.8	6.3	358.8	1.11	2.2
31	1360.00	28.34	31.36	9	30.825	30.825	3.752	2.239	7.9	332.2	146.7	1273.84	363.1	6.2	363.1	1.49	16.6
32	1369.00	27.53	32.46	9	31.910	31.910	3.579	2.229	8.0	335.8	148.9	1281.79	367.3	6.1	367.3	0.96	10.7
33	1380.00	26.10	33.52	11	32.990	32.990	4.162	2.702	9.8	339.9	151.6	1291.61	372.2	6.0	372.2	1.51	13.7
34	1389.00	24.58	34.02	9	33.770	33.770	3.202	2.141	8.1	343.1	153.8	1299.74	376.0	5.9	376.0	1.53	17.1
35	1420.00	22.39	32.15	31	33.085	33.085	10.351	6.744	28.4	353.5	160.5	1328.18	388.2	5.6	388.2	2.31	7.5
36	1448.00	20.27	31.86	28	32.005	32.005	8.637	5.398	26.1	362.1	165.9	1354.26	398.3	5.4	398.3	2.12	7.6
37	1480.00	17.92	32.73	32	32.295	32.295	8.849	5.593	30.2	371.0	171.5	1384.50	408.7	5.2	408.7	2.37	7.4
38	1517.00	16.83	33.72	37	33.225	33.225	9.243	6.054	35.3	380.2	177.6	1419.81	419.6	5.0	419.6	1.13	3.1
39	1555.00	17.44	34.11	38	33.915	33.915	9.291	6.247	36.3	389.5	183.8	1456.12	430.7	4.7	430.7	0.62	1.6
40	1595.00	18.07	34.51	40	34.310	34.310	10.075	6.876	38.1	399.6	190.7	1494.22	442.7	4.5	442.7	0.64	1.6
41	1776.00	19.20	36.2	181	35.355	35.355	47.170	33.467	171.5	446.7	224.1	1665.73	499.8	3.4	499.8	1.25	0.7
42	1805.00	18.56	34.2	29	35.200	35.200	7.668	5.409	27.4	454.4	229.6	1693.17	509.1	3.2	509.1	0.91	3.1
43	1863.00	14.85	33.73	58	33.965	33.965	13.827	9.314	55.6	468.2	238.9	1748.72	525.6	3.0	525.6	3.71	6.4
44	1930.00	13.18	34.15	67	33.940	33.940	13.461	9.059	65.0	481.7	247.9	1813.73	541.8	2.8	541.1	1.67	2.5
45	1995.00	12.58	14.01	65	24.080	24.080	13.228	5.912	63.4	494.9	253.8	1877.09	556.2	2.8	555.5	4.51	6.9
46	2015.00	11.70	14.85	20	14.430	14.430	4.073	1.048	19.6	499.0	254.9	1896.64	560.3	2.9	559.6	0.90	4.5
47	2082.00	11.89	15.38	67	15.115	15.115	13.222	3.571	65.6	512.2	258.5	1962.23	573.7	3.2	572.8	0.22	0.3
48	2209.00	10.58	13.84	127	14.610	14.610	23.944	6.241	124.6	536.2	264.7	2086.79	597.9	3.7	596.7	1.34	1.1
49	2330.00	10.43	12.3	121	13.070	13.070	21.489	4.989	119.0	557.7	269.7	2205.77	619.4	4.2	617.8	0.32	0.3

Figure 10: Complete well trajectory of Menengai well MW-15A.Shaded in green is the sidetrack data

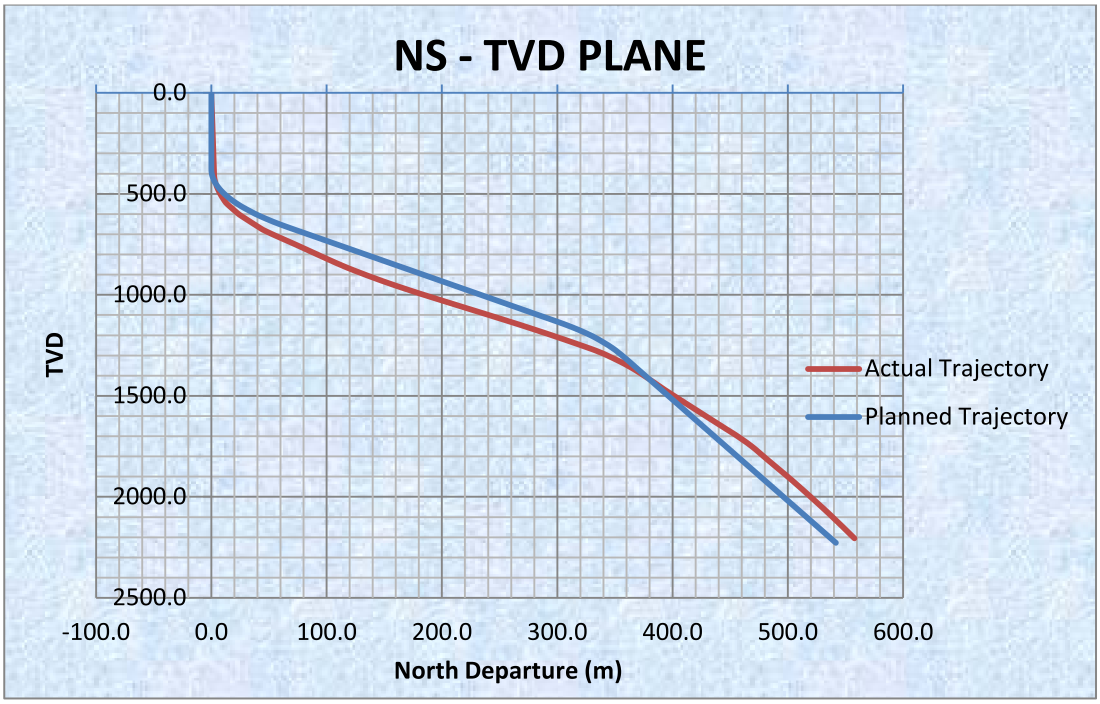

Figure 11: North-South TVD plane

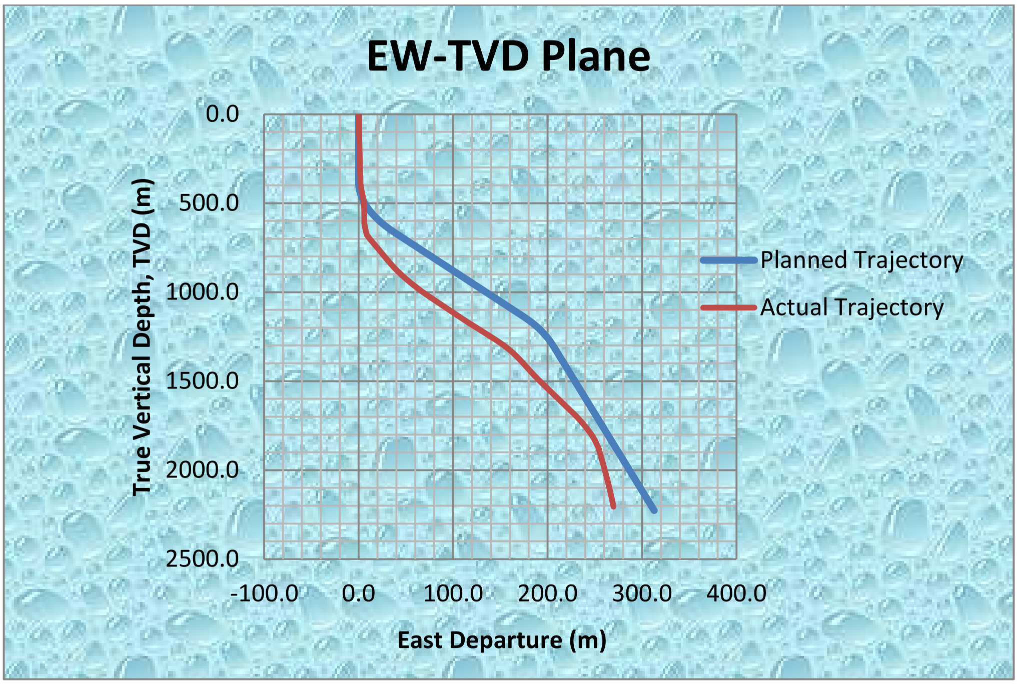

Figure 12: East-West TVD plane

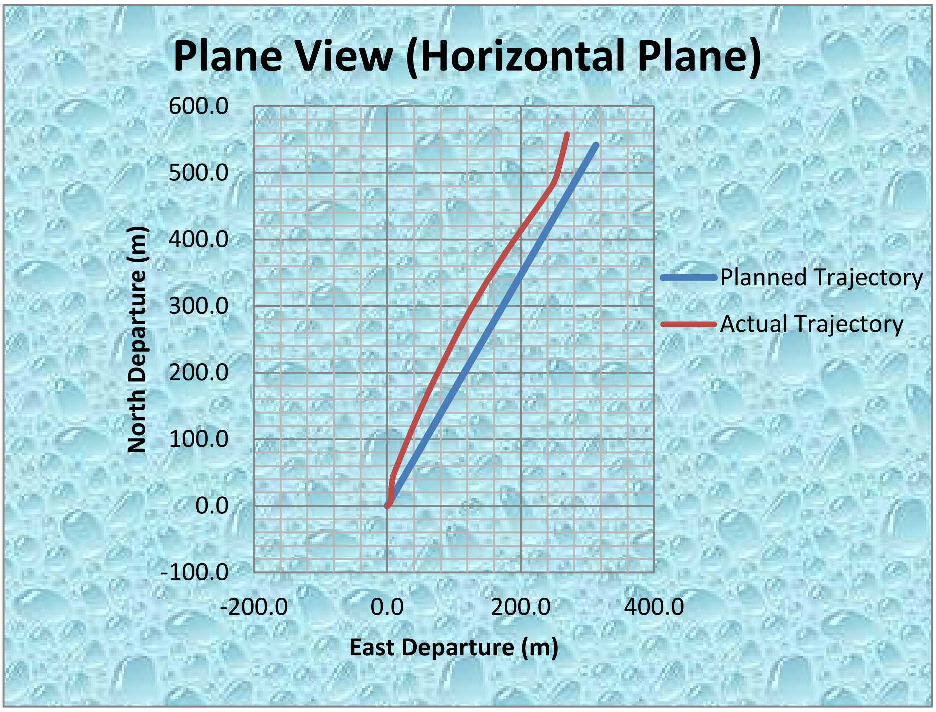

Figure 13: Horizontal plane

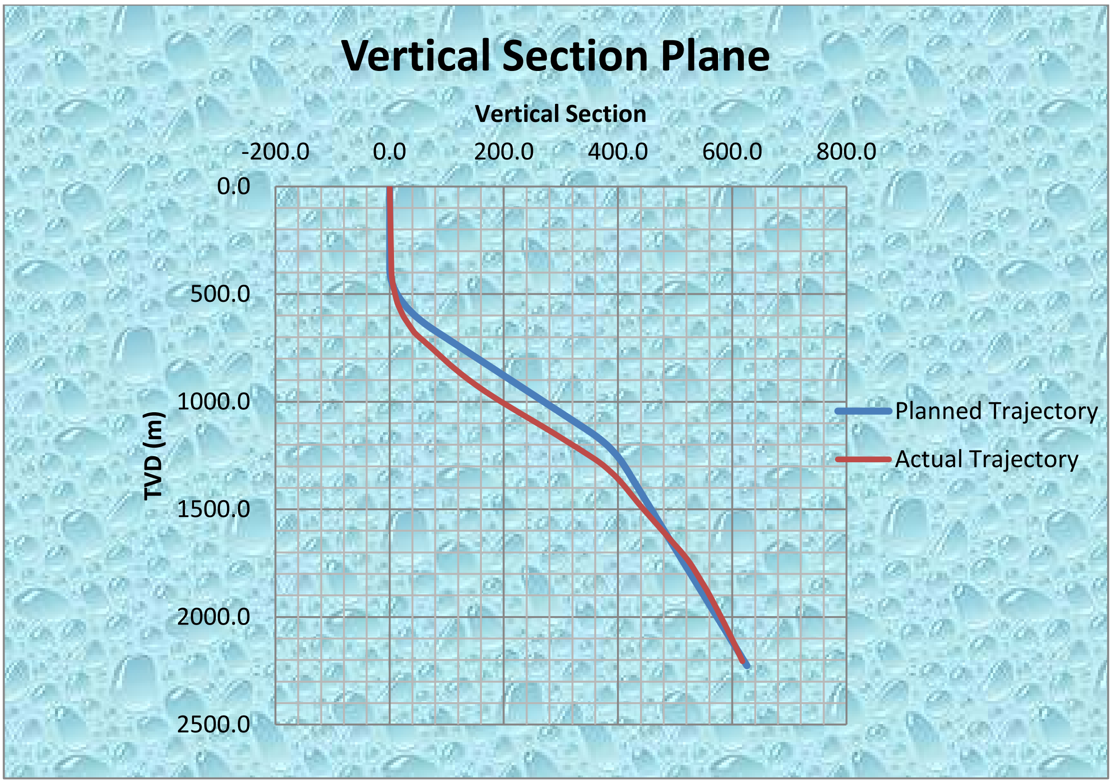

Figure 14: Vertical section plane

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