# SURVEY CALCULATION PROCEDURES
# ON AEGEAN PART OF TURKEY GEOTHERMAL WELLS

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## ABSTRACT

## SURVEY CALCULATION PROCEDURES ON AEGEAN PART OF TURKEY GEOTHERMAL WELLS

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Productive sections of geothermal wells generally exceed hundreds of meters which is substantially longer than that of the oil and gas reservoirs. This brings a flexibility and cost-effective solutions in the application of directional drilling activities during geothermal drilling.

Well trajectory, especially the bottom hole position, is critical for geothermal operators and three parameters (measured depth, inclination, and azimuth) obtained from MWD surveys are used to carry out survey calculations. The minimum curvature method (MCM) is considered the most accurate and the industry standard, although there exist several other calculations.

The novelty of this thesis is to find out the geothermal well directional needs, on Aegean part of Turkey, in terms of survey calculation methods; later on, recommend which method(s) should be utilized at what conditions. In order to address this gap, 5 methods were chosen taking into account popularities and complexities; tangential, balanced tangential, average angle, radius of curvature, and minimum curvature methods. Afterwards, these 5 procedures were applied on 9 drilled pre-selected geothermal wells by using Python programming language. As a result, most divergence from MCM was observed with tangential method, having the easiest calculation formulas, on J type wells with increasing dogleg, inclination, and depth; which is around 5-6 m. Under the usual conditions the geothermal wells drilled in Turkey, it will be maximum of 10 m; even though it is quite satisfactory for most of the operators, average angle method, which is the easiest one after tangential, would also be utilized to have better results. This means that the operators, willing to establish their own directional drilling departments to decrease the costs of directional operations, may utilize a basic software or a spreadsheet, for their each well, depending on average angle, or even tangential method, to eliminate complicated formulas, while calculating the positions of each survey or interpolation depths. An only advanced software may be preferred for operator office.

**Keywords:** Survey Calculations, Directional Drilling, Geothermal, Python

## ÖZ

## ROTA HESAPLAMA YÖNTEMLERİNİN TÜRKİYE’NİN EGE BÖLGESİ’NDEKİ JEOTERMAL KUYULAR ÜZERİNDE UYGULANMASI

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Yüzlerce metrelik üretken kısım kalınlıklarıyla jeotermal rezervuarlar petrol ve doğal gaz rezervuarlarından farklılık göstermektedir. Jeotermal kuyuların çok uzun üretim zonlarına sahip olması yönlü sondaj uygulamaları için esneklik ve uygun maliyetli çözümler getirmektedir.

Bir sondaj kuyusunun gerçekleşmiş rotası ve özellikle kuyu dibi pozisyonu, jeotermal şirketleri için çok önemlidir. MWD ölçümlerinden elde edilen 3 parametre (ölçülen derinlik, açı ve yön), rota hesaplama yöntemlerinde kullanılmaktadır. Pek çok farklı yöntem olmasına rağmen; en az eğri yöntemi, en hassas olarak kabul edilmekte ve endüstri standardı olarak kullanılmaktadır.

Bu tezin getirmiş olduğu yenilik, Türkiye’nin Ege Bölgesi’ndeki jeotermal kuyuların yönlü sondaj ihtiyaçlarını, rota hesaplama yöntemleri açısından belirlemek; sonrasında, farklı yöntemlerin hangi şartlar altında kullanılması konusunda önerilerde bulunmaktır. Bu doğrultuda, beş farklı rota hesaplama yöntemi, kullanılma sıklıkları ve hesap karmaşaları dikkate alınarak seçilmiştir; bu yöntemler tanjant, dengeli tanjant, ortalama açı, eğri yarı çapı ve en az eğri yöntemleridir. Daha sonra, bu yöntemler, 9 adet önceden seçilmiş ve kazılmış jeotermal sondaj kuyuları üzerinde, Python programlama dili kullanılarak uygulanmıştır. Sonuç olarak, en az eğri yönteminden maksimum ayrışma, tanjant yönteminin (en kolay hesaplama formüllerine sahip teknik) J tipi kuyu uygulamalarında artan dogleg, açı ve derinlikle gözlenmiş olup ayrışma 5-6 m civarındadır. Türkiye'deki jeotermal kuyuların kazıldığı normal koşullarda, bu ayrışma en fazla 10 m'ye kadar çıkabilir. Bu durum jeotermal şirketler için yeterli olmasına rağmen, daha iyi sonuçlar için ortalama açı yöntemi (tanjanttan sonra en kolay yöntem) kullanılabilir. Elde edilen sonuçlar, yönlü sondaj maliyetlerini düşürmek isteyerek kendi yönlü sondaj bölümlerini kurmak isteyen şirketlerin, her kuyusu için ortalama açı (ve hatta tanjant) yöntemine dayalı basit bir yazılım veya hesap tablosu kullanabileceğini göstermiştir. Böylelikle, kuyuların rotası veya ara derinlikler hesaplanırken karmaşık formüllerden kaçınılacak, ileri seviye yazılımların sahada kullanılmasından vazgeçilip sadece ana ofiste kullanımı yeterli olabilecektir.

**Anahtar kelimeler:** Survey Hesaplamaları, Yönlü Sondaj, Jeotermal, Python

*to my beloved family*

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## NOMENCLATURE

| | |
|---|---|
| AA | Average Angle Method |
| AZ | Azimuth, degrees |
| $AZ_1$ | Azimuth at 1st survey station, degrees |
| $AZ_2$ | Azimuth at 2nd survey station, degrees |
| BHA | Bottom Hole Assembly |
| BUR | Build Up Rate |
| BT | Balanced Tangential Method |
| CL | Course Length, meters |
| DKO | Deep Kick Off |
| DLS | Dogleg Severity, degree/30m |
| E | Eastern Coordinate, meters |
| EOR | Enhanced Oil Recovery |
| ERD | Extended Reach Drilling |
| I / Inc | Inclination, degrees |
| $I_1$ | Inclination at 1st survey station, degrees |
| $I_2$ | Inclination at 2nd survey station, degrees |
| KOP | Kick-Off Point, meters |
| Local N | Local Northern Coordinate, meters |

| | |
|---|---|
| Local S | Local Southern Coordinate, meters |
| Local E | Local Eastern Coordinate, meters |
| Local W | Local Western Coordinate, meters |
| MCM | Minimum Curvature Method |
| MD | Measured Depth, meters |
| MWD | Measurement While Drilling |
| N | Northern Coordinate, meters |
| RCM | Radius of Curvature Method |
| ROP | Rate of Penetration, m/hr |
| S | Southern Coordinate, meters |
| T | Tangential Method |
| TD | Total Depth, meters |
| TF | Tool Face, degrees |
| TVD | True Vertical Depth, meters |
| VS | Vertical Section, meters |
| VSA | Vertical Section Azimuth, degrees |
| W | Western Coordinate, meters |
| WOB | Weight on Bit, tons |

# CHAPTER 1

# INTRODUCTION

Directional drilling can be defined as the process of intentionally directing a well throughout some predetermined path to hit one or more specified target (Bourgoyne Jr. et al., 1991). In the years of 1800s, operator companies drilled oil & gas wells supposing that they were vertical or at least near vertical. The years were early 1920s, the industry has just been aware of the drilled wells deviates from vertical, and basic surveying equipment was developed. Then, the companies realized that they drilled some wells around 50° of inclination unintentionally. It could be the result of majorly formation dips, faults, beddings, bending properties of the drill string, WOB, flow rate, rotary speed. Thereafter, the first intentionally directional wells were drilled in the late 1920s (IADC, 2015).

Until the present day, the directional drilling has been utilized for many purposes. It consists of drilling horizontal wells, multilateral wells, sidetracks, relief wells, vertical wells, sealed sand zones, inaccessible locations, faults, salt domes, ERD wells (PetroSkills, 2019). In oil & gas wells, the reservoirs are mostly sedimentary rocks; and, the reservoir thickness can be just a few meters. Hence, the operator companies should be highly sensitive about staying in the target zone as much as possible. On the other hand, for geothermal wells, the production formations are hot (usually between 160 to 300°C), hard, abrasive, and most significantly fractured. It includes basalt, granite, granodiorite, greywacke, rhyolite, volcanic tuff, and quartzite. The formations have dual porosity characteristics; namely matrix and fracture porosity & permeability. However, the high production geothermal wells usually have the high fracture permeabilities (Finger & Blankenship, 2010). The main point of view, to directional drilling, here is that the geothermal operator companies can be more flexible comparing with oil & gas operator companies since the geothermal reservoirs having high fractures are more convenient to be reached, especially in comparison with the oil reservoirs having very low thickness. Thus, understanding the geothermal directional needs, and applying them in an optimized way, may lead us cost-effective solutions.

Determining the coordinates of a well, is not like using GPS (global positioning system) as in our daily lives. The main reason is that GPS, which is a radio navigation system, is not quite accurate and is affected by obstructions easily. In the drilling industry, the normal procedure is to calculate the well path or trajectory from three parameters; MD (measured depth), inclination, and azimuth. MD is a preselected value; inclination and azimuth are measured by some type of surveying instrument, usually and most basically with an MWD tool. For calculating well trajectory, there are lots of methods, which is listed in Literature Review chapter.

In the literature, there are various studies comparing these directional survey calculation techniques. And currently, the industry standard is minimum curvature method (MCM) since considered most accurate. However, there should be studies; initially, finding the needs of a specific drilling field, and then suggesting an optimum method(s). This is needed for cost-effective solutions because; although some of the methods are easy enough to make manual calculations, some requires advanced software solutions.

The novelty of this thesis is to specify the geothermal well directional needs, on Aegean part of Turkey, in terms of survey calculation procedures; then, recommend which method(s) should be used at what conditions. For this aim, 5 methods were chosen in terms of popularities and complexities of the related formulas; tangential, balanced tangential, average angle, radius of curvature, and minimum curvature methods. Then, these 5 techniques were applied on 9 actual pre-selected geothermal wells by using Python programming language. Finally, the interpretations and suggestions were made.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Fundamental Definitions

As a first step, fundamental definitions regarding directional drilling are explained below, in order to understand further subjects better. Regarding this part, the sources of (Athumani, 2018; Dr. Stoner & Reyes, 2019; Geomagnetism Canada, 2019; Schlumberger, 2019) are utilized.

**3D Directional Well:** A well containing azimuthal turn for one or more sections.

**Actual Wellpath:** An optimum estimate of where a wellpath exits in 3D space, with use of survey calculation methods, after or during drilling a well.

**Azimuth (Direction):** The angle of the vertical projection of the interested line onto a horizontal surface, relative to true north or magnetic north. It is measured in horizontal plane with clockwise from the north.

**BHA (Bottom Hole Assembly):** The lower part of the total drill string, consisting of bit, mud motor, stabilizer, measurement while drilling tool (MWD), drill collars (DC), heavy weight drill pipes (HWDP), and jar. The main purpose of BHA is to provide weight to the bit, and directional control.

**Build:** It can refer to increase the wellbore inclination or that segment of the well; the opposite of the term drop.

**Closure:** It represents the shortest straight line from the projected surface location to the last survey station in horizontal plane. While defining closure, the azimuth or direction must be specified to point out the last survey station exactly.

**Convergence (Grid Convergence):** It is the direction of Grid North, measured from True North.

**Course Length:** The difference in depths of two consecutive surveys, usually calculated in meters of foot.

**Curve:** The section of a hole connecting the vertical segment to the landing point.

**Declination (Magnetic Declination):** It is the direction of Magnetic North, measured from True North.

**Departure (Horizontal Deviation):** The horizontal distance measured from the surface location to a bottom hole point. It is independent of vertical depth.

For horizontal wells, the departure can be defined as the displacement from vertical section to the beginning of horizontal section. And horizontal deviation or horizontal displacement is defined as the sum of departure and horizontal section length.

**Deviation:** A quantitative definition to understand how a directional well trajectory differs from the planned one; which ties mathematically the planned wellpath to actual wellpath.

**Directional Difference:** It refers to the angle between the target direction and the closure.

**Directional Survey:** Geometric information regarding the well, which is calculated with directional survey data and a directional survey calculation technique.

**Directional Survey Data:** The raw data of inclination and azimuth at a predetermined depth or directional survey station.

**Directional Survey Station:** A predetermined depth where hole inclination and azimuth data measured.

**Dogleg:** Total curvature of a wellpath between two consecutive survey stations; expressed in degrees. It is the combination of changes in inclination and azimuth. It can also refer to sudden changes in hole inclination or azimuth, which can result in severe hole problems.

**Dogleg Severity:** A normalized calculation of total curvature of a wellpath between two consecutive survey stations; usually expressed in degrees/30m or degrees/100ft. It is the combination of changes in inclination and azimuth.

**Drift Angle:** Inclination of a well from vertical.

**Drop:** It can refer to decrease the wellbore inclination or that segment of the well; the opposite of the term build.

**Geosteering:** Drilling a horizontal well located within or near desired layers of formation. Or it can refer to interpretation of stratigraphic depth location of a well in part by understanding the structure of local geometric bedding, while or after drilling.

**Grid North:** It is the north direction of grid lines on a map projection. It always points upwards comparing with True and Magnetic Norths. Although we are drilling wells on a curved surface, due to surface shape of our planet, it is assumed that the surface is flat while calculating coordinates of a wellpath. Because of this discrepancy, corrections are applied to raw measured survey data.

**Horizontal Drilling:** Drilling a well whose inclination exceeds 80°. There are wells with inclination of more than 110°.

**Inclination:** The angle of a wellbore deviating from the vertical line or Earth's gravity line. 0° of inclination refer to vertical well; and 90° of inclination refer to horizontal well. If the inclination is more than 90°, then the term "drilling up" comes into play.

**Kick-Off Point (KOP):** The measured depth where the well begins deviating from the vertical, on purpose.

**Landing Point:** The measured depth where wellbore inclination will stay constant and the horizontal or lateral section will begin.

**Local Coordinates:** Its reference point is usually the rig kelly bushing (KB). Cartesian coordinates of North, East, and TVD are 0 at measured depth of 0.

**Magnetic North:** Due to the structure of our planet, there is an enormous magnetic core, which provides a good reference for our compasses. The north pole of this magnetic field is called as Magnetic North. And all magnetic type instruments are referenced to Magnetic North. But, the calculated coordinates of a wellpath is always referenced to Grid or True North.

**Map View (Plan View):** A projection of a well path onto a horizontal plane, displaying cartesian coordinates North, South, East, and West.

**Measured Depth:** The measured length of a wellbore; which is always greater than True Vertical Depth (TVD), if the well is not perfectly vertical as in theory.

**Measurement While Drilling (MWD):** It usually refers to the downhole tool, which primarily measure the hole inclination and azimuth. It can also measure other data, if desired, such as temperature, and pressure.

**Nudging:** If there are offset wellbores around the reference well, creating magnetic interference and anti-collision risks; the reference well is deflected or nudged to pass hazard sections safely and then steered back to vertical. This method is called as nudging, and often utilized for top hole sections.

**Planned Wellpath:** An optimum estimate of where a wellpath exits in 3D space, with use of survey calculation methods, in plan phase of a well.

**Rate of Penetration (ROP):** It refers to drilling speed; usually expressed in m/hr or ft/hr.

**Rotary Steerable System (RSS):** A directional drilling system, which differs from the conventional mud motor & MWD assembly in not interrupting the drill string rotation to steer the well.

**Sidetracking:** Drilling a secondary wellbore from an existing wellbore. Sometimes it can be done unintentionally. The main aim of this operation can be avoiding a well collapse, instable zone, section containing unretrieved fish; initiating multilateral drilling. Additionally, sometimes vertical pilot holes are drilled to justify reservoir TVD, afterwards sidetrack can be done to maximize reservoir exposure. Also, if expected target is not reached, sidetrack can be performed.

**Total Depth (TD):** The total measured depth of a well.

**Toolface:** There are two types; high-side (gravity) toolface, and magnetic toolface.

Gravity toolface is the angle of MWD tool (or any other survey instrument) within the wellbore measured clockwise relative to up and in the perpendicular plane according to wellbore axis. 4 essential gravity toolface angles are listed below.

High-Side (Max Build) : 0°

Max Right : 90°

Low-Side (Max Drop) : 180°

Max Left : 270°

Magnetic toolface is the angle of MWD tool (or any other survey instrument) within the wellbore measured clockwise relative to magnetic north and in the perpendicular plane according to wellbore axis. It can be corrected to true or grid north, if desired. 4 essential magnetic toolface angles are listed below.

North : 0°

East : 90°

South : 180°

West : 270°

**True (Geographic) North:** It is the direction of geographic north representing the Earth's axis of rotation. It is the same direction of the meridians on a map.

**True Vertical Depth (TVD):** The vertical distance of a well from the surface, usually kelly bushing, to the bottom-hole point of interest.

**Turn:** Intentionally drilling or steering a well to change its direction or azimuth towards right or left.

**Wellpath (Trajectory):** It can refer to actual or planned wellpath usually expressed in cartesian coordinates, and in angular orientations.

**Vertical Section (VS):** Horizontal departure or distance of a well projected onto a vertical plane of predetermined direction or azimuth. The direction can coincide with the plane defined by surface to Total Depth or be the dominant direction of the lateral section of the well.

**Vertical Section Azimuth (Section Azimuth):** It refers to the angle relative to North, expressing a vertical plane onto which horizontal distance is projected to calculate Vertical Section.

**Vertical Section View:** Vertical Section vs True Vertical Depth plot of a well.

**Weight on Bit (WOB):** The amount of weight applied on the bit during drilling. Note that only a small portion of the total weight of the drill string is applied as WOB; other part is in tension.

Please see the following Figure 2.1, Figure 2.2, and Figure 2.3 to visually see the directional drilling fundamental terms.

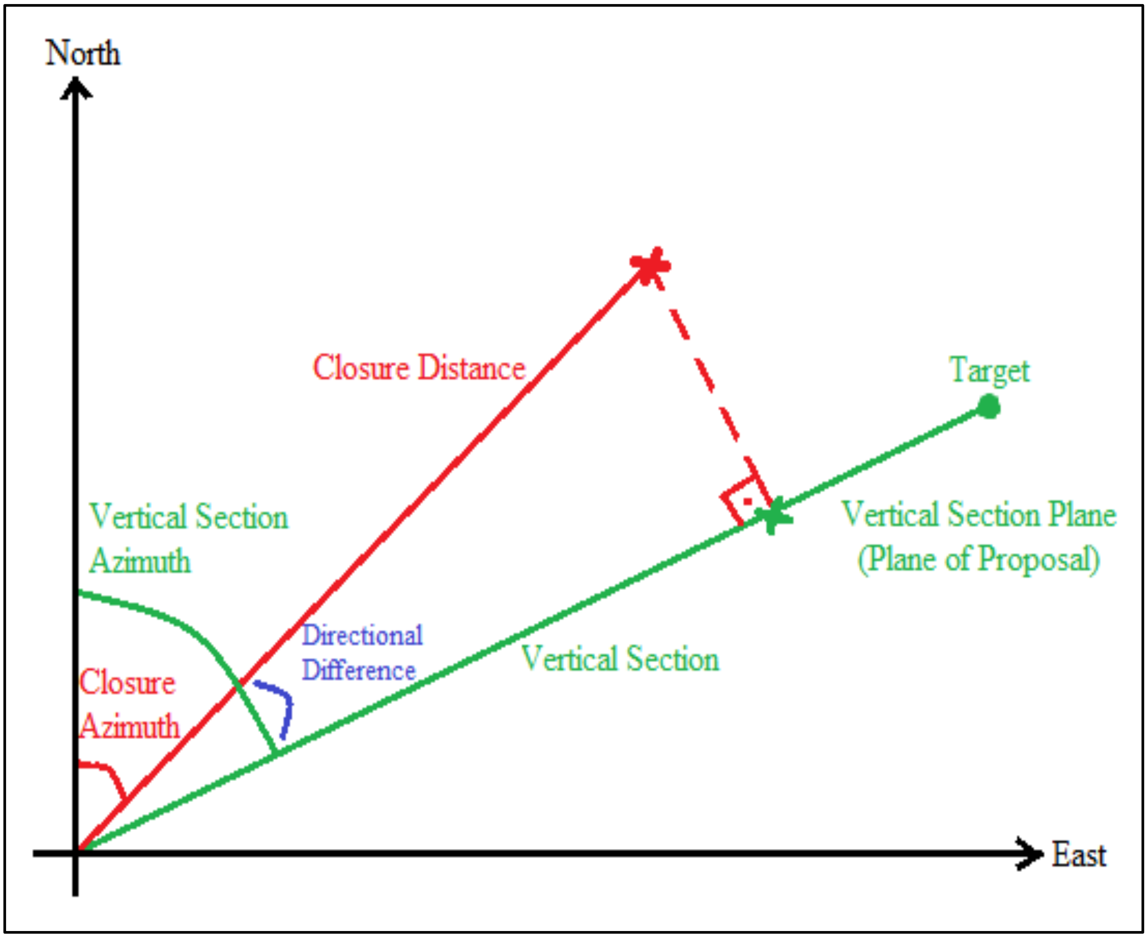


**Figure 2.1** Vertical Section vs. Closure Distance

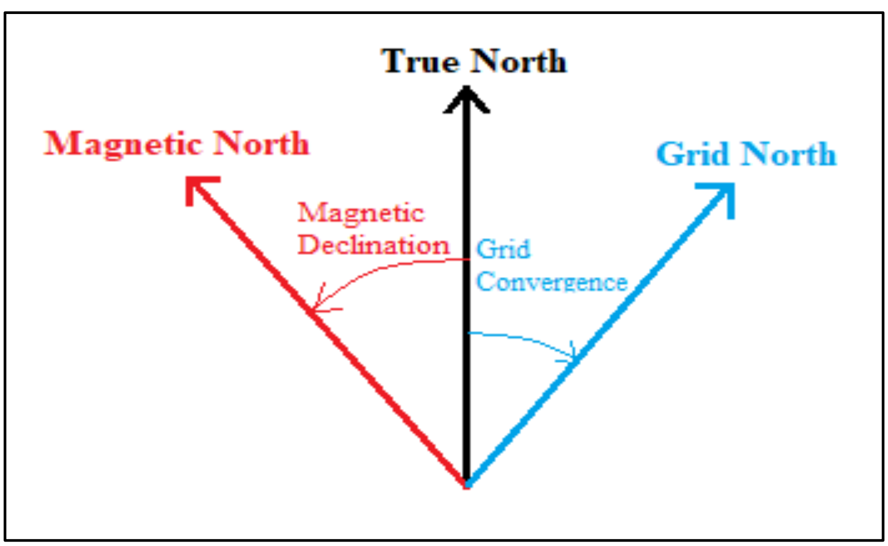


**Figure 2.2** Magnetic Declination vs. Grid Convergence

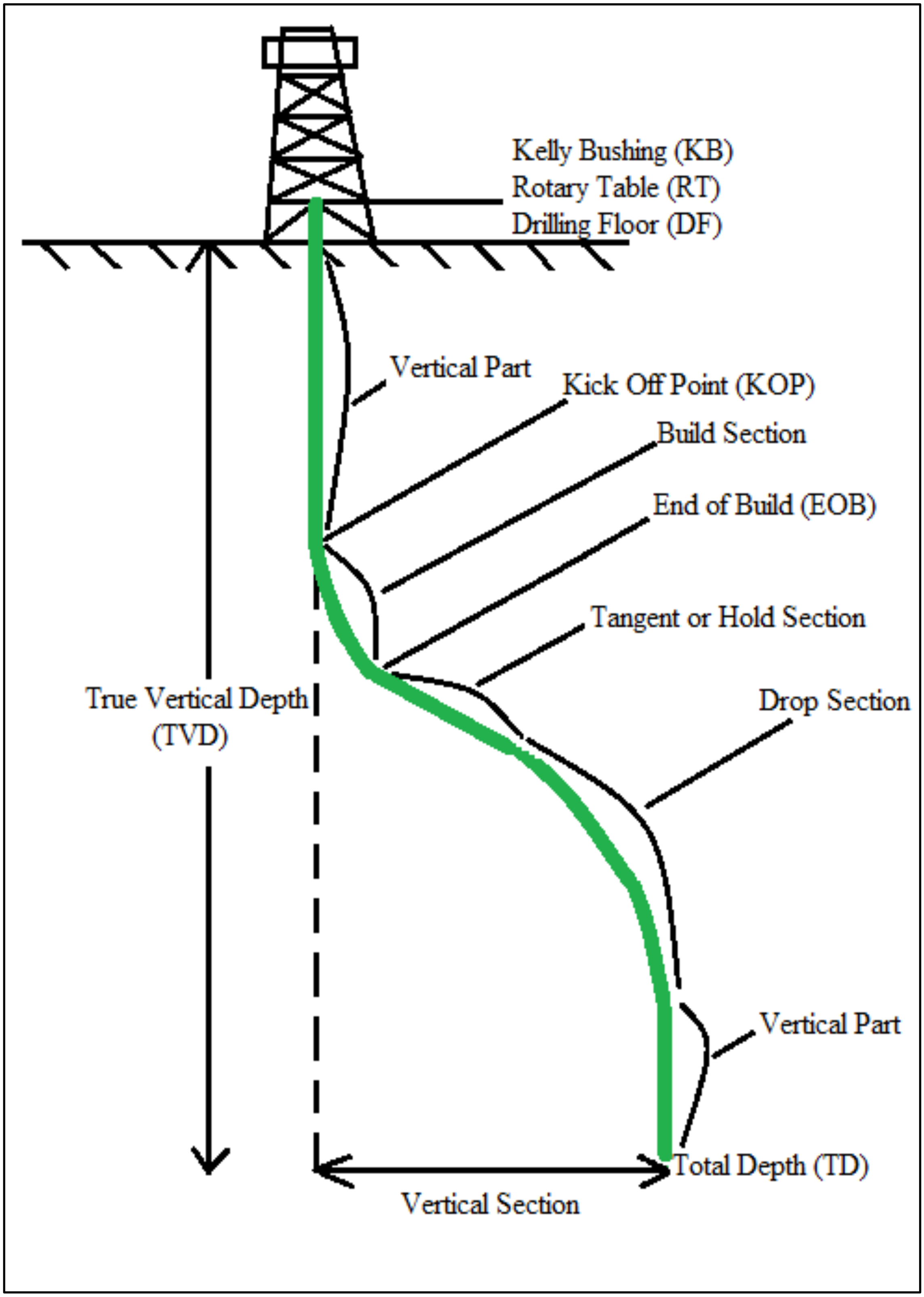


**Figure 2.3** Fundamental Terms

## 2.2 Well Profile Types

To specify a well profile, initially surface location of rig and bottom hole location of target, i.e. TVD and rectangular coordinates, must be known. Only after that it is possible to calculate a profile that fits inside these points (Rabia, 2001). There are basically 4 types of directional well profiles. Most of the wells can be categorized within these types. However, there are some exceptional cases, which cannot be classified. They are frequently called "Designer Wells". They have several bottom hole targets, which are spaced widely. They need significant changes in direction with changing inclination, and requires high engineering (Carden & Grace, 2007). The basic 4 types of directional well profiles are explained below in detail.

But before further detail about profiles, please see the following lists for some rules of thumbs related with directional well planning (Kuru, 2014):

- Type I is cheaper and more feasible comparing with other types.
- If selection of KOP is high, it will require more directional footage and job.
- Optimum slant angles are in the range of 15-40°.
- Directional control is not easy for angles less than 15°.
- If slant angle is more than 40°, problems can be expected about running desired tools.
- If slant angle is more than 60°, very time-consuming methods are necessary about running some tools.
- While build gradients of 10°/30m can be tolerable in shallow holes; more than 3°/30m of build rates can be acute problems in deep wells.

### 2.2.1 Type-I (J Type, Slant Type or Build and Hold)

This type of well can also be referred to as J Type; the trajectory is consisted of build and hold sections, as seen in Figure 2.4 below. The well is drilled vertical to some shallow depth. After that, it is kicked off from vertical until a maximum angle required as per plan smoothly, through the desired direction or azimuth. Then, if desired, casing can be run and cemented. Thereafter, the drilling continues up to the pre-planned target by keeping or holding the inclination and azimuth steady. One or more casing strings can be run if desired (Carden & Grace, 2007).

J type well profiles usually be utilized for relatively shallow wells containing one producing zones (Carden & Grace, 2007). Also, they are used for cases of large horizontal displacements are desirable at relatively shallow target depths. Because there are no major changes regarding inclination and azimuth after build section is performed, less drilling problems are experienced such as key seats, dogleg etc. comparing with other types (Dipl.-Ing. Prassl, 2005).

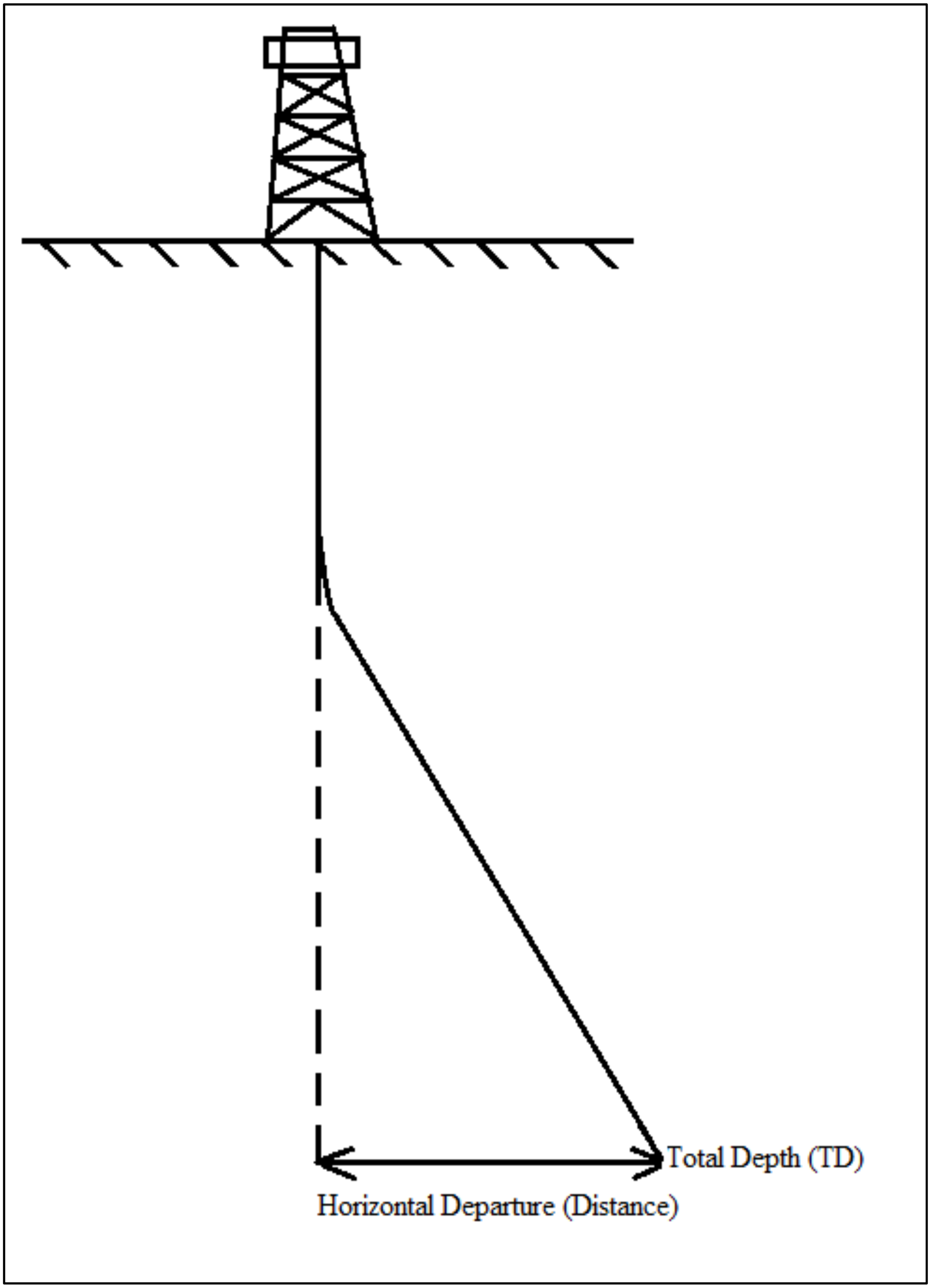


**Figure 2.4** Type-I Well Profile

### 2.2.2 Type-II (S Type)

This type is usually called as S Type, due to its shape, as seen in Figure 2.5 below. As for the beginning, it is similar to Type I well profiles, since the well is drilled up to a shallow depth vertically and then deflected until a required angle through a direction, and frequently surface casing is run through the curve section. Again, the inclination and azimuth are kept constant until a desired depth and horizontal departure or displacement. Thereafter, the inclination is dropped to make the well vertical or near vertical. After this process, intermediate casing is usually run. Then, vertical drilling continues until reaching the target. S Type wells are utilized if there are generally multiple pay zones (Carden & Grace, 2007).

Additionally, after the well is returned to vertical, directional drilling service may be released if there is no strong formation tendency, and ROP is satisfactory without a mud motor or RSS. If it is possible to release directional service, it can reduce total cost because most of the directional job is done in the shallower sections of the well, where trips are easier and ROPs are higher (Carden & Grace, 2007). However, this is not the case usually for geothermal wells as metamorphic section quite hard to drill and has strong tendency to orient the well any other direction.

S Type wells requires more considerations since the angle change will be deeper, where formations are usually more problematic and harder which makes directional control difficult. Also, azimuth control can be another issue because angle dropping BHAs needs fewer stabilizers. Additionally, if a wellbore has a high angle to return vertical and last vertical section is longer, it can result in keyseating problems. Due to the challenges of S Type wells, it will usually take 10-20 % more drilling times, in comparison with J Type wells (Adams & Charrier, 1985). Please also note that S Type wells create more torque and drag for the same horizontal displacement. Hence, these disadvantages should always be kept in mind prior to choosing an appropriate well profile.

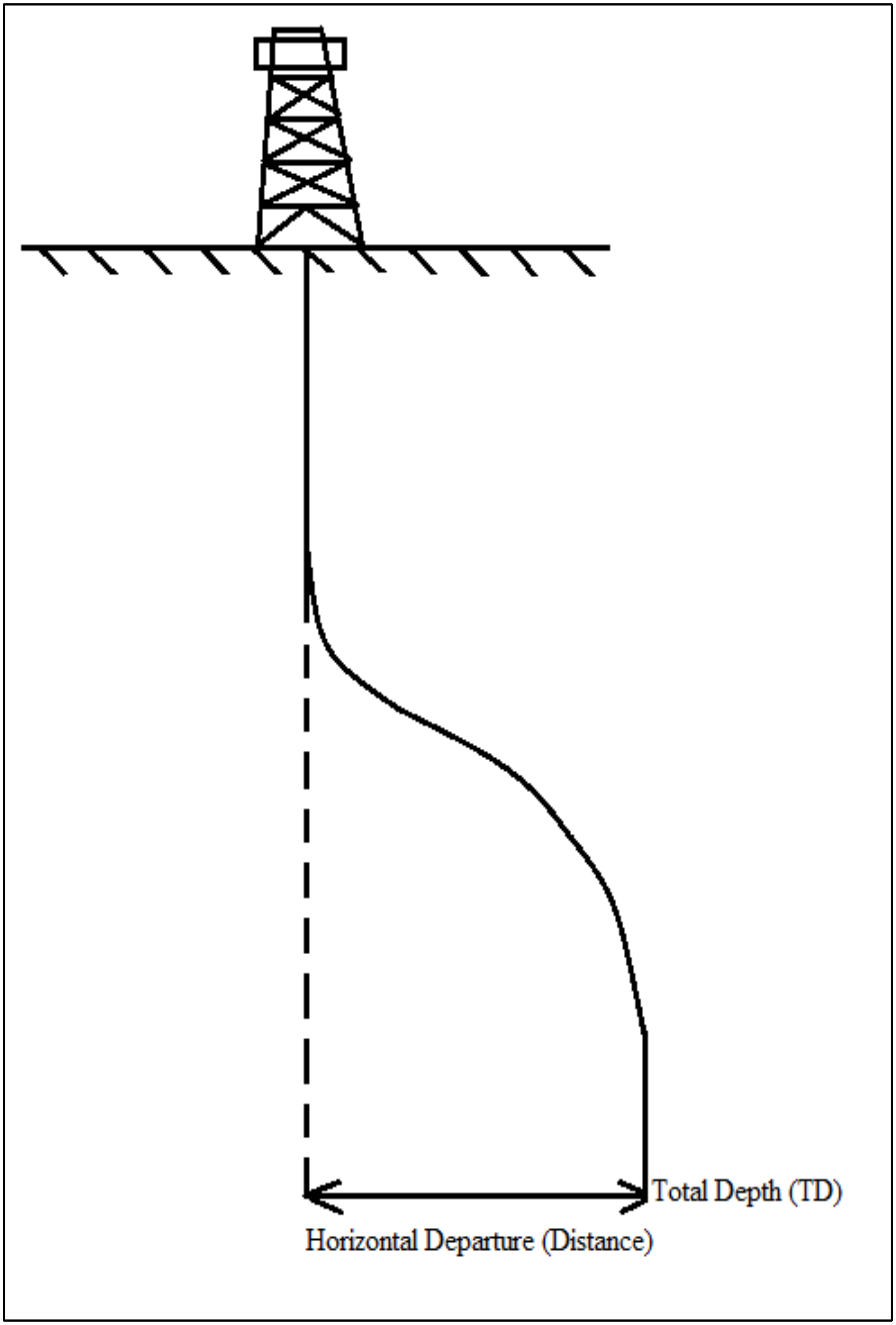


**Figure 2.5** Type-II Well Profile

### 2.2.3 Type-III (Continuous Build or Deep Kick Off)

This type is similar to Type I profile, except for the kick-off point (KOP) is much deeper, and so surface casing is run before KOP. After deflecting the well, the inclination is continuously increased intentionally through desired interval. That is to say, horizontal displacements are low, and inclinations are high usually, as can be visualized in Figure 2.6 below. Although it is not utilized frequently; the purpose is generally hit multiple sand zones, faults, salt domes, and stratigraphic tests (Carden & Grace, 2007). It can also be utilized for old fields to sidetrack from the original wellbore, which is stopped to produce oil economically. Since deviated section is placed deeper in Type-III wells, tripping type is higher in comparison with other types and the casing usually is not run for curved section (Athumani, 2018). Please note that mostly J type refers to Type-I; sometimes it is used for Type-III wells.

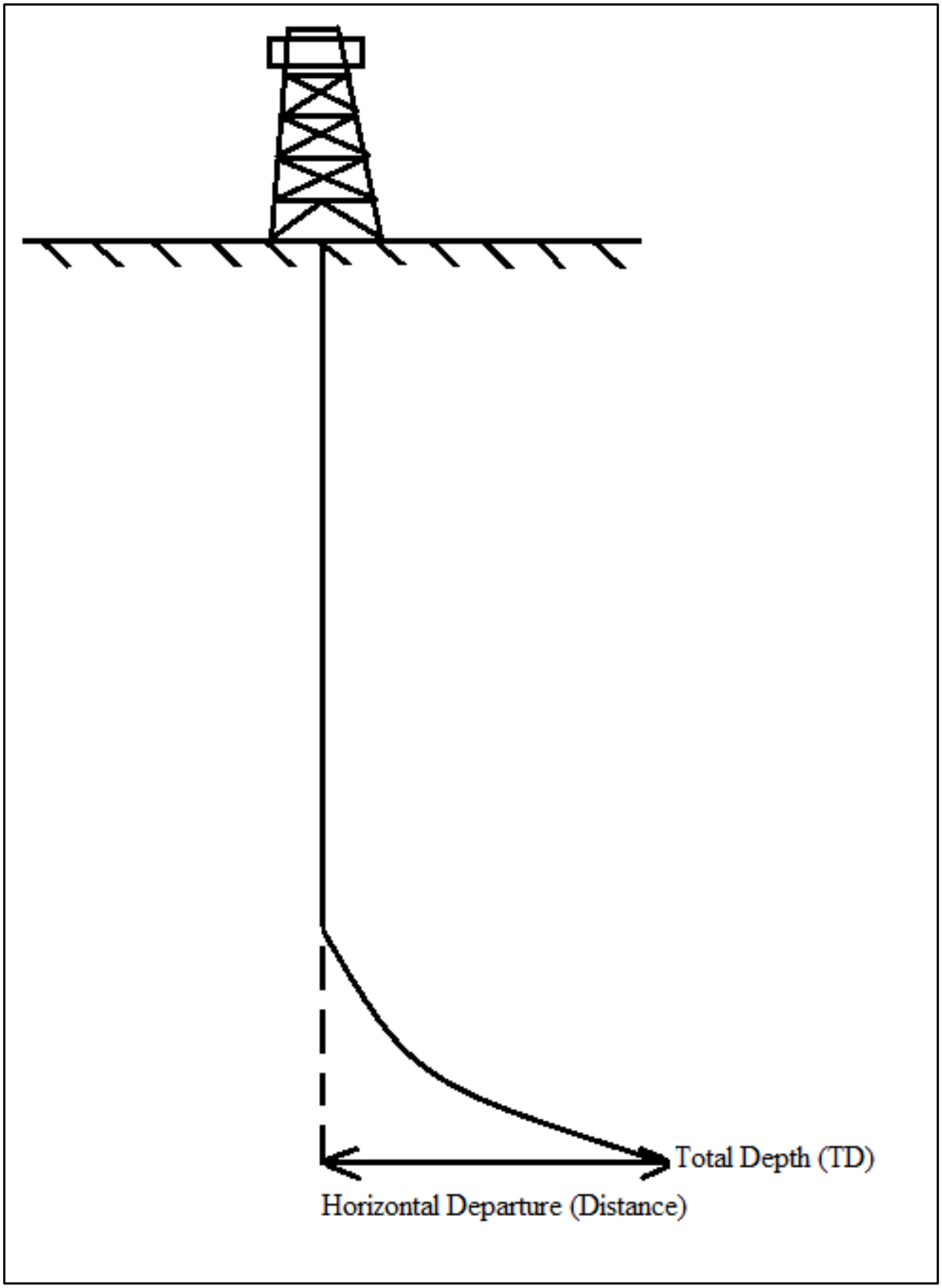


**Figure 2.6** Type-III Well Profile

### 2.2.4 Type-IV (Horizontal)

This type refers to horizontal or ERD wells (Extended Reach Drilling wells). The design can change dramatically. Horizontal wells have high inclinations, more than 80°, and large horizontal displacements (Carden & Grace, 2007). The wells having inclination of greater than 90°, are drilled sometimes to produce oil & gas placed in the upper part of the related formation. Additionally, in that case, gravity increases production. But, the main purpose to drill horizontal wells, is to increase reservoir exposure of the well. They can also be drilled for EOR, like waterflooding, and for control of water & gas. For horizontal wells, the departure can be explained as the displacement from vertical to the beginning of horizontal section. And horizontal deviation or horizontal displacement can be defined as the sum of departure and horizontal or lateral section (Mitchell & Miska, 2011). Please see following Figure 2.7 for an example horizontal well diagram.

Although horizontal wells are drilled to develop reservoir performance by deploying a long wellbore section through the reservoir, ERD wells are drilled to intersect a target bottom hole point with a high angle. Before 1985, there was not much horizontal drilling operations. The Austin Chalk Play in the U.S. has created a boom in horizontal drilling activity. Then, horizontal drilling is taken into account as an effective reservoir development method (Chen, 2006).

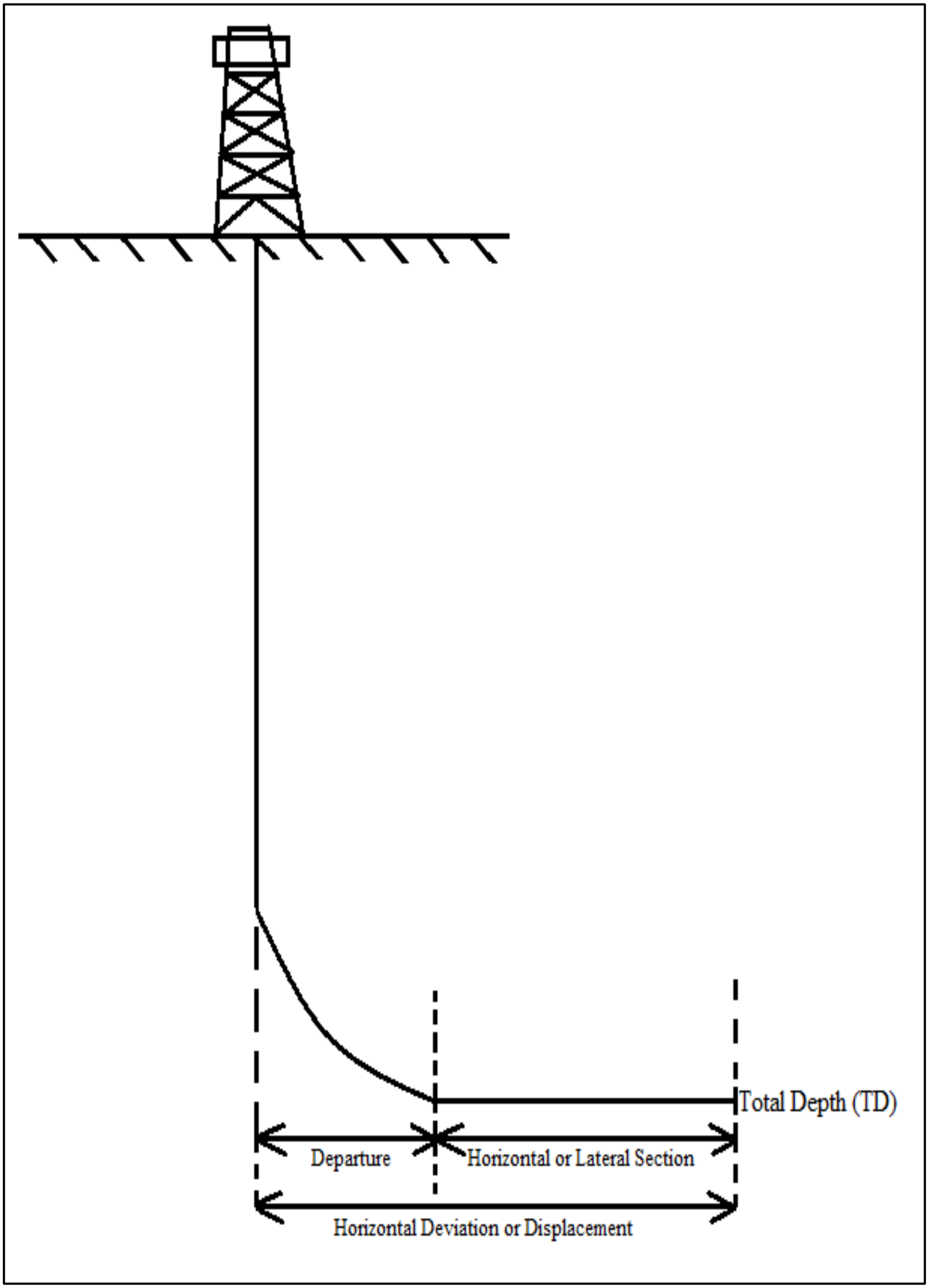


**Figure 2.7** Type-IV Well Profile

## 2.3 Directional Surveying

During drilling of a directional well, by the help of a surveying instrument, hole inclinations and directions are measured for the predetermined depths. These data are then utilized as input to calculate well trajectory, in order to finally make a comparison with the planned well trajectory. If then, for instance, the well is getting away from the plan, deviation control procedures are conducted to redirect the well through the required or planned direction (Mian, 1992). For deviation control, if conventional motor & MWD system is in play, sliding will be done; or sometimes just changing drilling parameters can be a solution. Otherwise, if there is RSS, required downlink commands would be utilized.

The directional surveys are carried out by single or multi-shot magnetic instruments, gyroscopic instruments, and various MWD tools. Thereafter, if magnetic type is used, the measurements must be corrected for True North. The correction angle is called as declination. It can be defined as the angle between Magnetic North, which is the magnetic type instrument referenced to, and True North. Additionally, another type of correction can be in the question, which is called as grid convergence, which is the angle between True North and Grid North (Jamieson, 2012). If gyroscope is used, they must be corrected for drift. Further details about these corrections are beyond the scope of this thesis. Whenever the survey measurements, i.e. inclination and azimuth, are corrected, the wellbore trajectory can be calculated (Mian, 1992).

## 2.4 Directional Survey Calculations

A conventional survey is composed of measured depth (MD), inclination (I), and azimuth (AZ). Throughout the years, within directional drilling industry, various survey calculations methods have been utilized in order to understand the real position of a well from raw measurements of these three parameters.

The list of popular methods in the literature is provided below (Dipl.-Ing. Prassl, 2005; Dr. Mitchell, 1995; Hassan, 2012):

1. Acceleration method
2. Average angle method (J.E. Edison, in 1957)
3. Angle-averaging method
4. Backward station method
5. Balanced tangential method (J.E. Walstrom, in 1971)
6. Circular arc method (W.A. Zaremba, in 1973)
7. Compensated acceleration method
8. Constant curvature method (Xiushan Liu, in 1991)
9. Mercury method
10. Minimum curvature method (MCM; Mason, C.M. and Taylor, H.L. in 1971)
11. Quadratic method
12. Radius of curvature method (RCM; G.J. Wilson, in 1968)
13. Secant method
14. Sectional method (Oblique circular arc; Roy Long’s method)
15. Tangential method
16. Terminal angle method
17. Trapezoidal method
18. Vector averaging method

By the help of these methods, N-S (North-South), E-W (East-West), and TVD (True Vertical Depth) coordinates of a well is determined. Thereafter, they are plotted for visualization and better understanding. In this way, the rig personnel, especially DDs (Directional Drillers), can follow the progress of the well and make required changes to be in line with plan and hit desired target(s). The five mostly used, and also the selected ones for our application, namely; tangential, balanced tangential, average angle, radius of curvature, and minimum curvature methods have been introduced in this section to understand the theoretical backgrounds of each technique.

### 2.4.1 Directional Survey Calculation Methods

#### 2.4.1.1 Tangential Method

This is the most basic method of calculating the well trajectory, which has been utilized many years. The person or group who introduced the tangential method to the industry is unknown (Bourgoyne Jr. et al., 1991).

The calculation assumes that the well path starts from the first survey station point A, as in Figure 2.8, and continues with inclination ($I_2$) and azimuth ($AZ_2$) values of second survey station point B as a tangent or straight line. That is to say, inclination ($I_1$) and azimuth ($AZ_1$) values of first survey station are not considered at all.

As a result of this methodology, it is obvious that if inclination increases throughout a well profile, horizontal departure will be larger than normal and vertical displacement will be smaller than normal. If the well inclination decreases, the situation is vice versa. Additionally, North-South and East-West coordinates are calculated by assuming that the direction of horizontal departure are the same with that of lower survey station azimuth ($AZ_2$). Thus, this situations increase errors (Carden & Grace, 2007). Also, if the wellpath changes abruptly between two survey stations, again this method gives significant errors. That is why the industry does not recommend it officially for long years. However, there are cases this method may be useful for some situations, which will be explained while application of this procedure to our sample geothermal wells in Turkey.

Beyond that, the industry standard for taking survey frequency, to be accurate for calculating well trajectories, is 30 m or 100 ft (1 stand) of max course length. Please note that this standard applies, if DLS (dogleg severity) values are less than 3°/30 m; otherwise, most companies suggest taking surveys for every single joint, i.e. 10 m or 30 ft, (Jamieson, 2012). So, if the frequency is increased, i.e. decreasing the course length enough, so much that the wellpath accuracy can be independent of the survey calculation method used. For example, if survey intervals are less than 3 m or 10 ft, tangential method can be utilized for all profiles with relatively acceptable errors (Carden & Grace, 2007). However, in this case, to take more surveys, extra rig time will be consumed. Hence, it can be optimized by taking into consideration of client needs.

From Figure 2.8 below, the following equations (Carden & Grace, 2007; Farah, 2013) can be seen easily:

$$\Delta TVD = \Delta MD . \cos (I_2) \tag{2.1}$$

$$\Delta North = \Delta MD . \sin(I_2) . \cos (AZ_2) \tag{2.2}$$

$$\Delta East = \Delta MD . \sin(I_2) . \sin (AZ_2) \tag{2.3}$$

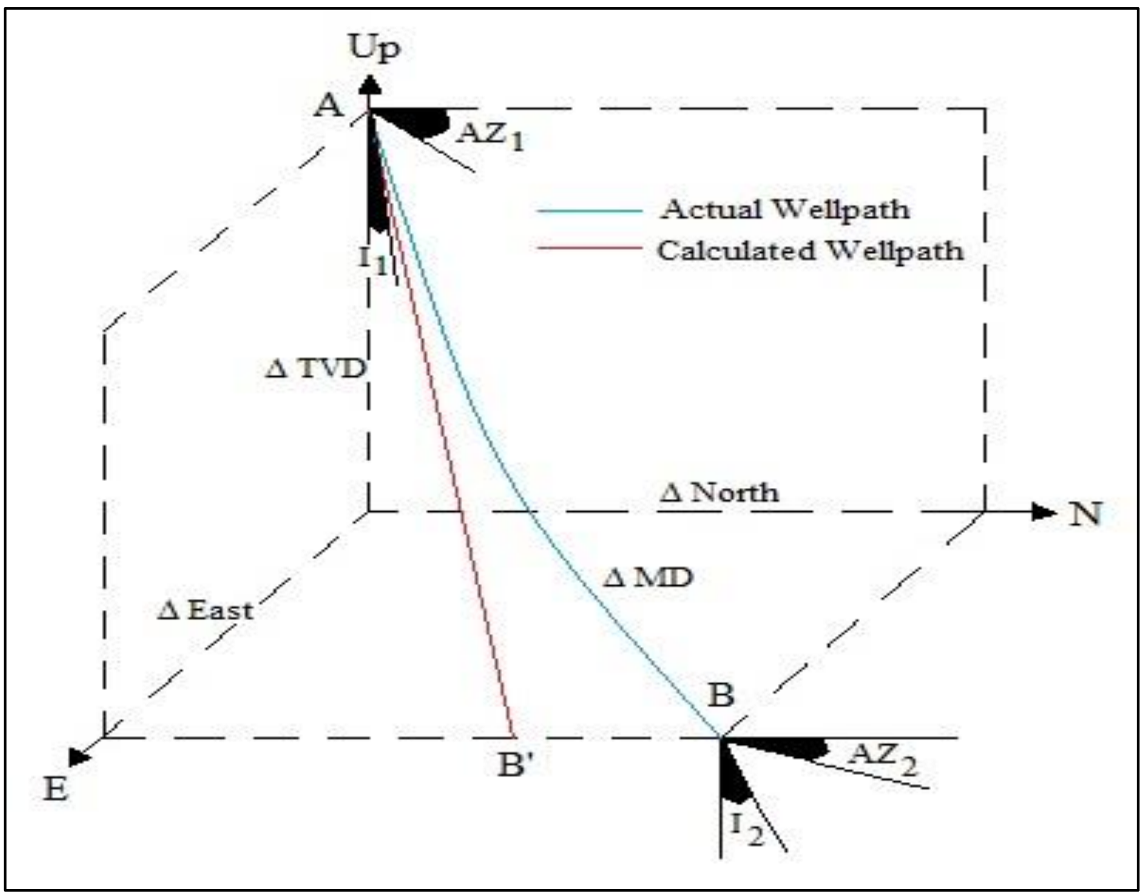


**Figure 2.8** Tangential Method

### 2.4.1.2 Balanced Tangential Method

Balanced tangential technique uses two equal length straight lines. The first line has the inclination ($I_1$) and azimuth ($AZ_1$) of the first survey station. And, the second line utilizes the other, second, survey station's inclination ($I_2$) and azimuth ($AZ_2$) values. Please see Figure 2.9 below, to clearly see the well trajectory and north, east, & vertical depth calculations.

This method is obviously accurate than the tangential method since both survey stations measurements are considered in the calculations. If compared with the average angle method, although balanced tangential technique has more complicated calculations, in terms of error they are similar. Further improvement of balanced tangential method, with a ratio factor, yields the minimum curvature method, which is the industry standard for directional drilling software products (Inglis, 1987).

By analysis of Figure 2.9, the following derivations (Inglis, 1987) can be done:

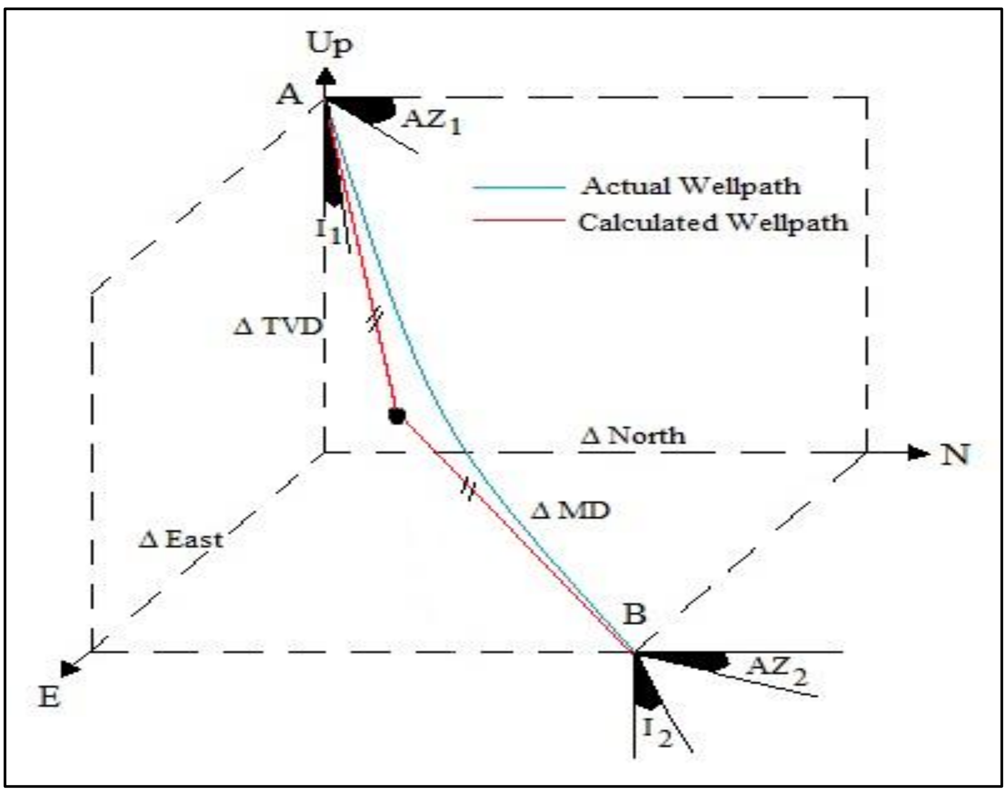


**Figure 2.9** Balanced Tangential Method

$$\Delta TVD = \left(\frac{1}{2}\right).\Delta MD.\cos(I_1) + \left(\frac{1}{2}\right).\Delta MD.\cos(I_2) \tag{2.4}$$

$$\Delta TVD = \left(\frac{1}{2}\right).\Delta MD.[\cos(I_1) + \cos(I_2)] \tag{2.5}$$

$$\Delta North = \left(\frac{1}{2}\right).\Delta MD.\sin(I_1).\cos(AZ_1) + \left(\frac{1}{2}\right).\Delta MD.\sin(I_2).\cos(AZ_2) \tag{2.6}$$

$$\Delta North = \left(\frac{1}{2}\right).\Delta MD.[\sin(I_1).\cos(AZ_1) + \sin(I_2).\cos(AZ_2)] \tag{2.7}$$

$$\Delta East = \left(\frac{1}{2}\right).\Delta MD.\sin(I_1).\sin(AZ_1) + \left(\frac{1}{2}\right).\Delta MD.\sin(I_2).\sin(AZ_2) \tag{2.8}$$

$$\Delta East = \left(\frac{1}{2}\right).\Delta MD.[\sin(I_1).\sin(AZ_1) + \sin(I_2).\sin(AZ_2)] \tag{2.9}$$

#### 2.4.1.3 Average Angle Method

Average angle method uses a single straight line, just like tangential method, but in this case the inclination and azimuth values are the averages of the both survey stations. The popularity of this technique relies on simple utilization by field personnel, and accuracy if the survey stations are close enough. The drawback of this procedure is that it can give large errors in near vertical wells due to large changes in azimuth within low inclinations (Inglis, 1987). Before the widespread use of personal computers, this method was the preferred one in the drilling industry (Jamieson, 2012).

North, East, and TVD determinations are based on the trigonometric calculations (Farah, 2013), as seen in Figure 2.10 below.

$$\Delta TVD = \Delta MD.\cos\left(\frac{I_1+I_2}{2}\right) \tag{2.10}$$

$$\Delta North = \Delta MD.\sin\left(\frac{I_1+I_2}{2}\right).\cos\left(\frac{AZ_1+AZ_2}{2}\right) \tag{2.11}$$

$$\Delta East = \Delta MD.\sin\left(\frac{I_1+I_2}{2}\right).\sin\left(\frac{AZ_1+AZ_2}{2}\right) \tag{2.12}$$

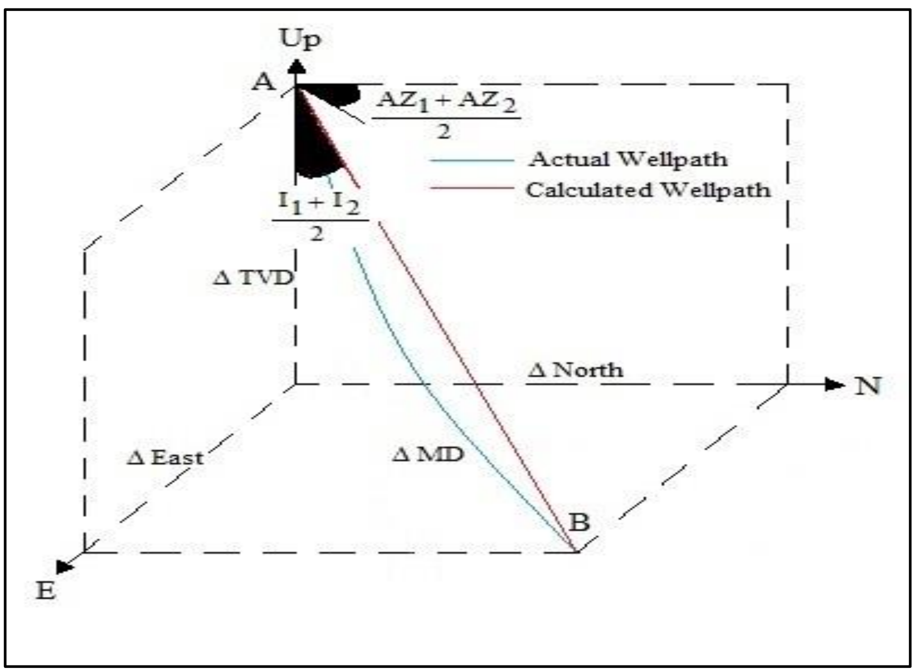


**Figure 2.10** Average Angle Method

#### 2.4.1.4 Radius of Curvature Method (RCM)

Radius of curvature method is accepted as one of the most accurate method by the directional drilling industry. Although the previously explained techniques use one or two straight lines, this one uses curvature to represent the wellpath just like Minimum Curvature Method, which will be explained as a last method. However, the complexity of calculation formulas can be considered as a drawback for RCM.

In this technique, wellpath is assumed as an arc if projected on both vertical and horizontal planes, as seen in Figure 2.11 below. And, the trajectory is tangent to inclination & azimuth of both survey stations, respectively A and B, as described in Figure 2.12 (Inglis, 1987). So, if the inclination & azimuth measurements are same for the two survey stations, i.e. the section is tangent, the radius R will be infinite and then the method will be undefined due to zero division error. In such cases, other methods can be utilized or just a small number, like $10^{-4}$, can be added to both survey points which will create insignificant error (Carden & Grace, 2007).

In other words, according to radius of curvature method, the well trajectory lies on a cylinder; and it may have a horizontal & vertical radius. The cylinder is unwrapped to calculate the wellpath length (Farah, 2013). If the actual wellpath is more similar to an arc, then application of this method in comparison with average angle method gives more realistic results; like in a kick-off section. On the other hand, the disadvantage is that it utilizes a constant radius in calculations, which cannot represent a wellpath for a long interval (Inglis, 1987).

In order to derive North, East, and TVD, vertical and horizontal planes should be analyzed separately, as seen in Figure 2.12 below (Inglis, 1987).

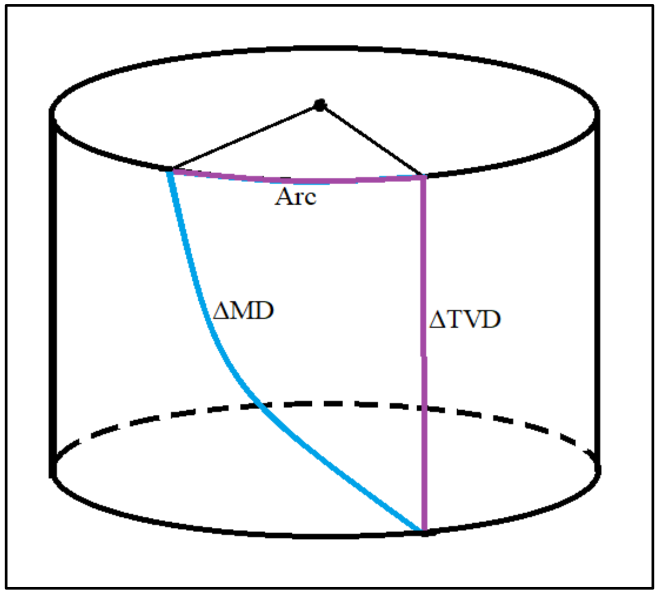


**Figure 2.11** Radius of Curvature Method

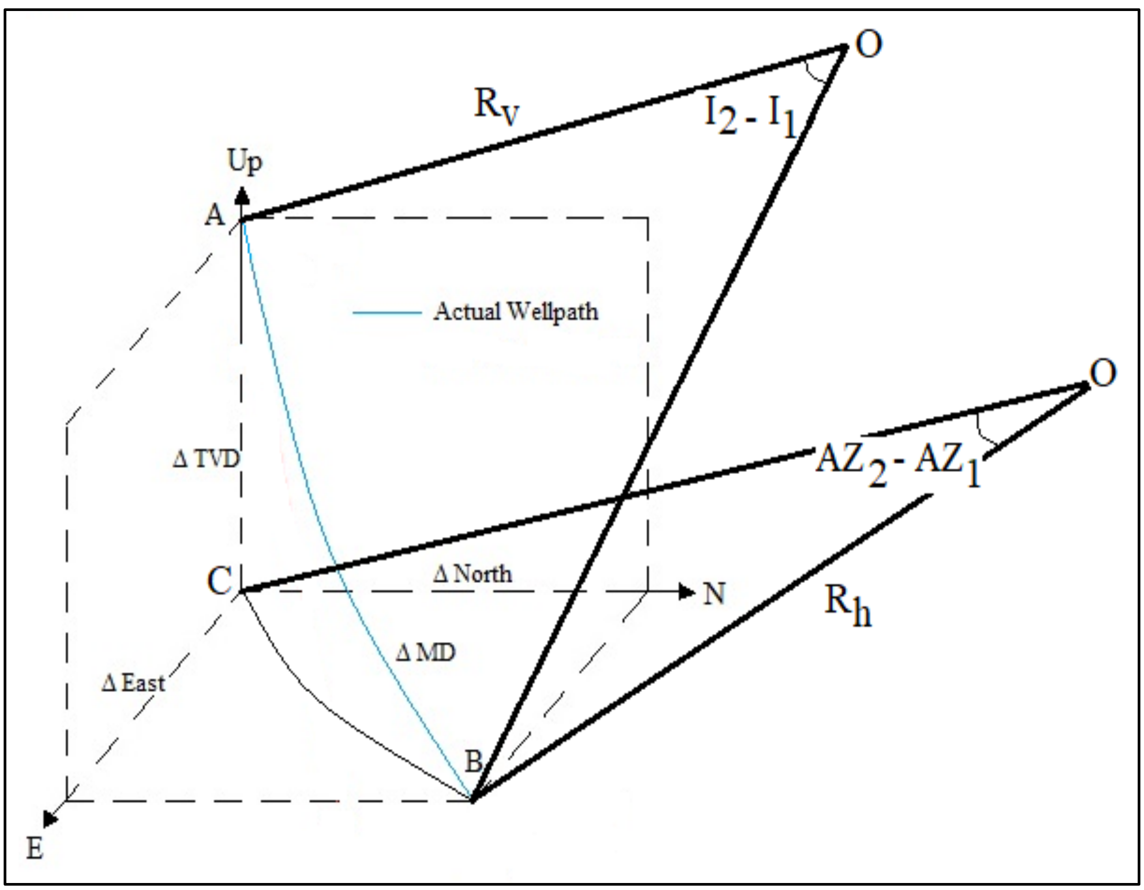


**Figure 2.12** Radius of Curvature Method - Horizontal and Vertical Planes

**For the vertical plane:**

$$AOB = I_2 - I_1 \tag{2.13}$$

$$\frac{I_2-I_1}{360} = \frac{\Delta MD}{2.\pi.R_v} \tag{2.14}$$

$R_v$, the radius of the vertical plane can be calculated from:

$$R_v = \frac{\Delta MD}{I_2-I_1}.\frac{180}{\pi} \tag{2.15}$$

$$\Delta TVD = R_v.\sin(I_2) - R_v.\sin(I_1) \tag{2.16}$$

$$\Delta TVD = R_v.[\sin(I_2) - \sin(I_1)] \tag{2.17}$$

If we substitute $R_v$ into the above equation, we get:

$$\Delta TVD = \frac{\Delta MD}{I_2-I_1}.\frac{180}{\pi}.[\sin(I_2) - \sin(I_1)] \tag{2.18}$$

$\Delta H$, the horizontal displacement can be calculated as follows:

$$\Delta H = R_v.[cos(I_1) - cos(I_2)] \tag{2.19}$$

**For the horizontal plane:**

$$COB = AZ_2 - AZ_1 \tag{2.20}$$

$$\frac{AZ_2 - AZ_1}{360} = \frac{\Delta H}{2.\pi.R_h} \tag{2.21}$$

$R_h$, the radius of the horizontal plane can be calculated from:

$$R_h = \frac{\Delta H}{AZ_2 - AZ_1}.\frac{180}{\pi} \tag{2.22}$$

$$\Delta N = R_h.\sin(AZ_2) - R_h.\sin(AZ_1) \tag{2.23}$$

$$\Delta N = R_h.[\sin(AZ_2) - \sin(AZ_1)] \tag{2.24}$$

If we substitute $R_h$ into the above equation, we get:

$$\Delta N = \frac{\Delta H}{AZ_2 - AZ_1}.\frac{180}{\pi}.[\sin(AZ_2) - \sin(AZ_1)] \tag{2.25}$$

If we substitute $\Delta H$ into the above equation, we get:

$$\Delta N = \frac{R_v.[cos(I_1) - cos(I_2)]}{AZ_2 - AZ_1}.\frac{180}{\pi}.[\sin(AZ_2) - \sin(AZ_1)] \tag{2.26}$$

If we substitute $R_v$ into the above equation, we get:

$$\Delta N = \frac{\Delta MD}{I_2 - I_1}.(\frac{180}{\pi})^2.\frac{[\cos(I_1) - \cos(I_2)].[\sin(AZ_2) - \sin(AZ_1)]}{AZ_2 - AZ_1} \tag{2.27}$$

$\Delta E$ can be found as follows, similar to the derivation of $\Delta N$:

$$\Delta E = \frac{\Delta MD}{I_2 - I_1}.(\frac{180}{\pi})^2.\frac{[\cos(I_1) - \cos(I_2)].[\cos(AZ_1) - \cos(AZ_2)]}{AZ_2 - AZ_1} \tag{2.28}$$

#### 2.4.1.5 Minimum Curvature Method (MCM)

Minimum curvature method uses an arc, like Radius of Curvature Method. MCM is actually an advanced version of balanced tangential method because the method assumes a circular arc, instead of two equal length straight lines, to construct wellpath. This is performed by using a ratio factor based on the dogleg angle between the two survey stations (Inglis, 1987). Due to its complicated mathematical calculations, it should be programmable; i.e. not easy to the field personnel for hand calculations. MCM, currently, is the industry standard, and have been used globally for the long years.

In other words, according to MCM, the well trajectory lies on a sphere; it has only one radius which minimizes the curvature necessary to fit the angular measurements (Jamieson, 2012). So, it is clear that if there are no changes in azimuth, the results of the RCM and MCM will be identical (Carden & Grace, 2007). Throughout the course length, the angle is changed continuously, as summarized in the following Figure 2.13.

MCM uses the shortest arc possible by taking into account both survey stations. In near vertical wells, if azimuth changes abruptly, the shortest arc or wellpath section can be dropping inclination or turning as well. The RCM, tangential, and angle averaging techniques treat the inclination and azimuth changes separately. So, horizontal departures will be larger, as will be seen later in the sample geothermal wells in Turkey. Nevertheless, according to the RCM methodology, the well inclination must be in the range of both survey stations; and thus, horizontal displacement will be less than that of average angle and tangential ones (Carden & Grace, 2007).

Although the MCM formulas and derivations are more complicated than the RCM, MCM is more flexible. For example, if the change in inclination or azimuth is zero, it will not be problem for MCM in terms of zero division. To illustrate another example, if wellpath goes from the quadrant of northeast to northwest, the RCM need adjustments since it will choose the long path in theory (Carden & Grace, 2007). For better understanding, let us assume that the azimuth of first survey station ($AZ_1$) is 45°, and the azimuth of second survey station ($AZ_2$) is 315°; and it means that the wellpath walk left 90°. However, the RCM will calculate the path walk right 360 – 90 = 270°. For RCM to calculate the correct coordinates, lower or upper survey azimuth must be adjusted, i.e. ($AZ_1$) can be 45° – 360 = – 315° or ($AZ_2$) can be 315 – 360 = – 45°.

Please see Figure 2.13 below, to visually understand the derivations of North, East, and TVD calculations explained (Heriot-Watt University, 2005; Inglis, 1987).

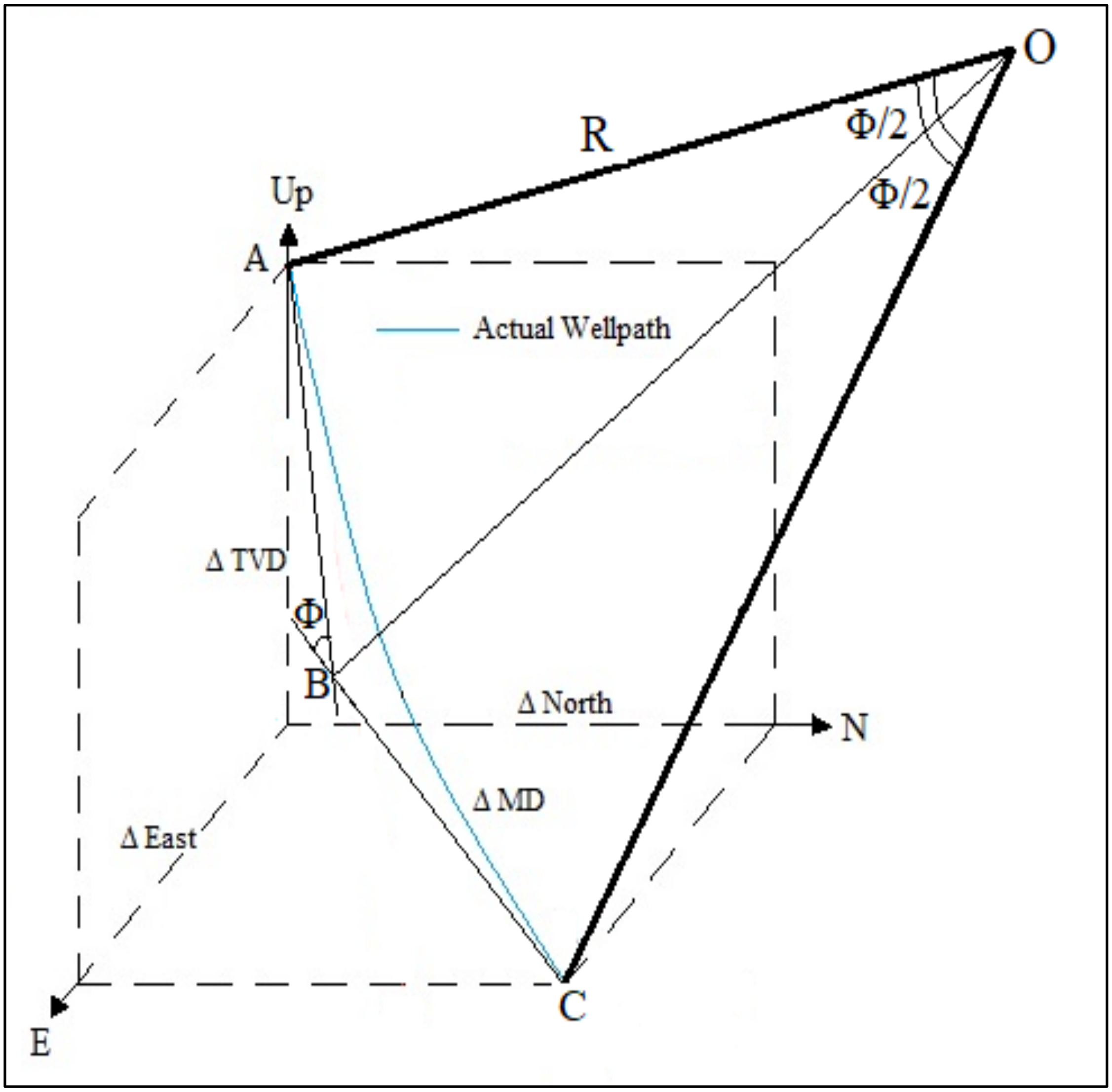


**Figure 2.13** Minimum Curvature Method

The dogleg angle, Φ, formula is as follows, which will be derived later separately:

$$\phi = cos^{-1}[\cos(I_1).\cos(I_2) + \sin(I_1).\sin(I_2).\cos(AZ_2 - AZ_1)] \tag{2.29}$$

The ratio factor, RF, just a simple smoothing factor, can be found from:

$$RF = \frac{AB+BC}{arc\ AC} \tag{2.30}$$

It is seen that:

$$AB = BC = R.\tan\left(\frac{\phi}{2}\right) \tag{2.31}$$

Also:

$$\frac{AC}{2\pi R} = \frac{\phi}{360} \tag{2.32}$$

$$AC = \frac{\pi R \phi}{180} \tag{2.33}$$

Hence:

$$RF = \frac{2}{\phi}\frac{180}{\pi}\tan\left(\frac{\phi}{2}\right) \tag{2.34}$$

The derived ratio factor, RF, is then applied to the balanced tangential method equations to yield:

$$\Delta TVD = \left(\frac{RF.\Delta MD}{2}\right).[\cos(I_1) + \cos(I_2)] \tag{2.35}$$

$$\Delta North = \left(\frac{RF.\Delta MD}{2}\right).[\sin(I_1).\cos(AZ_1) + \sin(I_2).\cos(AZ_2)] \tag{2.36}$$

$$\Delta East = \left(\frac{RF.\Delta MD}{2}\right).[\sin(I_1).\sin(AZ_1) + \sin(I_2).\sin(AZ_2)] \tag{2.37}$$

RF is simply defined as the ratio of the straight-line section to the curved section. Please note that if DLS equals to 0, i.e. the inclination and azimuth are the same for the two consecutive survey stations; RF will be undefined due to zero division case. In this situation, RF can be set to 1. If the dogleg angle is less than 0.25 radians, it is again reasonable to take the RF as 1 (Amorin & Broni-Bediako, 2010). Additionally, in Minimum Curvature Method, as the name implies the smoothest curve is in use; if we think using a smooth approximation technique rather than straight line segments, what degree of smoothness will be used must be determined (Taylor & Mason, 1972).

### 2.4.2 Dogleg Angle and Dogleg Severity (DLS)

Dogleg represents the curvature of a wellbore, both inclination and direction have contributions, and usually expressed in degrees/30 meters or degrees/100 ft. The wellbore can be visualized as a three-dimensional space curve, intersecting the center line of that well. The space curve can be defined as a circular arc with its extremities specified by survey stations. If the course length, the difference between survey stations, is extreme, then a dogleg of greater severity can be ignored unintentionally. So, it is the only way, to detect abrupt doglegs, that surveys should be taken at closer spacings (Dr. Mitchell, 1995).

When Lubinski (1961) clearly states that care should be given to changes of angles rather than hole angles; his paper named "Maximum Permissible Dog-Legs in Rotary Boreholes" had perhaps the greatest effect, among all other papers of him, on the drilling industry. With this progress, a maximum permissible DLS quickly placed into drilling contracts (Lubinski, 1987). This is because of changes of angles, indeed, are responsible for drilling and production problems. The paper shows the formula for maximum permissible changes of angles to ensure drilling a hole without problem and with minimum amount of surveys. He summarized that excessive doglegs can lead to fatigue failure of drill pipes & drill collar connections, worn tool joints & drill pipes, becoming key seats & grooved casing etc. (Lubinski, 1961).

When it comes to derivation of dogleg angle, $\Phi$, which has more significance within the scope of this thesis, we will use Figure 2.14 below. There are two survey stations; first one is with inclination of $I_1$ and azimuth of $AZ_1$ at the survey station A, and second one is with inclination of $I_2$ and azimuth of $AZ_2$ at the survey station B. These angles result in two straight line segments of $L_1$ and $L_2$ (Inglis, 1987).

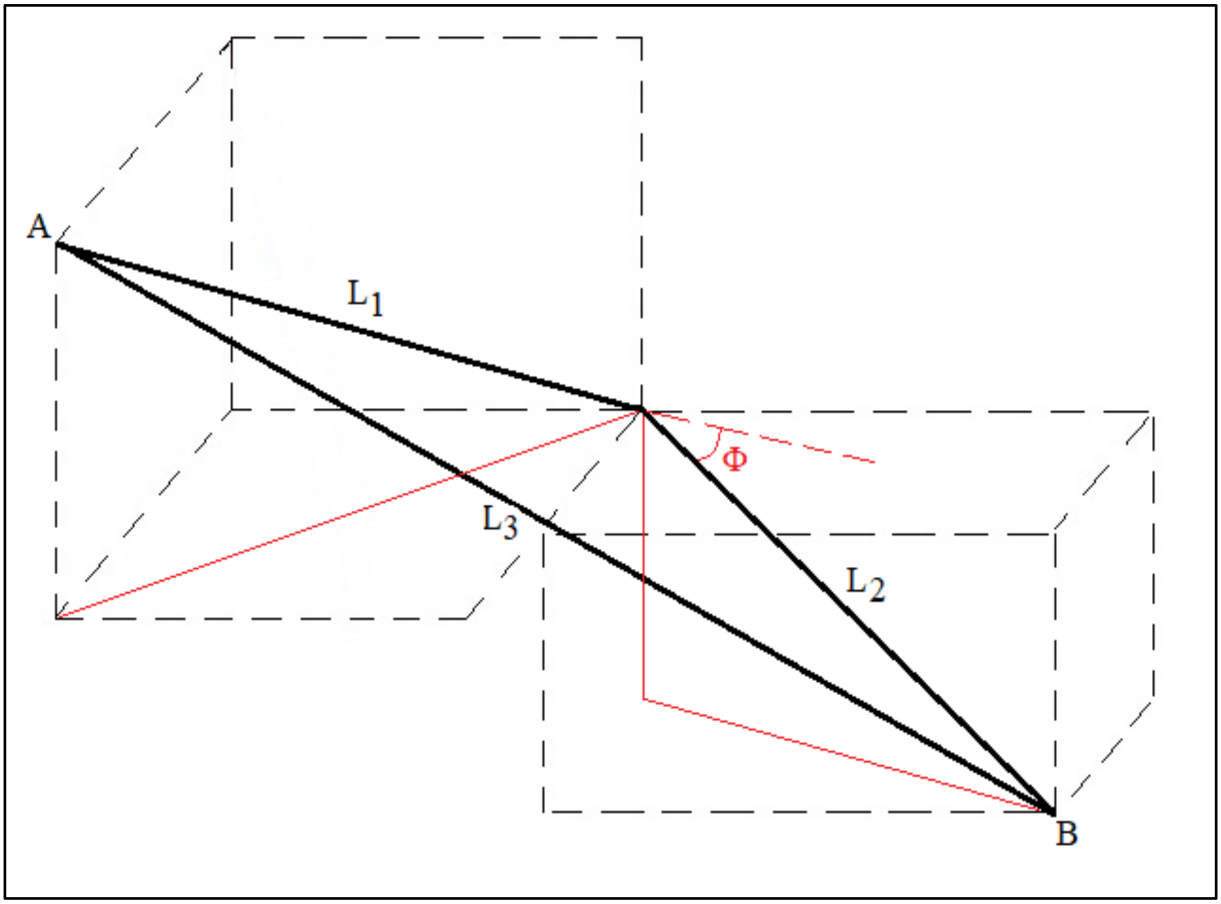


**Figure 2.14** Derivation of Dogleg

First of all, TVD difference can be defined as:

$$\Delta TVD = L_1.\cos(I_1) + L_2.\cos(I_2) \tag{2.38}$$

By considering the horizontal projections of $L_1$ and $L_2$, ΔH can be found as below:

$$(\Delta H)^2 = (L_1.\sin(I_1))^2 + (L_2.\sin(I_2))^2 - 2.L_1.\sin(I_1).L_2.\sin(I_2).\cos(180 - (AZ_2 - AZ_1)) \tag{2.39}$$

$$(\Delta H)^2 = (L_1.\sin(I_1))^2 + (L_2.\sin(I_2))^2 + 2.L_1.\sin(I_1).L_2.\sin(I_2).\cos(AZ_2 - AZ_1) \tag{2.40}$$

To calculate $L_3$:

$$(L_3)^2 = (\Delta TVD)^2 + (\Delta H)^2 \quad (2.41)$$

Substitute ΔTVD and ΔH into the above equation:

$$(L_3)^2 = (L_1)^2 + (L_2)^2 + 2.L_1.L_2.(\cos(I_1).\cos(I_2) + \sin(I_1).\sin(I_2).\cos(AZ_2 - AZ_1)) \quad (2.42)$$

Cosine rule for the triangle bounded by $L_1$, $L_2$, and $L_3$:

$$\cos(180 - \phi) = \frac{(L_1)^2 + (L_2)^2 - (L_3)^2}{2.L_1.L_2} \quad (2.43)$$

$$\cos(180 - \phi) = -\cos(I_1).\cos(I_2) - \sin(I_1).\sin(I_2).\cos(AZ_2 - AZ_1) \quad (2.44)$$

$$\cos(\phi) = \cos(I_1).\cos(I_2) + \sin(I_1).\sin(I_2).\cos(AZ_2 - AZ_1) \quad (2.45)$$

Finally dogleg angle, Φ, is found as:

$$\phi = cos^{-1}[\cos(I_1).\cos(I_2) + \sin(I_1).\sin(I_2).\cos(AZ_2 - AZ_1)] \quad (2.46)$$

And, dogleg severity, DLS, by definition is as follows:

$$DLS = 30.\frac{\phi}{\Delta MD} \quad (2.47)$$

### 2.4.3 Closure

The terms closure, directional difference, and vertical section are already defined in Fundamental Definitions part of this thesis. Here we will go further and learn the related formulas.

Closure represents the shortest straight line from the projected surface location to the last survey station in horizontal plane. As defining closure, closure direction must also be expressed to point out the last survey station exactly. For simple terms, it is shortest distance or length from the surface location to the horizontal projection of the last survey station. It is represented by polar coordinates for a specified survey station, comparing with the north and east to be rectangular coordinates (Short, 1993). Therefore, it is obvious to see the closure formulas below (Rabia, 2001), if we consider Figure 2.1 placed at the Fundamental Definitions part:

$$Closure\ Distance\ or\ Length = \sqrt{North^2 + East^2} \tag{2.48}$$

$$Closure\ Angle\ or\ Direction\ or\ Azimuth = \ tan^{-1}(\frac{East}{North}) \tag{2.49}$$

### 2.4.4 Directional Difference (DD)

It is the angle between the target direction or bearing and the closure angle. It is used to calculate vertical section. So, by using Figure 2.1, the below equation can be found (Hassan, 2012):

$$DD = AZ_{vs} - AZ_{cl} \tag{2.50}$$

### 2.4.5 Vertical Section (VS)

The vertical profile regarding a well can be specified in a plane surrounded by the direction from the surface location to the target through a straight line. This direction is called as target direction or vertical section azimuth. And, the total horizontal displacement regarding a well projected onto this plane is defined as the vertical section. In other words, it is the horizontal departure or distance of a well projected onto a vertical plane of predetermined direction. And it is scaled with TVD. The direction can coincide with the plane defined by surface to Total Depth or be the dominant direction of the lateral section of the well. Thus, by definition, and using Figure 2.1, the following equation is found (Rabia, 2001):

$$VS = \cos(DD)\,.\,Closure\ Distance \tag{2.51}$$

### 2.4.1 Comparison of Directional Survey Calculation Methods

There is no method to calculate bottom hole position of a well with a complete certainty. For maximum certainty, we can apply different survey calculation techniques for each particular segments of a wellbore, i.e. modelling of each survey interval (Walstrom et al., 1972), or take surveys in a continuous fashion; however, it will be much more far away from economic feasibility.

From the experiences, it is stated that uncertainty due to measurement of data or surveying is much more than the used survey calculation method by a factor of 10 or even more, in general (Harvey et al., 1971). This situation may provide more space to make relatively rough calculations and so errors, in some directional wells, in order for optimization and cost minimization. Additionally, although the used survey calculation method is strongly dependent of course lengths or number of survey stations, the measurement error due to tool is nearly independent of course lengths (Fruhwirth & Lorbach, 1987). Thus, in some situations, we can increase number of survey stations to decrease errors resulting from survey calculation technique in use, to some extent, by keeping in mind that increasing survey stations may increase the time spent.

Özbayoğlu (2006) have made a comparison between directional survey calculation techniques by assuming a theoretical well. The well is in a due North direction, TD is 2000 ft, BUR of 3°/100ft, and survey stations of 100 ft apart. Except tangential method, he finds that other methods, including all the methods analyzed throughout this thesis, have given errors both on TVD and horizontal displacement of less than 1 ft. He clearly states that, the errors are only relative, and the actual well can behave very differently. He added that this comparison does not have any turn, i.e. only 2D, and we must pay attention while comparing methods on different kinds of wells (Özbayoğlu, 2006).

In his paper, regarding Tangential Method applied on an S type well profile, Wilson (1968) asserted that if drop section is drilled at the same rate and surveyed as the same frequency with build section, total error will cancel out. However, in case of a slant type hole, there will be no vanishing of total error; even, the error will increase as max. inclination angle, rate of build, and survey station lengths increase (Wilson, 1968). Therefore, this situation will be a good point while making the analysis of our sample geothermal wells in Turkey.

# CHAPTER 3

## STATEMENT OF THE PROBLEM

Figuring out the directional needs of a field and optimizations are critical in terms of total drilling costs. To determine the path of a well, especially the bottom hole position, which is more important for operators, there are three parameters as a result of MWD surveys; measured depth, inclination, and azimuth. By using these three parameters, several survey calculation methods can be used, differentiating from each other by their accuracies and complexities. There are various studies making comparisons between them. Currently, as accepted most accurate, the industry standard is minimum curvature method (MCM). However, an optimum method(s) should be recommended, after determining the needs of a specific drilling field to apply cost-effective solutions. The reason is that although some methods are easy even for hand calculations, some needs advanced computer programs.

The main purpose of this study is to find out the geothermal well directional needs, located on Aegean Part of Turkey, in terms of survey calculation methods; namely tangential, balanced tangential, average angle, radius of curvature, and minimum curvature; and to understand which method should be used at what conditions. For this aim, a Python program script will be written for each method. Then, actual geothermal wells having different profiles will be applied on this program. Finally, according to the results of the program, interpretations and suggestions will be made.

# CHAPTER 4

# METHODOLOGY

## 4.1 Sample Wells

To analyze 5 different directional survey calculation methods, namely, tangential, balanced tangential, average angle, radius of curvature, and minimum curvature methods; 9 drilled geothermal wells, located on Aegean part of Turkey, selected based on real data. Taking into account the types, inclinations, doglegs, and total drilled depths; all of them represent the usual geothermal wells drilled in Turkey.

First 3 of them are J type wells. They are chosen according to their inclinations, in order to see the effect of inclination on directional survey calculation methods.

2 of them are S type wells. They are chosen again according to their inclinations. For both wells, build and drop doglegs are almost same. That is, both wells can be considered as symmetrical assuming that the vertical axis passes through the middle of horizontal displacement. If there is no drop, i.e. drop doglegs are much less than the build doglegs, which means the well is J type. By choosing these two S type wells, the effect of geometrical symmetry on directional survey calculation methods will be seen.

2 of them are selected as DKO (Deep Kick Off) types, comparing with the 3 J type wells. Hence, we will see the effect of kicking off deeper on survey calculation techniques.

Finally, last 2 wells are vertical.

The summary information about the selected wells are provided below.

**Table 4.1** Summary Information of Selected J-Type Wells

| Name | J-1 | J-2 | J-3 |
|---|---|---|---|
| Total Depth (TD), m | 3605.00 | 1327.50 | 2412.00 |
| Average Inclination, deg | 8.00 | 17.00 | 27.00 |
| Average Dogleg, deg/30m | 0.70 | 1.30 | 2.00 |
| Kick-Off Depth, m | 225.00 | 105.00 | 185.00 |

**Table 4.2** Summary Information of Selected S-Type Wells

| Name | S-1 | S-2 |
|---|---|---|
| Total Depth (TD), m | 3477.00 | 3101.00 |
| Average Inclination, deg | 12.00 | 23.00 |
| Build Average Dogleg, deg/30m | 0.80 | 1.35 |
| Drop Average Dogleg, deg/30m | 1.00 | 0.90 |

**Table 4.3** Summary Information of Selected Deep Kick Off Type Wells

| Name | DKO-1 | DKO-2 |
|---|---|---|
| Total Depth (TD), m | 2575.10 | 2808.00 |
| Average Inclination, deg | 12.00 | 13.80 |
| Average Dogleg, deg/30m | 1.50 | 1.20 |
| Kick-Off Depth, m | 1550.00 | 940.00 |

**Table 4.4** Summary Information of Selected Vertical Wells

| Name | V-1 | V-2 |
|---|---|---|
| Total Depth (TD), m | 2011.60 | 3000.00 |

Besides general information, survey data of the well J-1 is listed at the next page. The other surveys regarding the other selected wells are provided in Appendix. Since the written python programming code is reading the surveys directly from .txt files, survey information is provided as screen shots of the related .txt files. In other words, these .txt files are the inputs of our python code.

The columns of the survey tables are as follows.

1st column : MD (Measured Depth)

2nd column : Inc (Inclination)

3rd column : Az (Azimuth)

**Table 4.5** Survey Data of the Well J-1

| | | |
|---|---|---|
| 0.00 | 0.00 | 180.00 |
| 5.20 | 0.00 | 180.00 |
| 112.00 | 0.10 | 180.00 |
| 133.00 | 0.13 | 360.00 |
| 152.00 | 0.10 | 129.09 |
| 171.90 | 0.07 | 137.57 |
| 188.90 | 0.13 | 225.60 |
| 207.30 | 0.19 | 82.55 |
| 226.10 | 0.65 | 116.94 |
| 245.40 | 1.14 | 94.60 |
| 264.85 | 1.97 | 95.93 |
| 284.02 | 3.08 | 88.71 |
| 302.56 | 4.23 | 87.58 |
| 322.00 | 5.63 | 84.08 |
| 341.40 | 6.29 | 83.37 |
| 360.27 | 7.02 | 81.14 |
| 379.20 | 7.48 | 79.20 |
| 399.50 | 7.83 | 76.90 |
| 418.50 | 7.61 | 75.37 |
| 437.20 | 7.64 | 76.27 |
| 456.20 | 8.28 | 78.70 |
| 476.63 | 8.45 | 79.73 |
| 495.64 | 8.51 | 78.18 |
| 514.87 | 8.78 | 76.31 |
| 534.10 | 9.20 | 75.88 |
| 553.20 | 9.14 | 74.90 |
| 572.75 | 9.31 | 75.08 |
| 591.62 | 9.25 | 74.92 |
| 611.11 | 9.27 | 73.36 |
| 630.30 | 9.19 | 74.52 |
| 649.70 | 8.92 | 74.46 |
| 669.10 | 9.02 | 75.12 |
| 688.13 | 9.46 | 74.25 |
| 707.55 | 9.44 | 73.54 |
| 729.90 | 9.28 | 72.79 |
| 746.27 | 9.08 | 72.42 |
| 765.62 | 9.07 | 73.33 |
| 784.99 | 9.00 | 73.48 |
| 804.15 | 8.71 | 73.77 |
| 822.94 | 8.88 | 73.02 |
| 842.26 | 8.90 | 75.28 |
| 861.70 | 8.96 | 77.90 |
| 881.05 | 8.85 | 78.39 |
| 900.05 | 8.71 | 77.42 |
| 919.92 | 8.49 | 77.20 |
| 939.20 | 8.36 | 77.11 |
| 958.60 | 8.23 | 76.43 |
| 998.40 | 7.49 | 76.80 |
| 1018.15 | 8.20 | 77.42 |
| 1038.20 | 8.67 | 77.83 |
| 1057.50 | 8.65 | 78.11 |
| 1075.90 | 8.56 | 75.70 |
| 1095.39 | 8.52 | 74.49 |
| 1113.84 | 8.62 | 73.72 |
| 1133.14 | 8.80 | 72.09 |
| 1152.40 | 8.31 | 70.51 |
| 1172.01 | 8.00 | 71.15 |
| 1191.40 | 7.96 | 71.49 |
| 1210.58 | 7.73 | 70.09 |
| 1230.01 | 7.29 | 69.93 |
| 1248.35 | 7.40 | 69.21 |
| 1267.80 | 7.09 | 69.92 |
| 1287.50 | 7.06 | 68.50 |
| 1306.55 | 6.85 | 69.27 |
| 1325.60 | 7.14 | 70.72 |
| 1344.50 | 7.17 | 73.48 |
| 1364.47 | 7.01 | 73.16 |
| 1382.60 | 7.03 | 72.06 |
| 1402.15 | 6.84 | 72.02 |
| 1422.25 | 6.85 | 71.53 |
| 1441.53 | 6.74 | 71.55 |
| 1460.96 | 6.82 | 71.70 |
| 1480.19 | 7.74 | 72.49 |
| 1499.03 | 8.46 | 73.53 |
| 1517.80 | 9.36 | 71.61 |
| 1536.70 | 10.15 | 70.96 |
| 1556.10 | 10.82 | 72.51 |
| 1576.32 | 11.63 | 75.94 |
| 1595.69 | 12.32 | 78.04 |
| 1614.77 | 12.73 | 79.35 |
| 1633.50 | 12.70 | 79.57 |
| 1653.40 | 12.85 | 78.68 |
| 1672.09 | 12.61 | 77.10 |
| 1691.85 | 12.20 | 76.30 |
| 1711.27 | 11.79 | 76.44 |
| 1729.70 | 11.21 | 76.82 |
| 1749.10 | 10.54 | 78.69 |
| 1769.01 | 10.45 | 79.94 |
| 1788.30 | 10.60 | 80.28 |
| 1806.80 | 10.74 | 79.80 |
| 1826.98 | 10.33 | 78.93 |
| 1845.13 | 10.69 | 78.73 |
| 1864.30 | 11.07 | 78.99 |
| 1884.02 | 11.08 | 79.44 |
| 1903.77 | 11.01 | 79.44 |
| 1922.75 | 10.43 | 79.65 |
| 1941.45 | 10.16 | 80.00 |
| 1961.75 | 9.62 | 81.66 |
| 1981.15 | 9.10 | 82.85 |
| 1999.95 | 8.87 | 80.94 |
| 2018.66 | 8.48 | 75.67 |
| 2037.87 | 8.41 | 73.78 |
| 2057.66 | 7.99 | 73.78 |
| 2076.90 | 8.25 | 70.08 |
| 2095.98 | 8.89 | 65.80 |
| 2115.82 | 9.31 | 64.46 |
| 2134.69 | 9.45 | 63.20 |
| 2153.82 | 9.23 | 62.40 |
| 2173.95 | 9.88 | 63.26 |
| 2193.25 | 9.84 | 68.00 |
| 2212.60 | 8.84 | 71.85 |
| 2231.73 | 8.47 | 74.84 |
| 2250.62 | 8.35 | 75.48 |
| 2257.39 | 8.42 | 76.36 |
| 2291.55 | 8.70 | 75.68 |
| 2309.98 | 8.78 | 73.74 |
| 2329.15 | 8.89 | 75.15 |
| 2349.15 | 8.60 | 81.03 |
| 2368.82 | 8.05 | 81.16 |
| 2389.12 | 6.97 | 81.16 |
| 2407.15 | 7.13 | 79.82 |
| 2426.50 | 7.77 | 77.10 |
| 2444.95 | 7.58 | 74.61 |
| 2464.60 | 7.46 | 75.03 |
| 2484.05 | 7.40 | 75.29 |
| 2503.53 | 7.31 | 75.29 |
| 2523.41 | 8.42 | 71.28 |
| 2542.46 | 9.17 | 70.50 |
| 2560.67 | 8.77 | 70.15 |
| 2579.25 | 8.30 | 73.75 |
| 2599.30 | 7.94 | 71.14 |
| 2618.70 | 7.72 | 70.69 |
| 2637.90 | 7.06 | 70.56 |
| 2656.80 | 7.10 | 71.12 |
| 2677.79 | 7.85 | 81.40 |
| 2695.69 | 8.09 | 83.22 |
| 2714.60 | 7.51 | 81.10 |
| 2734.80 | 6.79 | 78.64 |
| 2753.30 | 6.57 | 76.31 |
| 2772.70 | 6.32 | 79.06 |
| 2792.20 | 6.36 | 80.62 |
| 2811.90 | 6.54 | 80.88 |
| 2831.00 | 6.90 | 79.85 |
| 2850.10 | 7.00 | 79.32 |
| 2869.20 | 7.55 | 75.63 |
| 2889.10 | 7.67 | 71.92 |
| 2907.10 | 8.29 | 71.99 |
| 2927.00 | 7.94 | 76.84 |
| 2946.20 | 8.15 | 84.40 |
| 2965.50 | 8.26 | 86.78 |
| 2985.20 | 8.06 | 88.76 |
| 3004.60 | 8.12 | 87.84 |
| 3023.20 | 8.17 | 83.25 |
| 3041.00 | 8.33 | 81.29 |
| 3062.20 | 8.03 | 80.24 |
| 3081.00 | 7.55 | 77.11 |
| 3100.60 | 8.34 | 70.04 |
| 3119.80 | 8.69 | 71.09 |
| 3139.40 | 8.77 | 69.53 |
| 3158.60 | 8.60 | 68.25 |
| 3178.10 | 8.94 | 72.37 |
| 3196.90 | 8.55 | 68.96 |
| 3216.30 | 8.29 | 64.56 |
| 3235.10 | 8.64 | 64.78 |
| 3254.70 | 8.66 | 68.29 |
| 3274.00 | 8.13 | 68.13 |
| 3294.00 | 7.66 | 65.76 |
| 3313.20 | 7.41 | 66.80 |
| 3332.60 | 7.94 | 63.91 |
| 3351.60 | 8.14 | 64.24 |
| 3370.10 | 8.24 | 67.37 |
| 3390.00 | 8.23 | 62.04 |
| 3409.40 | 8.76 | 57.94 |
| 3428.70 | 8.89 | 56.93 |
| 3447.70 | 8.65 | 54.78 |
| 3467.10 | 8.45 | 50.48 |
| 3486.40 | 8.48 | 46.49 |
| 3505.60 | 8.40 | 41.88 |
| 3525.00 | 8.10 | 37.73 |
| 3544.30 | 8.20 | 33.87 |
| 3563.70 | 8.07 | 28.07 |
| 3582.90 | 8.26 | 22.85 |
| 3605.00 | 8.32 | 17.17 |

## 4.2 Working Principle of the Written Python Programming Code

Firstly, the script located in Appendix is open. Then, below code is found at page 140.

*with open (“…”, “r”, encoding = “utf-8”) as file:*

Afterwards, the directory of the survey information, belongs to the well that we want to calculate its directional data, should be written instead of triple dot, as below.

*with open (“/Users/01/Desktop/Selected_Wells/J-1.txt”, “r”, encoding = “utf-8”) as file:*

Now, the script is ready to be run. After running, we will see the screen as in Figure 4.1.

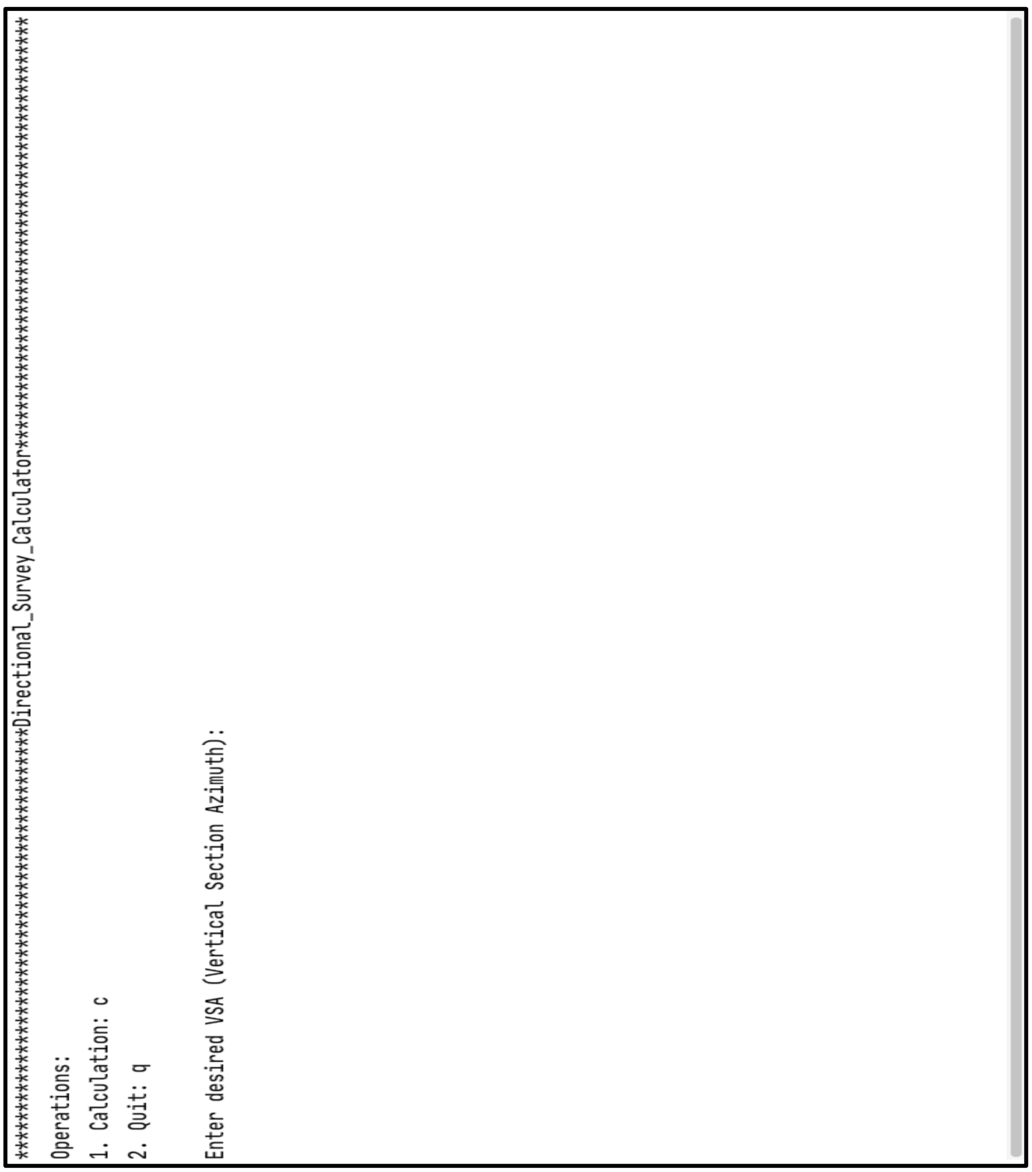


**Figure 4.1** Initial Screen of the Python Programming Code

Thereafter, desired vertical section azimuth should be entered, which is used only for the calculation of vertical section. Then, we should enter “c”, stands for calculation, as the next operation. At this stage, the program will calculate all we need at the background. Lastly, we should enter “q”, stands for quit, as indicated in Figure 4.2 below. Afterwards, the program will show the output.

```
****************************************************Directional_Survey_Calculator****************************************************
Operations:
1. Calculation: c
2. Quit: q

Enter desired VSA (Vertical Section Azimuth): 76.18
Enter desired operation: c
Enter desired operation: q
```

**Figure 4.2** Input Screen of the Python Programming Code

The output includes all the directional results calculated based on 5 different directional survey calculation techniques which are tangential, balanced tangential, average angle, radius of curvature, and minimum curvature method; and 1 3-D plot file showing all 5 different calculation results in 1 graph. The color coding of the methods in graphs is as follows.

1. Tangential (T) : Red
2. Balanced Tangential (BT) : Blue
3. Average Angle (AA) : Green
4. Radius of Curvature Method (RCM) : Yellow
5. Minimum Curvature Method (MCM) : Black

For more understanding, the screen shots of outputs are located in Results and Discussion chapter.

# CHAPTER 5

# RESULTS AND DISCUSSION

After explaining working principle and input part of the written python programming code in Methodology chapter; the output screen shots of tangential method, for the first selected well J-1, are provided below. The results of the remaining 4 methods for J-1 are located in Appendix.

Instead of attaching full output screen shots for the other 8 wells, only the 3D graphs of all 9 wells, for visual identification, are shown here, just after the tangential results regarding J-1. Please note that the scales of the plots are different in order to differentiate all directional methods as much as possible and clearly see the type of the well.

As per the needs of geothermal operators in Turkey, the most important 3D position throughout a well is usually the last point of the well in question. Thus, in addition to the work done above, to make a clear comparison, a summary table for each selected well is prepared which shows only the last point positions of all 9 wells. Please see Table 5.8-5.16, after the plots. In tables, differences between calculated TVDs, Local Norths, Local Easts, and Vertical Sections are represented as *Diff on TVD*, *Diff on N*, *Diff on E*, and *Diff on VS*, respectively. And the reference calculation method is always MCM, as it is the industry standard.

**Table 5.1** The Results of Tangential Method for the Well J-1 (1/7)

***********************************************Tangential*********************************************************

| Survey No | MD | Inc | Az | CL | TVD | Local N | Local E | DLS | VS |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 180.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2 | 5.20 | 0.00 | 180.00 | 5.20 | 5.20 | 0.00 | 0.00 | 0.00 | 0.00 |
| 3 | 112.00 | 0.10 | 180.00 | 106.80 | 112.00 | -0.19 | 0.00 | 0.03 | -0.04 |
| 4 | 133.00 | 0.13 | 360.00 | 21.00 | 133.00 | -0.14 | 0.00 | 0.33 | -0.03 |
| 5 | 152.00 | 0.10 | 129.09 | 19.00 | 152.00 | -0.16 | 0.03 | 0.33 | -0.01 |
| 6 | 171.90 | 0.07 | 137.57 | 19.90 | 171.90 | -0.18 | 0.04 | 0.05 | -0.00 |
| 7 | 188.90 | 0.13 | 225.60 | 17.00 | 188.90 | -0.20 | 0.01 | 0.26 | -0.03 |
| 8 | 207.30 | 0.19 | 82.55 | 18.40 | 207.30 | -0.20 | 0.08 | 0.50 | 0.03 |
| 9 | 226.10 | 0.65 | 116.94 | 18.80 | 226.10 | -0.29 | 0.27 | 0.81 | 0.19 |
| 10 | 245.40 | 1.14 | 94.60 | 19.30 | 245.39 | -0.32 | 0.65 | 0.92 | 0.55 |
| 11 | 264.85 | 1.97 | 95.93 | 19.45 | 264.83 | -0.39 | 1.31 | 1.28 | 1.18 |
| 12 | 284.02 | 3.08 | 88.71 | 19.17 | 283.98 | -0.37 | 2.34 | 1.80 | 2.19 |
| 13 | 302.56 | 4.23 | 87.58 | 18.54 | 302.46 | -0.31 | 3.71 | 1.86 | 3.53 |
| 14 | 322.00 | 5.63 | 84.08 | 19.44 | 321.81 | -0.12 | 5.61 | 2.21 | 5.42 |
| 15 | 341.40 | 6.29 | 83.37 | 19.40 | 341.09 | 0.13 | 7.72 | 1.03 | 7.52 |
| 16 | 360.27 | 7.02 | 81.14 | 18.87 | 359.82 | 0.49 | 10.00 | 1.23 | 9.82 |
| 17 | 379.20 | 7.48 | 79.20 | 18.93 | 378.59 | 0.95 | 12.42 | 0.83 | 12.28 |
| 18 | 399.50 | 7.83 | 76.90 | 20.30 | 398.70 | 1.57 | 15.11 | 0.69 | 15.05 |
| 19 | 418.50 | 7.61 | 75.37 | 19.00 | 417.54 | 2.21 | 17.54 | 0.48 | 17.56 |
| 20 | 437.20 | 7.64 | 76.27 | 18.70 | 436.07 | 2.80 | 19.96 | 0.20 | 20.05 |
| 21 | 456.20 | 8.28 | 78.70 | 19.00 | 454.87 | 3.34 | 22.64 | 1.14 | 22.78 |
| 22 | 476.63 | 8.45 | 79.73 | 20.43 | 475.08 | 3.87 | 25.60 | 0.33 | 25.78 |
| 23 | 495.64 | 8.51 | 78.18 | 19.01 | 493.88 | 4.45 | 28.35 | 0.37 | 28.59 |
| 24 | 514.87 | 8.78 | 76.31 | 19.23 | 512.88 | 5.14 | 31.20 | 0.61 | 31.53 |
| 25 | 534.10 | 9.20 | 75.88 | 19.23 | 531.87 | 5.89 | 34.18 | 0.66 | 34.60 |

**Table 5.2** The Results of Tangential Method for the Well J-1 (2/7)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 26 | 553.20 | 9.14 | 74.90 | 19.10 | 550.72 | 6.68 | 37.11 | 0.26 | 37.64 |
| 27 | 572.75 | 9.31 | 75.08 | 19.55 | 570.02 | 7.50 | 40.17 | 0.26 | 40.80 |
| 28 | 591.62 | 9.25 | 74.92 | 18.87 | 588.64 | 8.29 | 43.10 | 0.10 | 43.83 |
| 29 | 611.11 | 9.27 | 73.36 | 19.49 | 607.88 | 9.18 | 46.11 | 0.39 | 46.97 |
| 30 | 630.30 | 9.19 | 74.52 | 19.19 | 626.82 | 10.00 | 49.06 | 0.32 | 50.03 |
| 31 | 649.70 | 8.92 | 74.46 | 19.40 | 645.99 | 10.81 | 51.96 | 0.42 | 53.04 |
| 32 | 669.10 | 9.02 | 75.12 | 19.40 | 665.15 | 11.59 | 54.90 | 0.22 | 56.08 |
| 33 | 688.13 | 9.46 | 74.25 | 19.03 | 683.92 | 12.44 | 57.91 | 0.73 | 59.20 |
| 34 | 707.55 | 9.44 | 73.54 | 19.42 | 703.07 | 13.34 | 60.96 | 0.18 | 62.38 |
| 35 | 729.90 | 9.28 | 72.79 | 22.35 | 725.13 | 14.41 | 64.41 | 0.27 | 65.98 |
| 36 | 746.27 | 9.08 | 72.42 | 16.37 | 741.30 | 15.19 | 66.87 | 0.38 | 68.56 |
| 37 | 765.62 | 9.07 | 73.33 | 19.35 | 760.41 | 16.06 | 69.79 | 0.22 | 71.61 |
| 38 | 784.99 | 9.00 | 73.48 | 19.37 | 779.54 | 16.92 | 72.70 | 0.11 | 74.63 |
| 39 | 804.15 | 8.71 | 73.77 | 19.16 | 798.48 | 17.74 | 75.48 | 0.46 | 77.53 |
| 40 | 822.94 | 8.88 | 73.02 | 18.79 | 817.04 | 18.58 | 78.26 | 0.33 | 80.43 |
| 41 | 842.26 | 8.90 | 75.28 | 19.32 | 836.13 | 19.34 | 81.15 | 0.54 | 83.42 |
| 42 | 861.70 | 8.96 | 77.90 | 19.44 | 855.33 | 19.98 | 84.11 | 0.63 | 86.44 |
| 43 | 881.05 | 8.85 | 78.39 | 19.35 | 874.45 | 20.58 | 87.02 | 0.21 | 89.42 |
| 44 | 900.05 | 8.71 | 77.42 | 19.00 | 893.23 | 21.20 | 89.83 | 0.32 | 92.29 |
| 45 | 919.92 | 8.49 | 77.20 | 19.87 | 912.88 | 21.85 | 92.69 | 0.34 | 95.23 |
| 46 | 939.20 | 8.36 | 77.11 | 19.28 | 931.96 | 22.48 | 95.42 | 0.20 | 98.03 |
| 47 | 958.60 | 8.23 | 76.43 | 19.40 | 951.16 | 23.13 | 98.12 | 0.25 | 100.81 |
| 48 | 998.40 | 7.49 | 76.80 | 39.80 | 990.62 | 24.31 | 103.17 | 0.56 | 106.00 |
| 49 | 1018.15 | 8.20 | 77.42 | 19.75 | 1010.17 | 24.93 | 105.92 | 1.09 | 108.81 |
| 50 | 1038.20 | 8.67 | 77.83 | 20.05 | 1029.99 | 25.56 | 108.88 | 0.71 | 111.83 |
| 51 | 1057.50 | 8.65 | 78.11 | 19.30 | 1049.07 | 26.16 | 111.72 | 0.07 | 114.73 |
| 52 | 1075.90 | 8.56 | 75.70 | 18.40 | 1067.26 | 26.84 | 114.37 | 0.61 | 117.47 |

**Table 5.3** The Results of Tangential Method for the Well J-1 (3/7)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 53 | 1095.39 | 8.52 | 74.49 | 19.49 | 1086.54 | 27.61 | 117.15 | 0.28 | 120.36 |
| 54 | 1113.84 | 8.62 | 73.72 | 18.45 | 1104.78 | 28.39 | 119.81 | 0.25 | 123.12 |
| 55 | 1133.14 | 8.80 | 72.09 | 19.30 | 1123.85 | 29.29 | 122.62 | 0.47 | 126.07 |
| 56 | 1152.40 | 8.31 | 70.51 | 19.26 | 1142.91 | 30.22 | 125.24 | 0.85 | 128.84 |
| 57 | 1172.01 | 8.00 | 71.15 | 19.61 | 1162.33 | 31.10 | 127.83 | 0.49 | 131.56 |
| 58 | 1191.40 | 7.96 | 71.49 | 19.39 | 1181.53 | 31.96 | 130.37 | 0.10 | 134.23 |
| 59 | 1210.58 | 7.73 | 70.09 | 19.18 | 1200.54 | 32.84 | 132.80 | 0.47 | 136.80 |
| 60 | 1230.01 | 7.29 | 69.93 | 19.43 | 1219.81 | 33.68 | 135.11 | 0.68 | 139.25 |
| 61 | 1248.35 | 7.40 | 69.21 | 18.34 | 1238.00 | 34.52 | 137.32 | 0.23 | 141.59 |
| 62 | 1267.80 | 7.09 | 69.92 | 19.45 | 1257.30 | 35.34 | 139.58 | 0.50 | 143.98 |
| 63 | 1287.50 | 7.06 | 68.50 | 19.70 | 1276.85 | 36.23 | 141.83 | 0.27 | 146.38 |
| 64 | 1306.55 | 6.85 | 69.27 | 19.05 | 1295.76 | 37.04 | 143.95 | 0.36 | 148.63 |
| 65 | 1325.60 | 7.14 | 70.72 | 19.05 | 1314.67 | 37.82 | 146.19 | 0.53 | 150.99 |
| 66 | 1344.50 | 7.17 | 73.48 | 18.90 | 1333.42 | 38.49 | 148.45 | 0.55 | 153.35 |
| 67 | 1364.47 | 7.01 | 73.16 | 19.97 | 1353.24 | 39.19 | 150.78 | 0.25 | 155.78 |
| 68 | 1382.60 | 7.03 | 72.06 | 18.13 | 1371.23 | 39.88 | 152.89 | 0.22 | 157.99 |
| 69 | 1402.15 | 6.84 | 72.02 | 19.55 | 1390.64 | 40.60 | 155.11 | 0.29 | 160.32 |
| 70 | 1422.25 | 6.85 | 71.53 | 20.10 | 1410.60 | 41.36 | 157.38 | 0.09 | 162.71 |
| 71 | 1441.53 | 6.74 | 71.55 | 19.28 | 1429.75 | 42.07 | 159.53 | 0.17 | 164.96 |
| 72 | 1460.96 | 6.82 | 71.70 | 19.43 | 1449.04 | 42.80 | 161.72 | 0.13 | 167.26 |
| 73 | 1480.19 | 7.74 | 72.49 | 19.23 | 1468.10 | 43.58 | 164.19 | 1.44 | 169.85 |
| 74 | 1499.03 | 8.46 | 73.53 | 18.84 | 1486.73 | 44.36 | 166.85 | 1.17 | 172.61 |
| 75 | 1517.80 | 9.36 | 71.61 | 18.77 | 1505.25 | 45.33 | 169.74 | 1.51 | 175.66 |
| 76 | 1536.70 | 10.15 | 70.96 | 18.90 | 1523.85 | 46.41 | 172.89 | 1.27 | 178.97 |
| 77 | 1556.10 | 10.82 | 72.51 | 19.40 | 1542.91 | 47.51 | 176.37 | 1.12 | 182.61 |
| 78 | 1576.32 | 11.63 | 75.94 | 20.22 | 1562.71 | 48.50 | 180.32 | 1.56 | 186.69 |
| 79 | 1595.69 | 12.32 | 78.04 | 19.37 | 1581.64 | 49.35 | 184.36 | 1.26 | 190.82 |

**Table 5.4** The Results of Tangential Method for the Well J-1 (4/7)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 80 | 1614.77 | 12.73 | 79.35 | 19.08 | 1600.25 | 50.13 | 188.50 | 0.78 | 195.01 |
| 81 | 1633.50 | 12.70 | 79.57 | 18.73 | 1618.52 | 50.88 | 192.55 | 0.09 | 199.12 |
| 82 | 1653.40 | 12.85 | 78.68 | 19.90 | 1637.92 | 51.74 | 196.89 | 0.37 | 203.55 |
| 83 | 1672.09 | 12.61 | 77.10 | 18.69 | 1656.16 | 52.66 | 200.86 | 0.68 | 207.63 |
| 84 | 1691.85 | 12.20 | 76.30 | 19.76 | 1675.48 | 53.64 | 204.92 | 0.67 | 211.80 |
| 85 | 1711.27 | 11.79 | 76.44 | 19.42 | 1694.49 | 54.57 | 208.78 | 0.63 | 215.77 |
| 86 | 1729.70 | 11.21 | 76.82 | 18.43 | 1712.56 | 55.39 | 212.27 | 0.95 | 219.35 |
| 87 | 1749.10 | 10.54 | 78.69 | 19.40 | 1731.64 | 56.09 | 215.75 | 1.17 | 222.90 |
| 88 | 1769.01 | 10.45 | 79.94 | 19.91 | 1751.22 | 56.72 | 219.30 | 0.37 | 226.50 |
| 89 | 1788.30 | 10.60 | 80.28 | 19.29 | 1770.18 | 57.32 | 222.80 | 0.25 | 230.04 |
| 90 | 1806.80 | 10.74 | 79.80 | 18.50 | 1788.35 | 57.93 | 226.19 | 0.27 | 233.48 |
| 91 | 1826.98 | 10.33 | 78.93 | 20.18 | 1808.21 | 58.62 | 229.74 | 0.65 | 237.10 |
| 92 | 1845.13 | 10.69 | 78.73 | 18.15 | 1826.04 | 59.28 | 233.04 | 0.60 | 240.46 |
| 93 | 1864.30 | 11.07 | 78.99 | 19.17 | 1844.85 | 59.98 | 236.66 | 0.60 | 244.14 |
| 94 | 1884.02 | 11.08 | 79.44 | 19.72 | 1864.21 | 60.68 | 240.38 | 0.13 | 247.92 |
| 95 | 1903.77 | 11.01 | 79.44 | 19.75 | 1883.59 | 61.37 | 244.09 | 0.11 | 251.68 |
| 96 | 1922.75 | 10.43 | 79.65 | 18.98 | 1902.26 | 61.99 | 247.47 | 0.92 | 255.11 |
| 97 | 1941.45 | 10.16 | 80.00 | 18.70 | 1920.67 | 62.56 | 250.72 | 0.44 | 258.41 |
| 98 | 1961.75 | 9.62 | 81.66 | 20.30 | 1940.68 | 63.05 | 254.08 | 0.90 | 261.78 |
| 99 | 1981.15 | 9.10 | 82.85 | 19.40 | 1959.84 | 63.43 | 257.12 | 0.86 | 264.83 |
| 100 | 1999.95 | 8.87 | 80.94 | 18.80 | 1978.41 | 63.89 | 259.98 | 0.60 | 267.72 |
| 101 | 2018.66 | 8.48 | 75.67 | 18.71 | 1996.92 | 64.57 | 262.66 | 1.42 | 270.48 |
| 102 | 2037.87 | 8.41 | 73.78 | 19.21 | 2015.92 | 65.36 | 265.35 | 0.45 | 273.28 |
| 103 | 2057.66 | 7.99 | 73.78 | 19.79 | 2035.52 | 66.13 | 268.00 | 0.64 | 276.03 |
| 104 | 2076.90 | 8.25 | 70.08 | 19.24 | 2054.56 | 67.07 | 270.59 | 0.91 | 278.78 |
| 105 | 2095.98 | 8.89 | 65.80 | 19.08 | 2073.41 | 68.28 | 273.28 | 1.42 | 281.68 |
| 106 | 2115.82 | 9.31 | 64.46 | 19.84 | 2092.99 | 69.66 | 276.18 | 0.71 | 284.82 |

**Table 5.5** The Results of Tangential Method for the Well J-1 (5/7)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 107 | 2134.69 | 9.45 | 63.20 | 18.87 | 2111.60 | 71.06 | 278.94 | 0.40 | 287.84 |
| 108 | 2153.82 | 9.23 | 62.40 | 19.13 | 2130.49 | 72.48 | 281.66 | 0.40 | 290.82 |
| 109 | 2173.95 | 9.88 | 63.26 | 20.13 | 2150.32 | 74.03 | 284.75 | 0.99 | 294.19 |
| 110 | 2193.25 | 9.84 | 68.00 | 19.30 | 2169.33 | 75.27 | 287.80 | 1.26 | 297.45 |
| 111 | 2212.60 | 8.84 | 71.85 | 19.35 | 2188.45 | 76.19 | 290.63 | 1.83 | 300.42 |
| 112 | 2231.73 | 8.47 | 74.84 | 19.13 | 2207.37 | 76.93 | 293.35 | 0.91 | 303.23 |
| 113 | 2250.62 | 8.35 | 75.48 | 18.89 | 2226.06 | 77.62 | 296.01 | 0.24 | 305.98 |
| 114 | 2257.39 | 8.42 | 76.36 | 6.77 | 2232.76 | 77.85 | 296.97 | 0.65 | 306.97 |
| 115 | 2291.55 | 8.70 | 75.68 | 34.16 | 2266.53 | 79.13 | 301.98 | 0.26 | 312.14 |
| 116 | 2309.98 | 8.78 | 73.74 | 18.43 | 2284.74 | 79.92 | 304.68 | 0.50 | 314.95 |
| 117 | 2329.15 | 8.89 | 75.15 | 19.17 | 2303.68 | 80.68 | 307.54 | 0.38 | 317.91 |
| 118 | 2349.15 | 8.60 | 81.03 | 20.00 | 2323.46 | 81.14 | 310.49 | 1.41 | 320.89 |
| 119 | 2368.82 | 8.05 | 81.16 | 19.67 | 2342.93 | 81.57 | 313.22 | 0.84 | 323.63 |
| 120 | 2389.12 | 6.97 | 81.16 | 20.30 | 2363.08 | 81.94 | 315.65 | 1.60 | 326.09 |
| 121 | 2407.15 | 7.13 | 79.82 | 18.03 | 2380.97 | 82.34 | 317.85 | 0.38 | 328.32 |
| 122 | 2426.50 | 7.77 | 77.10 | 19.35 | 2400.15 | 82.92 | 320.40 | 1.13 | 330.94 |
| 123 | 2444.95 | 7.58 | 74.61 | 18.45 | 2418.44 | 83.57 | 322.75 | 0.62 | 333.37 |
| 124 | 2464.60 | 7.46 | 75.03 | 19.65 | 2437.92 | 84.23 | 325.21 | 0.20 | 335.92 |
| 125 | 2484.05 | 7.40 | 75.29 | 19.45 | 2457.21 | 84.87 | 327.64 | 0.11 | 338.42 |
| 126 | 2503.53 | 7.31 | 75.29 | 19.48 | 2476.53 | 85.49 | 330.03 | 0.14 | 340.90 |
| 127 | 2523.41 | 8.42 | 71.28 | 19.88 | 2496.19 | 86.43 | 332.79 | 1.87 | 343.80 |
| 128 | 2542.46 | 9.17 | 70.50 | 19.05 | 2515.00 | 87.44 | 335.65 | 1.20 | 346.82 |
| 129 | 2560.67 | 8.77 | 70.15 | 18.21 | 2533.00 | 88.39 | 338.26 | 0.67 | 349.58 |
| 130 | 2579.25 | 8.30 | 73.75 | 18.58 | 2551.38 | 89.14 | 340.84 | 1.15 | 352.26 |
| 131 | 2599.30 | 7.94 | 71.14 | 20.05 | 2571.24 | 90.03 | 343.46 | 0.77 | 355.02 |
| 132 | 2618.70 | 7.72 | 70.69 | 19.40 | 2590.47 | 90.89 | 345.92 | 0.35 | 357.62 |
| 133 | 2637.90 | 7.06 | 70.56 | 19.20 | 2609.52 | 91.68 | 348.14 | 1.03 | 359.97 |

**Table 5.6** The Results of Tangential Method for the Well J-1 (6/7)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 134 | 2656.80 | 7.10 | 71.12 | 18.90 | 2628.27 | 92.43 | 350.35 | 0.13 | 362.29 |
| 135 | 2677.79 | 7.85 | 81.40 | 20.99 | 2649.07 | 92.86 | 353.19 | 2.19 | 365.15 |
| 136 | 2695.69 | 8.09 | 83.22 | 17.90 | 2666.79 | 93.16 | 355.69 | 0.58 | 367.65 |
| 137 | 2714.60 | 7.51 | 81.10 | 18.91 | 2685.54 | 93.54 | 358.13 | 1.03 | 370.11 |
| 138 | 2734.80 | 6.79 | 78.64 | 20.20 | 2705.60 | 94.01 | 360.47 | 1.16 | 372.50 |
| 139 | 2753.30 | 6.57 | 76.31 | 18.50 | 2723.97 | 94.51 | 362.53 | 0.57 | 374.61 |
| 140 | 2772.70 | 6.32 | 79.06 | 19.40 | 2743.26 | 94.92 | 364.63 | 0.61 | 376.75 |
| 141 | 2792.20 | 6.36 | 80.62 | 19.50 | 2762.64 | 95.27 | 366.76 | 0.27 | 378.90 |
| 142 | 2811.90 | 6.54 | 80.88 | 19.70 | 2782.21 | 95.63 | 368.97 | 0.28 | 381.14 |
| 143 | 2831.00 | 6.90 | 79.85 | 19.10 | 2801.17 | 96.03 | 371.23 | 0.60 | 383.43 |
| 144 | 2850.10 | 7.00 | 79.32 | 19.10 | 2820.13 | 96.46 | 373.52 | 0.19 | 385.75 |
| 145 | 2869.20 | 7.55 | 75.63 | 19.10 | 2839.06 | 97.09 | 375.95 | 1.13 | 388.26 |
| 146 | 2889.10 | 7.67 | 71.92 | 19.90 | 2858.78 | 97.91 | 378.48 | 0.76 | 390.91 |
| 147 | 2907.10 | 8.29 | 71.99 | 18.00 | 2876.60 | 98.71 | 380.94 | 1.03 | 393.50 |
| 148 | 2927.00 | 7.94 | 76.84 | 19.90 | 2896.31 | 99.34 | 383.62 | 1.16 | 396.24 |
| 149 | 2946.20 | 8.15 | 84.40 | 19.20 | 2915.31 | 99.60 | 386.33 | 1.68 | 398.94 |
| 150 | 2965.50 | 8.26 | 86.78 | 19.30 | 2934.41 | 99.76 | 389.10 | 0.55 | 401.66 |
| 151 | 2985.20 | 8.06 | 88.76 | 19.70 | 2953.92 | 99.82 | 391.86 | 0.53 | 404.36 |
| 152 | 3004.60 | 8.12 | 87.84 | 19.40 | 2973.12 | 99.92 | 394.60 | 0.22 | 407.04 |
| 153 | 3023.20 | 8.17 | 83.25 | 18.60 | 2991.53 | 100.23 | 397.22 | 1.05 | 409.67 |
| 154 | 3041.00 | 8.33 | 81.29 | 17.80 | 3009.15 | 100.62 | 399.77 | 0.55 | 412.24 |
| 155 | 3062.20 | 8.03 | 80.24 | 21.20 | 3030.14 | 101.13 | 402.69 | 0.47 | 415.19 |
| 156 | 3081.00 | 7.55 | 77.11 | 18.80 | 3048.77 | 101.68 | 405.10 | 1.02 | 417.66 |
| 157 | 3100.60 | 8.34 | 70.04 | 19.60 | 3068.17 | 102.65 | 407.77 | 1.92 | 420.49 |
| 158 | 3119.80 | 8.69 | 71.09 | 19.20 | 3087.15 | 103.59 | 410.51 | 0.60 | 423.37 |
| 159 | 3139.40 | 8.77 | 69.53 | 19.60 | 3106.52 | 104.63 | 413.31 | 0.38 | 426.34 |
| 160 | 3158.60 | 8.60 | 68.25 | 19.20 | 3125.50 | 105.70 | 415.98 | 0.40 | 429.19 |

**Table 5.7** The Results of Tangential Method for the Well J-1 (7/7)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 161 | 3178.10 | 8.94 | 72.37 | 19.50 | 3144.77 | 106.61 | 418.87 | 1.10 | 432.21 |
| 162 | 3196.90 | 8.55 | 68.96 | 18.80 | 3163.36 | 107.62 | 421.48 | 1.03 | 434.98 |
| 163 | 3216.30 | 8.29 | 64.56 | 19.40 | 3182.55 | 108.82 | 424.00 | 1.07 | 437.72 |
| 164 | 3235.10 | 8.64 | 64.78 | 18.80 | 3201.14 | 110.02 | 426.56 | 0.56 | 440.49 |
| 165 | 3254.70 | 8.66 | 68.29 | 19.60 | 3220.52 | 111.11 | 429.30 | 0.81 | 443.41 |
| 166 | 3274.00 | 8.13 | 68.13 | 19.30 | 3239.62 | 112.13 | 431.83 | 0.82 | 446.12 |
| 167 | 3294.00 | 7.66 | 65.76 | 20.00 | 3259.44 | 113.23 | 434.26 | 0.86 | 448.74 |
| 168 | 3313.20 | 7.41 | 66.80 | 19.20 | 3278.48 | 114.20 | 436.54 | 0.44 | 451.18 |
| 169 | 3332.60 | 7.94 | 63.91 | 19.40 | 3297.70 | 115.38 | 438.95 | 1.01 | 453.80 |
| 170 | 3351.60 | 8.14 | 64.24 | 19.00 | 3316.51 | 116.55 | 441.37 | 0.32 | 456.43 |
| 171 | 3370.10 | 8.24 | 67.37 | 18.50 | 3334.82 | 117.57 | 443.82 | 0.74 | 459.05 |
| 172 | 3390.00 | 8.23 | 62.04 | 19.90 | 3354.51 | 118.90 | 446.33 | 1.15 | 461.82 |
| 173 | 3409.40 | 8.76 | 57.94 | 19.40 | 3373.68 | 120.47 | 448.84 | 1.24 | 464.62 |
| 174 | 3428.70 | 8.89 | 56.93 | 19.30 | 3392.75 | 122.10 | 451.34 | 0.31 | 467.44 |
| 175 | 3447.70 | 8.65 | 54.78 | 19.00 | 3411.54 | 123.75 | 453.67 | 0.64 | 470.10 |
| 176 | 3467.10 | 8.45 | 50.48 | 19.40 | 3430.73 | 125.56 | 455.87 | 1.04 | 472.67 |
| 177 | 3486.40 | 8.48 | 46.49 | 19.30 | 3449.81 | 127.52 | 457.93 | 0.91 | 475.14 |
| 178 | 3505.60 | 8.40 | 41.88 | 19.20 | 3468.81 | 129.61 | 459.81 | 1.06 | 477.46 |
| 179 | 3525.00 | 8.10 | 37.73 | 19.40 | 3488.02 | 131.77 | 461.48 | 1.03 | 479.60 |
| 180 | 3544.30 | 8.20 | 33.87 | 19.30 | 3507.12 | 134.06 | 463.01 | 0.86 | 481.63 |
| 181 | 3563.70 | 8.07 | 28.07 | 19.40 | 3526.33 | 136.46 | 464.30 | 1.28 | 483.45 |
| 182 | 3582.90 | 8.26 | 22.85 | 19.20 | 3545.33 | 139.00 | 465.37 | 1.20 | 485.10 |
| 183 | 3605.00 | 8.32 | 17.17 | 22.10 | 3567.19 | 142.06 | 466.31 | 1.11 | 486.75 |

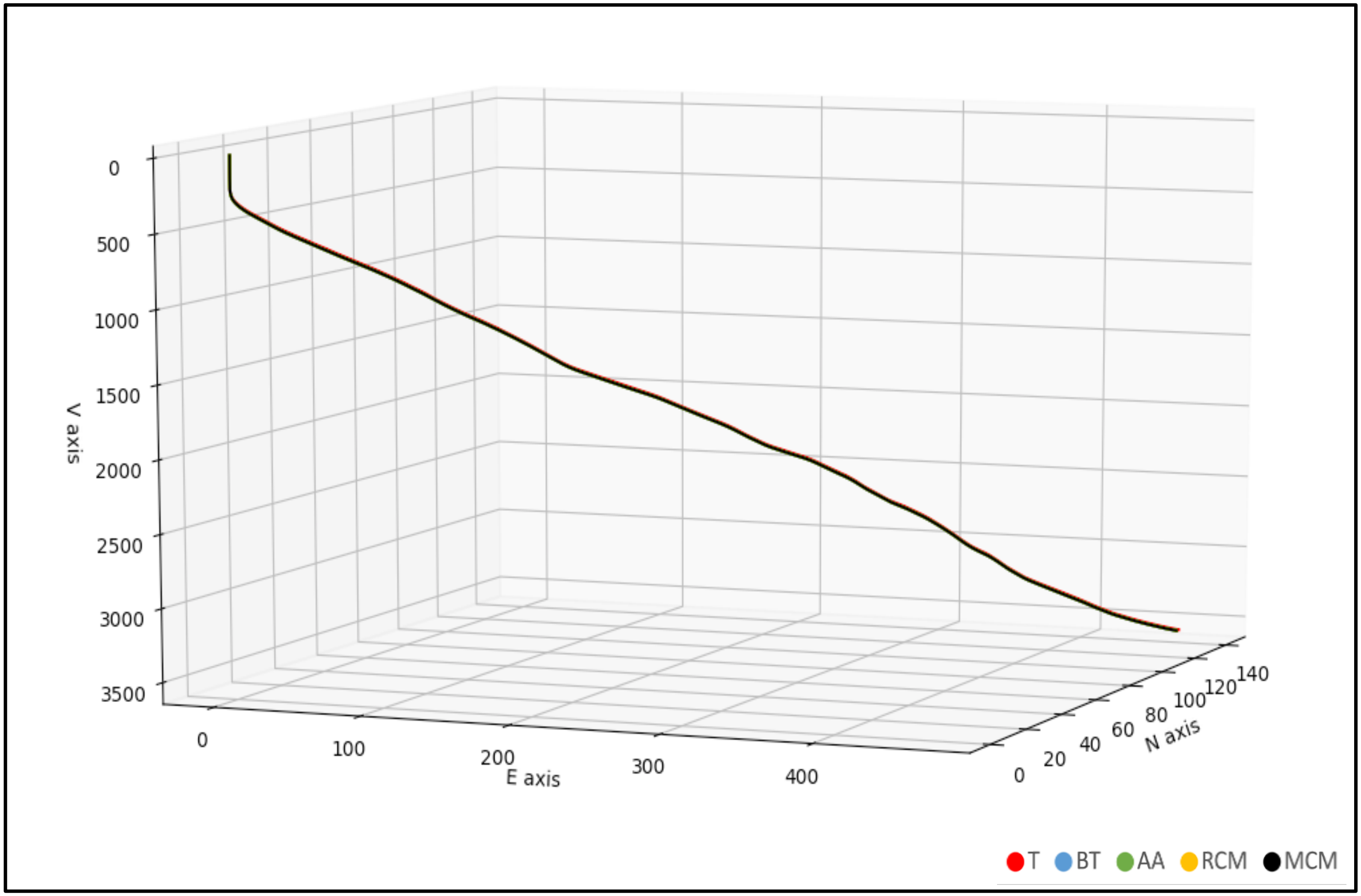


**Figure 5.1** Plot of the Well J-1

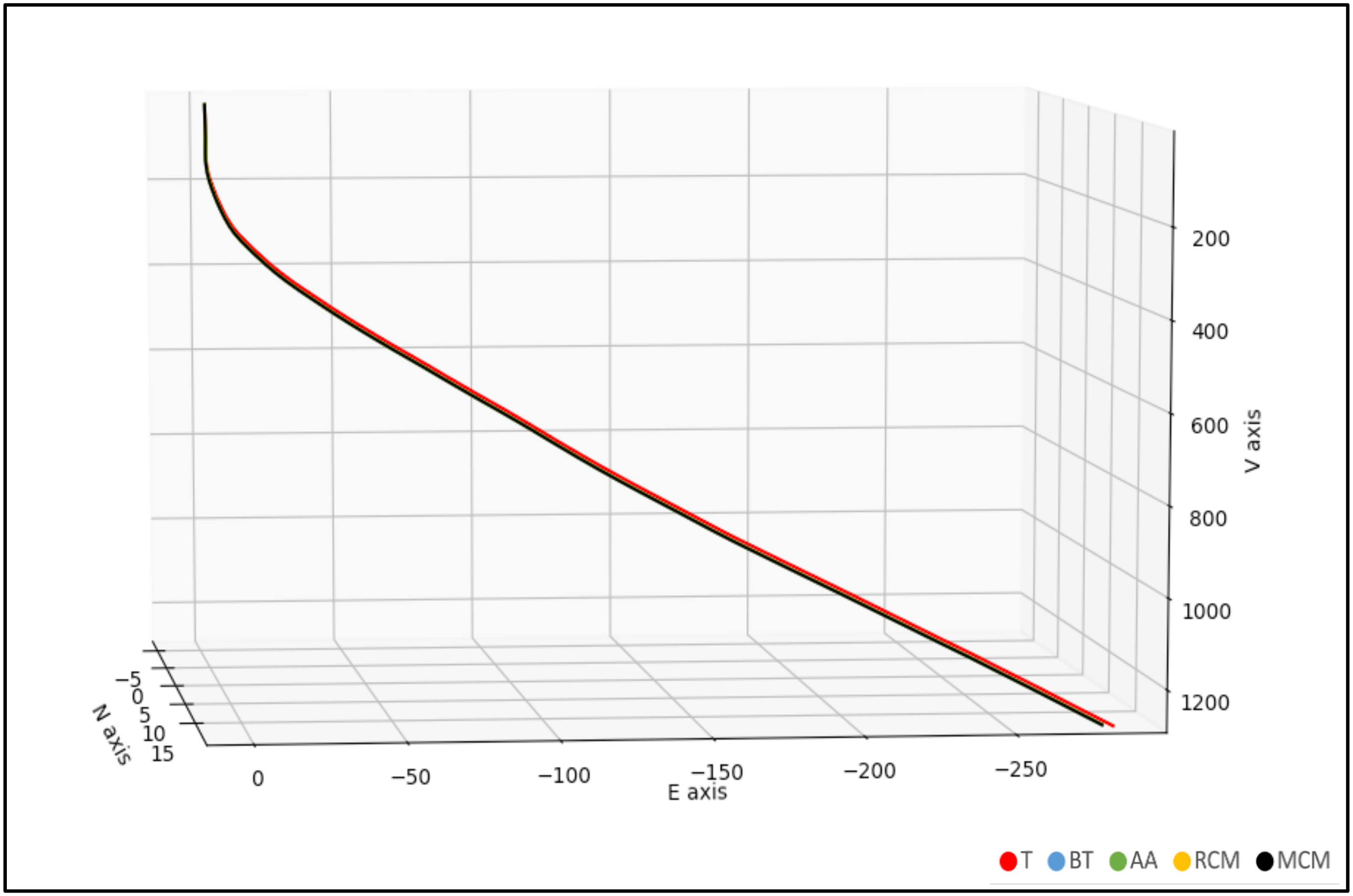


**Figure 5.2** Plot of the Well J-2

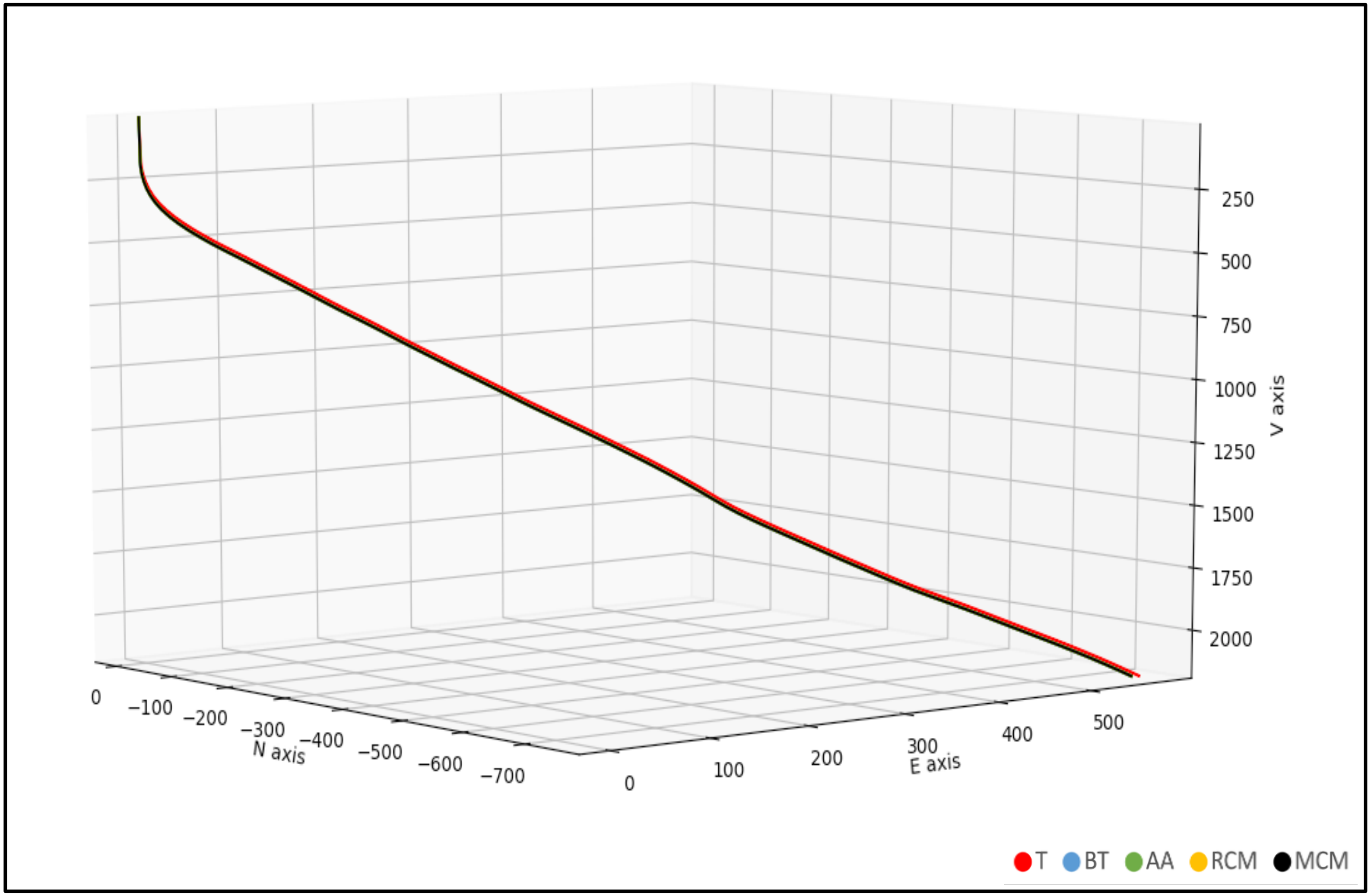


**Figure 5.3** Plot of the Well J-3

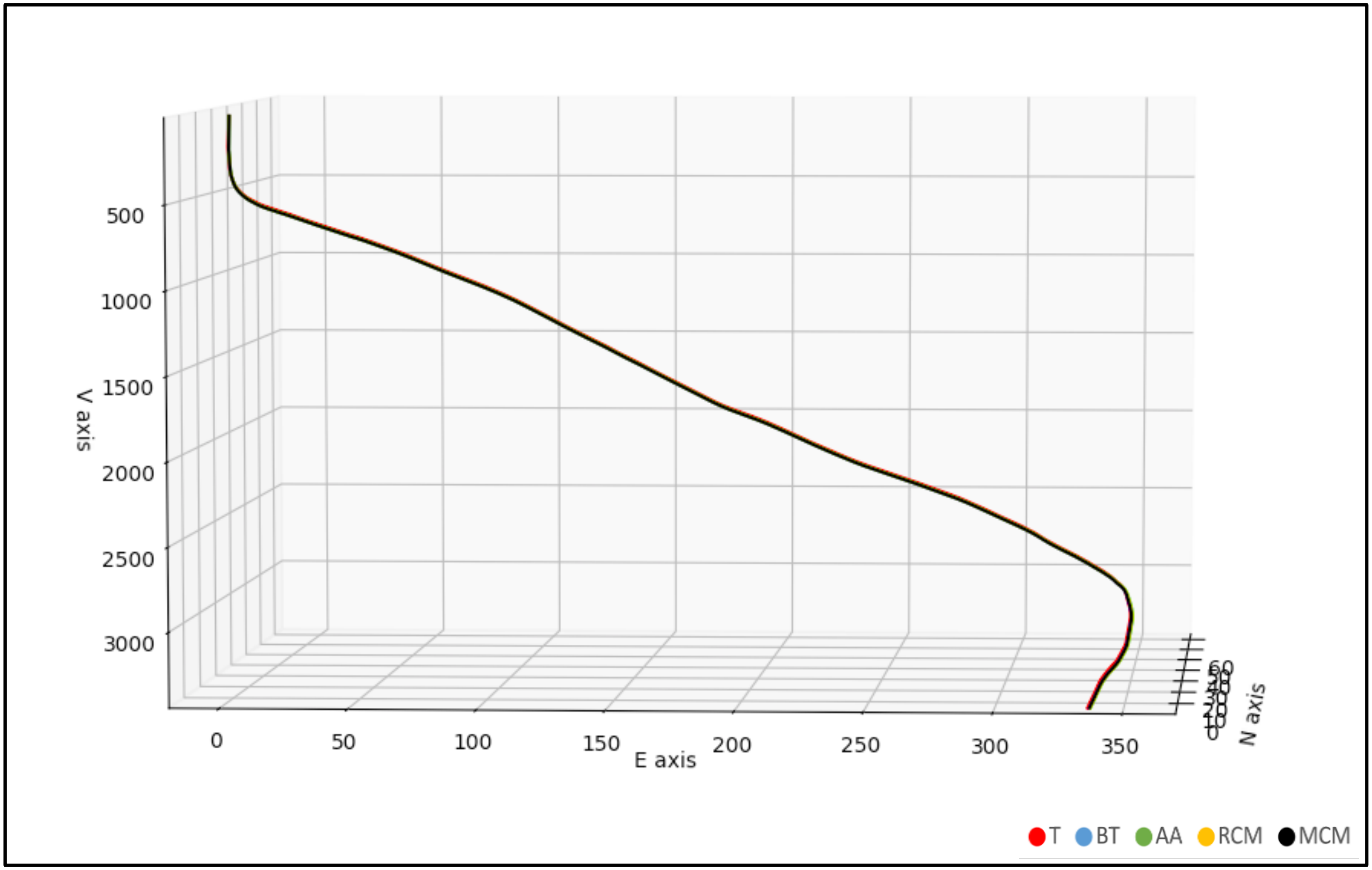


**Figure 5.4** Plot of the Well S-1

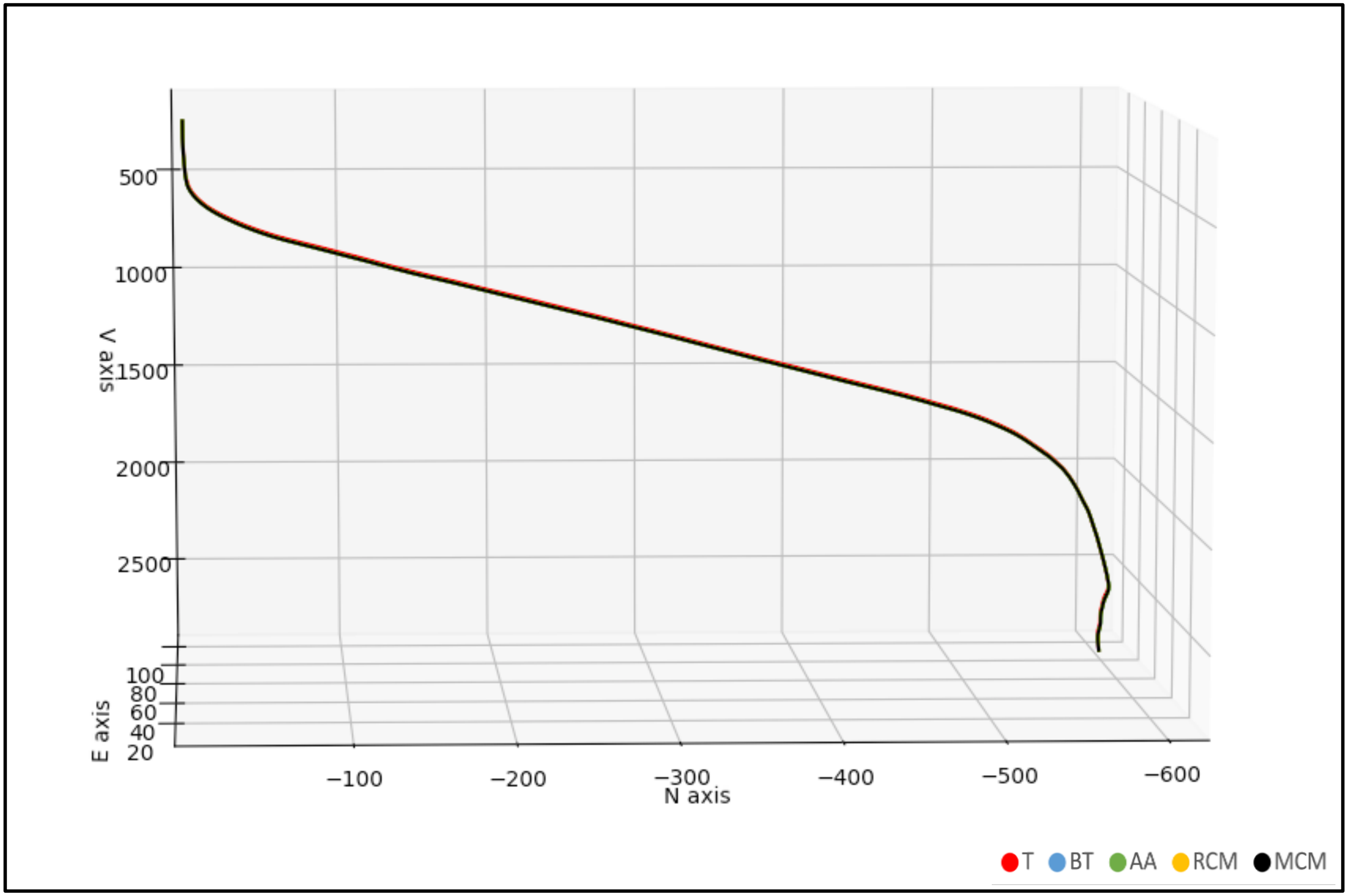


**Figure 5.5** Plot of the Well S-2

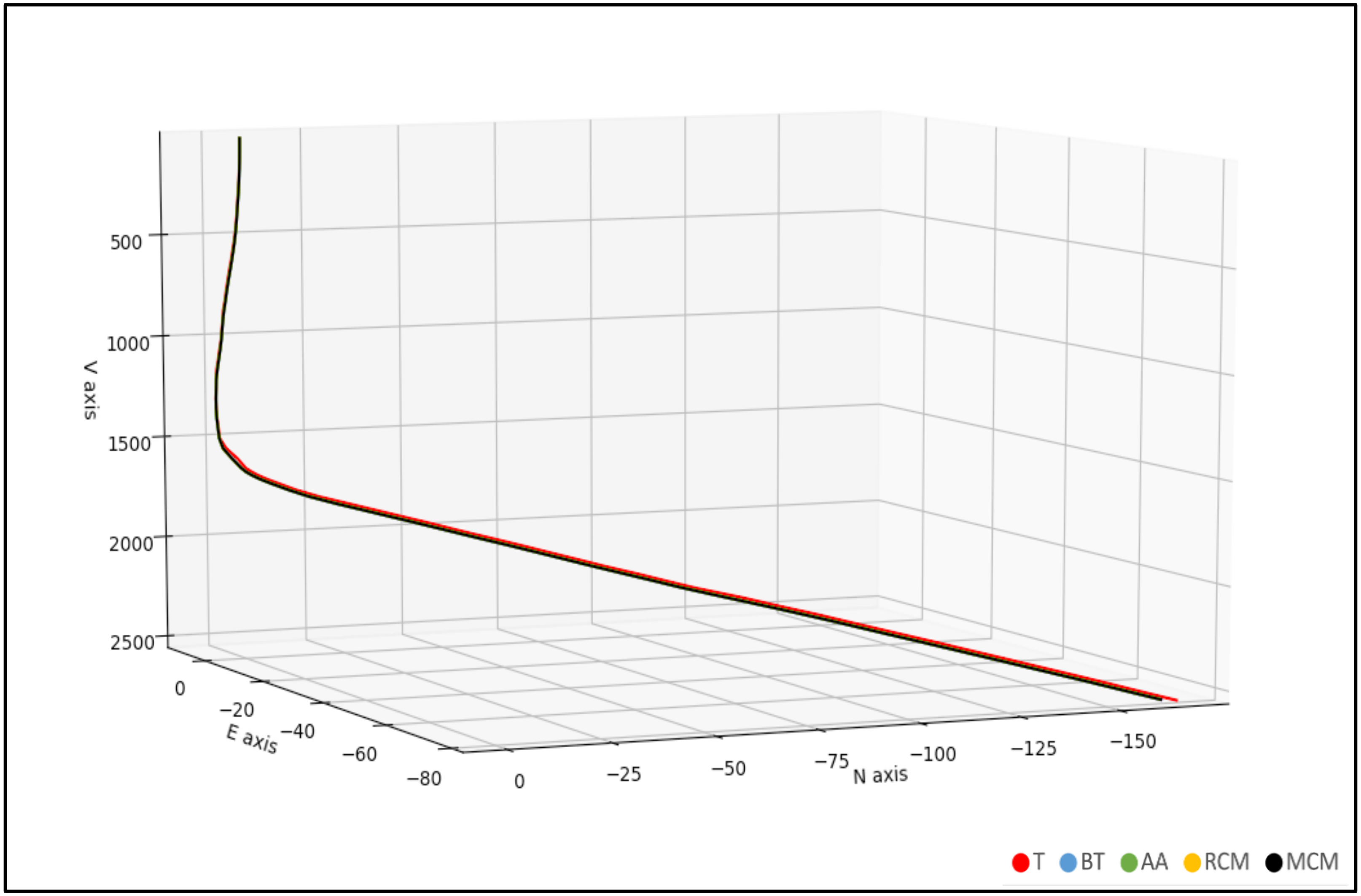


**Figure 5.6** Plot of the Well DKO-1

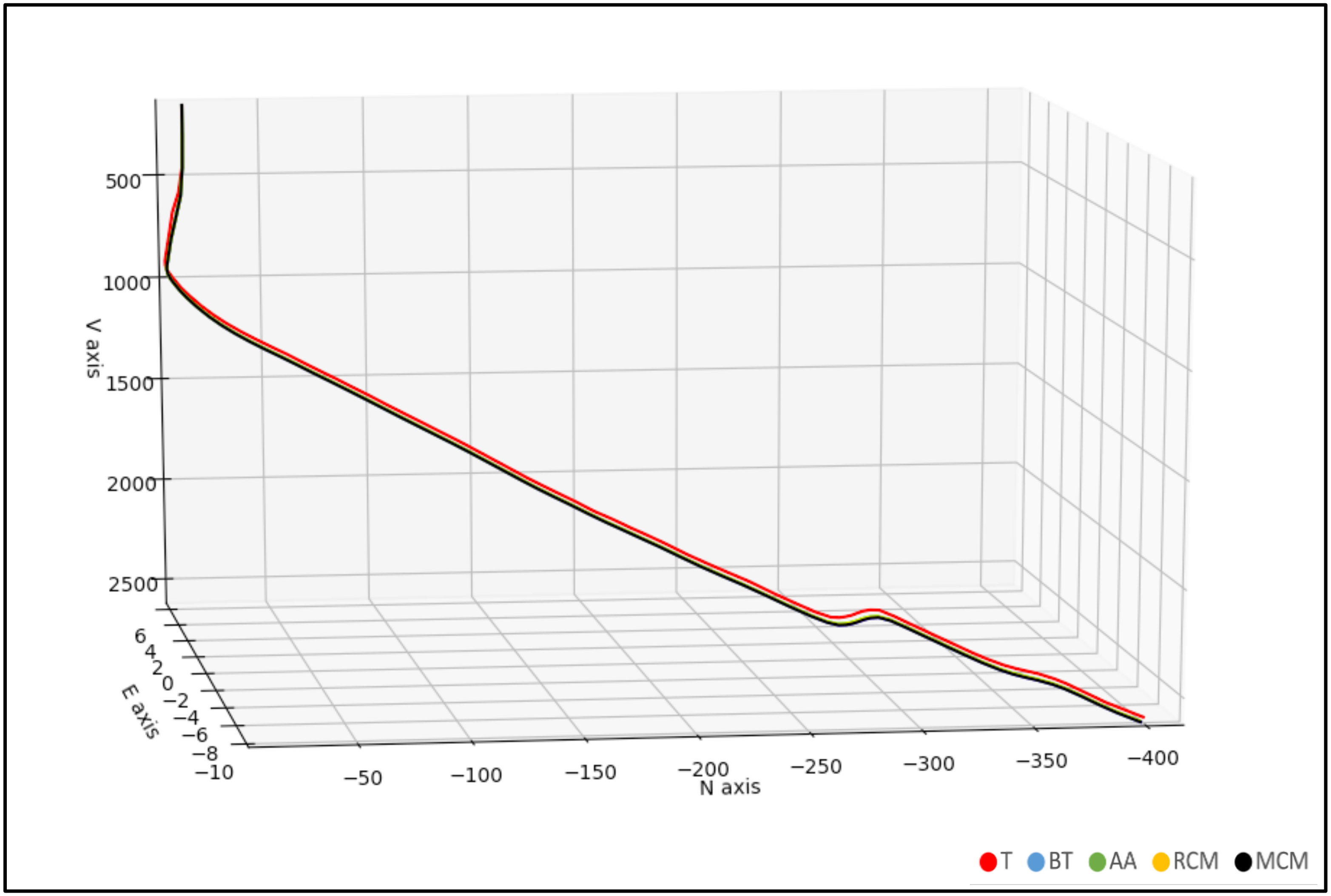


**Figure 5.7** Plot of the Well DKO-2

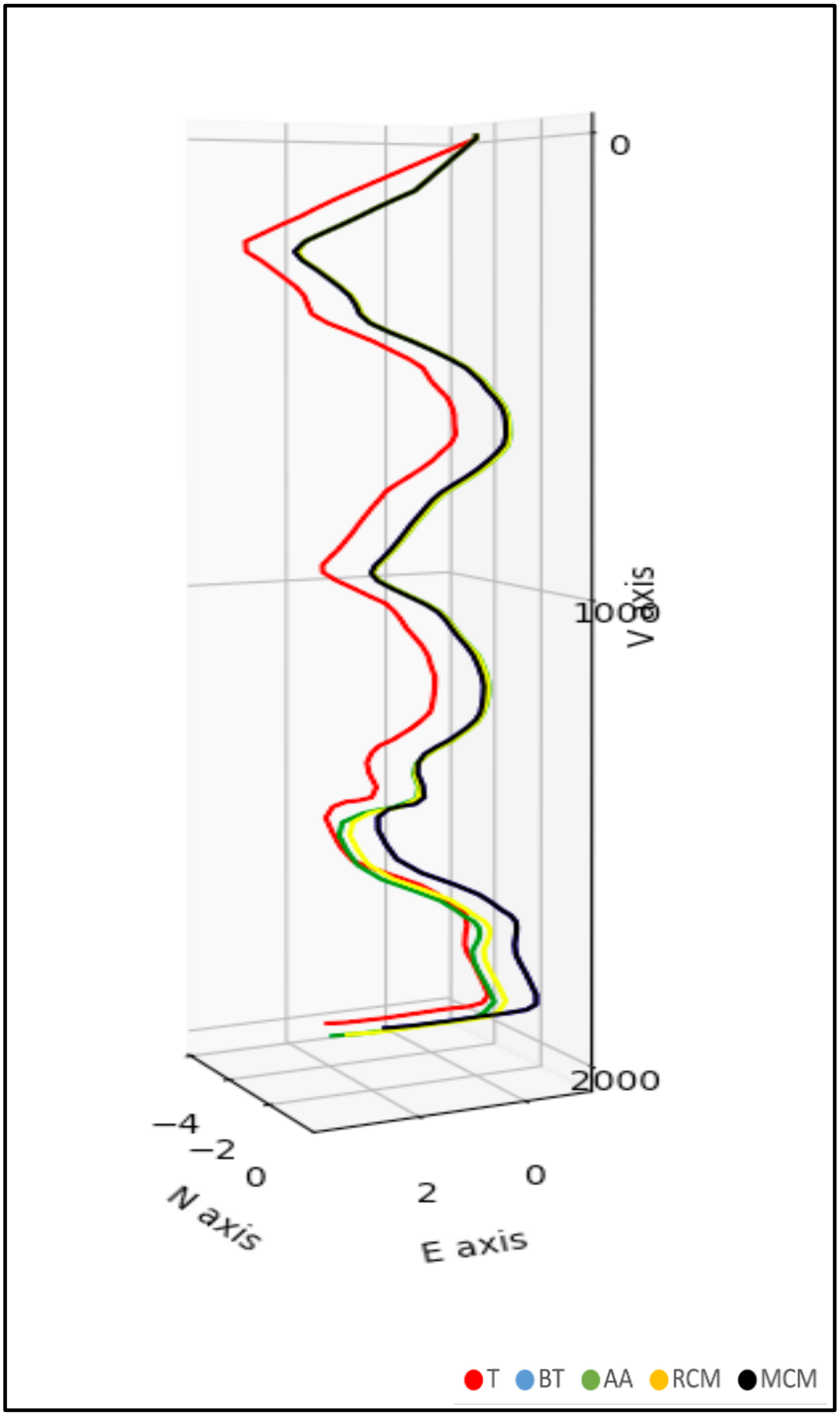


**Figure 5.8** Plot of the Well V-1

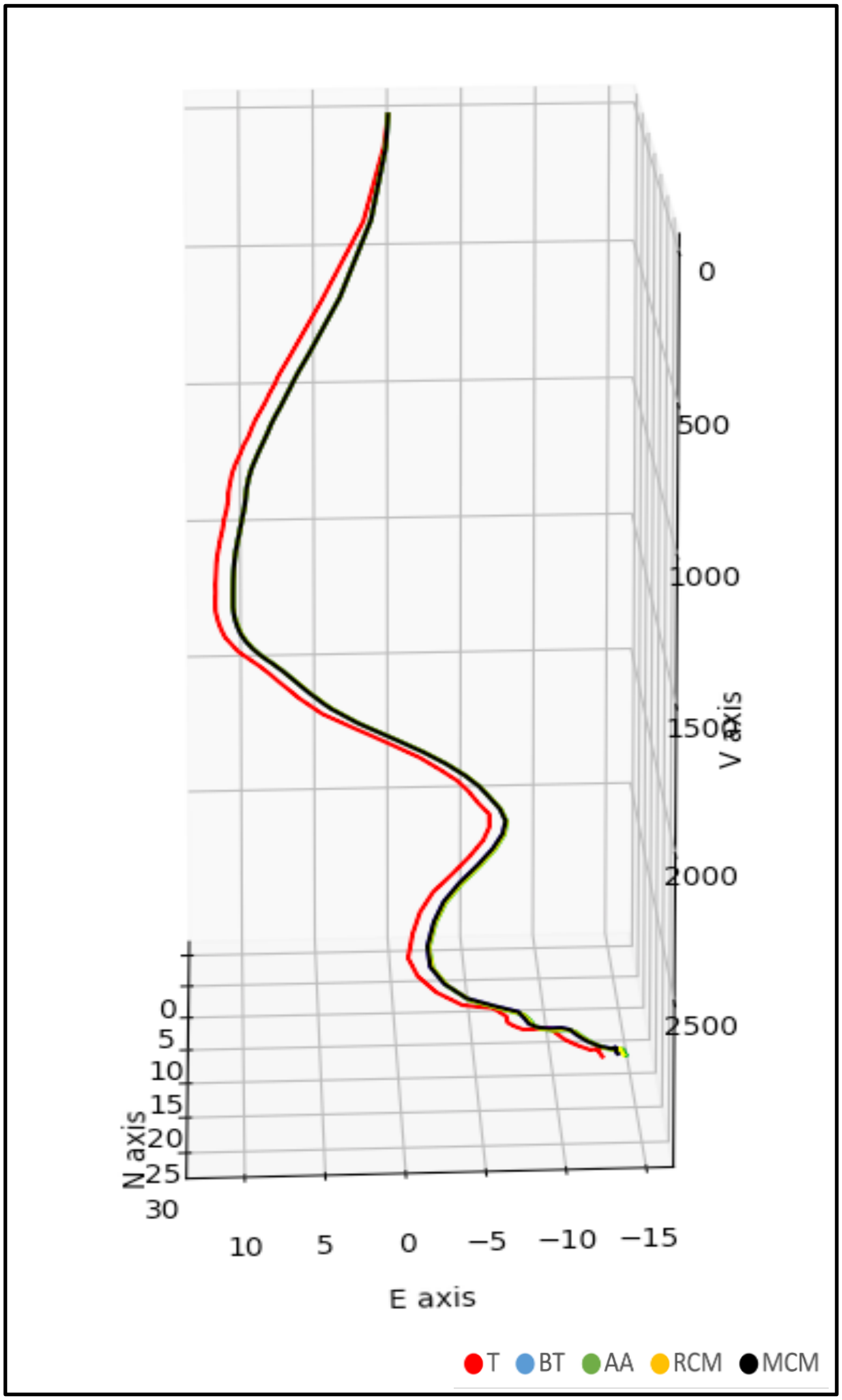


**Figure 5.9** Plot of the Well V-2

**Table 5.8** Summary Results of the Well J-1

| Well No | Well Name | INPUT | | | | METHOD | OUTPUT | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | MD | Inc | Az | VSA | | TVD | Diff on TVD | Local N | Diff on N | Local E | Diff on E | VS | Diff on VS |
| 1 | J-1 | 3605,00 | 8,32 | 17,17 | 76,18 | T | 3567,19 | 0,15 | 142,06 | -1,22 | 466,31 | -0,26 | 486,75 | -0,55 |
| | | | | | | BT | 3567,28 | 0,06 | 140,84 | 0,00 | 466,04 | 0,01 | 486,19 | 0,01 |
| | | | | | | AA | 3567,30 | 0,04 | 140,81 | 0,03 | 466,15 | -0,10 | 486,29 | -0,09 |
| | | | | | | RCM | 3567,29 | 0,05 | 140,81 | 0,03 | 466,11 | -0,06 | 486,26 | -0,06 |
| | | | | | | MCM | 3567,34 | 0,00 | 140,84 | 0,00 | 466,05 | 0,00 | 486,20 | 0,00 |



**Table 5.9** Summary Results of the Well J-2

| Well No | Well Name | INPUT | | | | METHOD | OUTPUT | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | MD | Inc | Az | VSA | | TVD | Diff on TVD | Local N | Diff on N | Local E | Diff on E | VS | Diff on VS |
| 2 | J-2 | 1327,50 | 17,78 | 276,90 | 274,08 | T | 1288,54 | 0,52 | 19,19 | -0,37 | -284,55 | 3,05 | 285,20 | -3,08 |
| | | | | | | BT | 1289,03 | 0,03 | 18,82 | 0,00 | -281,49 | -0,01 | 282,11 | 0,01 |
| | | | | | | AA | 1289,04 | 0,02 | 18,77 | 0,05 | -281,59 | 0,09 | 282,21 | -0,09 |
| | | | | | | RCM | 1289,04 | 0,02 | 18,78 | 0,04 | -281,56 | 0,06 | 282,18 | -0,06 |
| | | | | | | MCM | 1289,06 | 0,00 | 18,82 | 0,00 | -281,50 | 0,00 | 282,12 | 0,00 |

**Table 5.10** Summary Results of the Well J-3

| Well No | Well Name | INPUT | | | | METHOD | OUTPUT | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | MD | Inc | Az | VSA | | TVD | Diff on TVD | Local N | Diff on N | Local E | Diff on E | VS | Diff on VS |
| 3 | J-3 | 2412,00 | 27,39 | 142,30 | 141,97 | T | 2186,50 | 1,74 | -747,66 | 5,89 | 581,07 | -4,18 | 946,91 | -7,22 |
| | | | | | | BT | 2188,15 | 0,09 | -741,74 | -0,03 | 576,87 | 0,02 | 939,66 | 0,03 |
| | | | | | | AA | 2188,24 | 0,00 | -741,82 | 0,05 | 576,92 | -0,03 | 939,75 | -0,06 |
| | | | | | | RCM | 2188,21 | 0,03 | -741,80 | 0,03 | 576,90 | -0,01 | 939,72 | -0,03 |
| | | | | | | MCM | 2188,24 | 0,00 | -741,77 | 0,00 | 576,89 | 0,00 | 939,69 | 0,00 |

**Table 5.11** Summary Results of the Well S-1

| Well No | Well Name | INPUT | | | | METHOD | OUTPUT | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | MD | Inc | Az | VSA | | TVD | Diff on TVD | Local N | Diff on N | Local E | Diff on E | VS | Diff on VS |
| 4 | S-1 | 3477,00 | 3,17 | 217,11 | 91,89 | T | 3439,41 | 0,10 | -5,33 | 0,14 | 336,10 | 0,75 | 336,09 | 0,75 |
| | | | | | | BT | 3439,41 | 0,10 | -5,19 | 0,00 | 336,84 | 0,01 | 336,83 | 0,01 |
| | | | | | | AA | 3439,44 | 0,07 | -5,12 | -0,07 | 337,19 | -0,34 | 337,17 | -0,33 |
| | | | | | | RCM | 3439,43 | 0,08 | -5,15 | -0,04 | 337,13 | -0,28 | 337,12 | -0,28 |
| | | | | | | MCM | 3439,51 | 0,00 | -5,19 | 0,00 | 336,85 | 0,00 | 336,84 | 0,00 |

**Table 5.12** Summary Results of the Well S-2

| Well No | Well Name | INPUT | | | | METHOD | OUTPUT | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | MD | Inc | Az | VSA | | TVD | Diff on TVD | Local N | Diff on N | Local E | Diff on E | VS | Diff on VS |
| 5 | S-2 | 3101,00 | 2,23 | 133,50 | 170,30 | T | 2991,70 | 0,01 | -614,95 | 0,06 | 111,41 | -0,14 | 624,93 | -0,08 |
| | | | | | | BT | 2991,62 | 0,09 | -614,87 | -0,02 | 111,27 | 0,00 | 624,83 | 0,02 |
| | | | | | | AA | 2991,66 | 0,05 | -615,10 | 0,21 | 111,50 | -0,23 | 625,10 | -0,25 |
| | | | | | | RCM | 2991,64 | 0,07 | -615,07 | 0,18 | 111,43 | -0,16 | 625,05 | -0,20 |
| | | | | | | MCM | 2991,71 | 0,00 | -614,89 | 0,00 | 111,27 | 0,00 | 624,85 | 0,00 |

**Table 5.13** Summary Results of the Well DKO-1

| Well No | Well Name | INPUT | | | | METHOD | OUTPUT | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | MD | Inc | Az | VSA | | TVD | Diff on TVD | Local N | Diff on N | Local E | Diff on E | VS | Diff on VS |
| 6 | DKO-1 | 2575,10 | 11,83 | 207,55 | 204,77 | T | 2555,83 | 0,34 | -168,71 | 2,67 | -78,96 | 1,36 | 186,27 | -2,99 |
| | | | | | | BT | 2556,14 | 0,03 | -166,04 | 0,00 | -77,60 | 0,00 | 183,28 | 0,00 |
| | | | | | | AA | 2556,18 | -0,01 | -166,15 | 0,11 | -77,38 | -0,22 | 183,28 | 0,00 |
| | | | | | | RCM | 2556,16 | 0,01 | -166,11 | 0,07 | -77,42 | -0,18 | 183,26 | 0,02 |
| | | | | | | MCM | 2556,17 | 0,00 | -166,04 | 0,00 | -77,60 | 0,00 | 183,28 | 0,00 |

**Table 5.14** Summary Results of the Well DKO-2

| Well No | Well Name | INPUT | | | | METHOD | OUTPUT | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | MD | Inc | Az | VSA | | TVD | Diff on TVD | Local N | Diff on N | Local E | Diff on E | VS | Diff on VS |
| 7 | DKO-2 | 2808,00 | 13,64 | 180,42 | 180,81 | T | 2758,95 | 0,44 | -418,62 | 3,74 | -6,22 | -0,52 | 418,66 | -3,73 |
| | | | | | | BT | 2759,36 | 0,03 | -414,87 | -0,01 | -6,74 | 0,00 | 414,93 | 0,00 |
| | | | | | | AA | 2759,39 | 0,00 | -414,92 | 0,04 | -6,61 | -0,13 | 414,98 | -0,05 |
| | | | | | | RCM | 2759,38 | 0,01 | -414,90 | 0,02 | -6,61 | -0,13 | 414,95 | -0,02 |
| | | | | | | MCM | 2759,39 | 0,00 | -414,88 | 0,00 | -6,74 | 0,00 | 414,93 | 0,00 |

**Table 5.15** Summary Results of the Well V-1

| Well No | Well Name | INPUT | | | | METHOD | OUTPUT | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | MD | Inc | Az | VSA | | TVD | Diff on TVD | Local N | Diff on N | Local E | Diff on E | VS | Diff on VS |
| 8 | V-1 | 2011,60 | 2,24 | 175,54 | 0,00 | T | 2011,26 | 0,06 | -3,74 | 0,91 | 1,35 | -0,78 | -3,74 | 0,91 |
| | | | | | | BT | 2011,27 | 0,05 | -2,83 | 0,00 | 0,57 | 0,00 | -2,83 | 0,00 |
| | | | | | | AA | 2011,29 | 0,03 | -2,78 | -0,05 | 1,63 | -1,06 | -2,78 | -0,05 |
| | | | | | | RCM | 2011,28 | 0,04 | -2,72 | -0,11 | 1,36 | -0,79 | -2,72 | -0,11 |
| | | | | | | MCM | 2011,32 | 0,00 | -2,83 | 0,00 | 0,57 | 0,00 | -2,83 | 0,00 |

**Table 5.16** Summary Results of the Well V-2

| Well No | Well Name | INPUT | | | | METHOD | OUTPUT | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | MD | Inc | Az | VSA | | TVD | Diff on TVD | Local N | Diff on N | Local E | Diff on E | VS | Diff on VS |
| 9 | V-2 | 3000,00 | 1,15 | 204,37 | 0,00 | T | 2998,54 | 0,06 | 20,06 | -0,42 | -13,21 | -1,03 | 20,06 | -0,42 |
| | | | | | | BT | 2998,56 | 0,04 | 19,64 | 0,00 | -14,24 | 0,00 | 19,64 | 0,00 |
| | | | | | | AA | 2998,59 | 0,01 | 19,91 | -0,27 | -14,76 | 0,52 | 19,91 | -0,27 |
| | | | | | | RCM | 2998,58 | 0,02 | 19,86 | -0,22 | -14,62 | 0,38 | 19,86 | -0,22 |
| | | | | | | MCM | 2998,60 | 0,00 | 19,64 | 0,00 | -14,24 | 0,00 | 19,64 | 0,00 |

When the summary results tables are analyzed, we can make the following interpretations.

Firstly, in theory, as the tangential technique utilizes only the inclination and azimuth belonging to the last survey point, it should give good results only if the hole section is holding, i.e. going tangent. When we look at J-1, J-2, and J-3 wells, it can be obviously seen that the errors are increasing with increasing inclination from 8° to 27°. And also increasing doglegs, from 0.70°/30 m to 2.00°/30 m, added on errors since the hole diverges more rapidly. Within all 9 wells, and for each 5 directional survey calculation method; tangential technique for J-3 resulted in the worst errors, while specifying the last point of the well in 3D space. However, with this scenario, around 5-6 m errors, most of the geothermal operator companies would be satisfied because they usually do not target a thin production zone as in oil & gas wells.

When we look at S type wells, S-1 is 12° and S-2 is 23° at their build sections; the errors are almost negligible, relatively. Maximum error is seen on Local East value of S-1 for tangential method, which is less than 1 m; by taking into account geothermal well needs, it seems fairly enough. The reason behind this is that symmetrical S type wells are behaving like a tangent section of a hole. In other words, irrespective of build section inclinations, if an S type well is building and dropping with around same rates or doglegs, like in our cases, the curves are cancelling each other.

In order to see this effect closely, the plot of S-2 well is cut into three parts and zoomed, then provided as below Figure 5.10, 5.11, and 5.12. In Figure 5.10, while building angle, just like a J type well, survey calculation methods begin to diverge from each other; tangent technique is seen obviously. Note that the other methods can only be seen if we divide the plot much more than 3 pieces as the results of the methods are so close. For the sake of example, the plots of V-1 and V-2 wells, Figure 5.8 and 5.9, can be seen for more obvious divergence of the techniques. As for Figure 5.11, since the hole keeping its inclination, i.e. going tangent, the distance of tangent method to others almost does not change. For the last one, in Figure 5.12, the methods are converging to each other. In this drop section of the hole, they are canceling out what they gain from the build part.

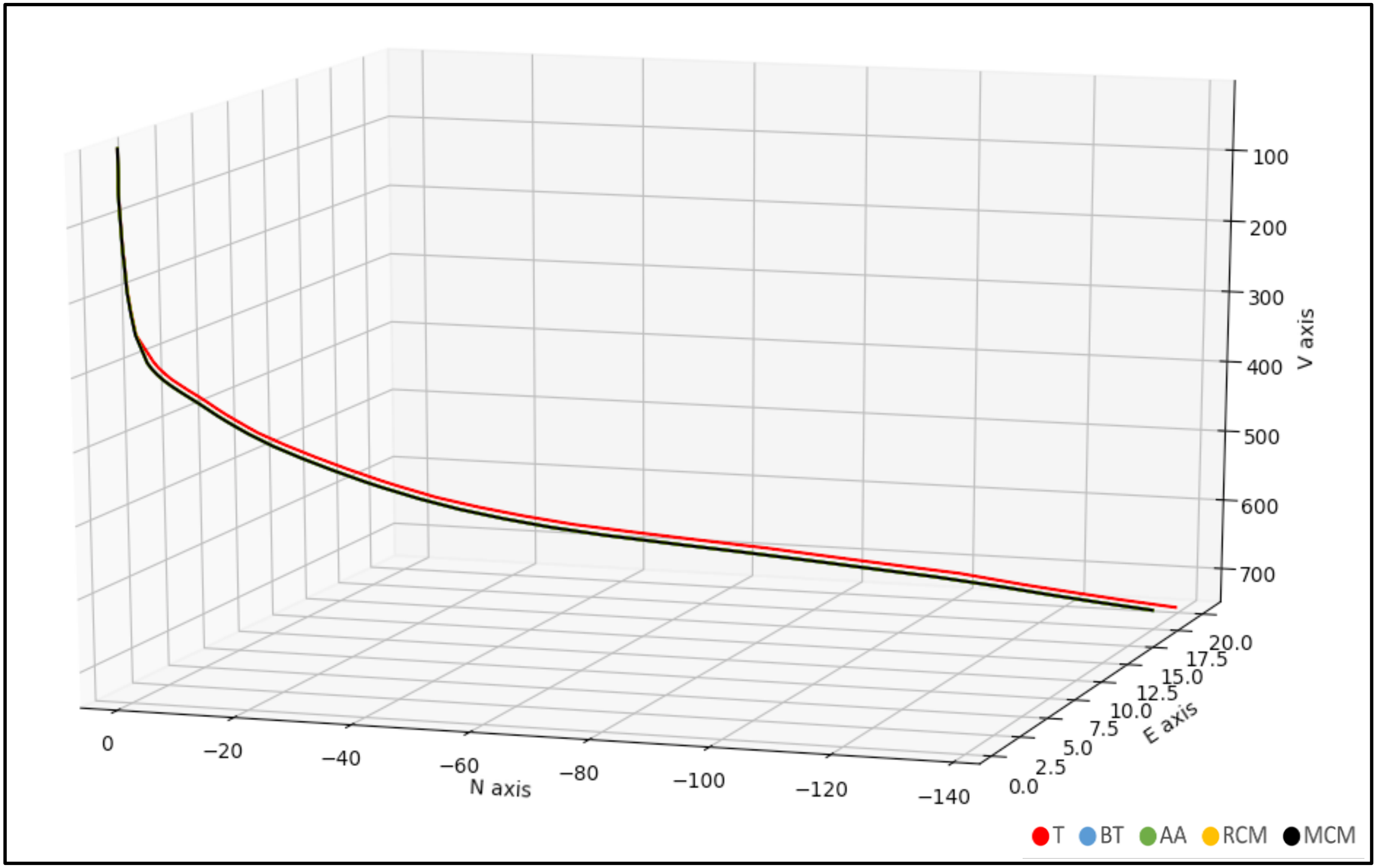


**Figure 5.10** Build Section of the Well S-2

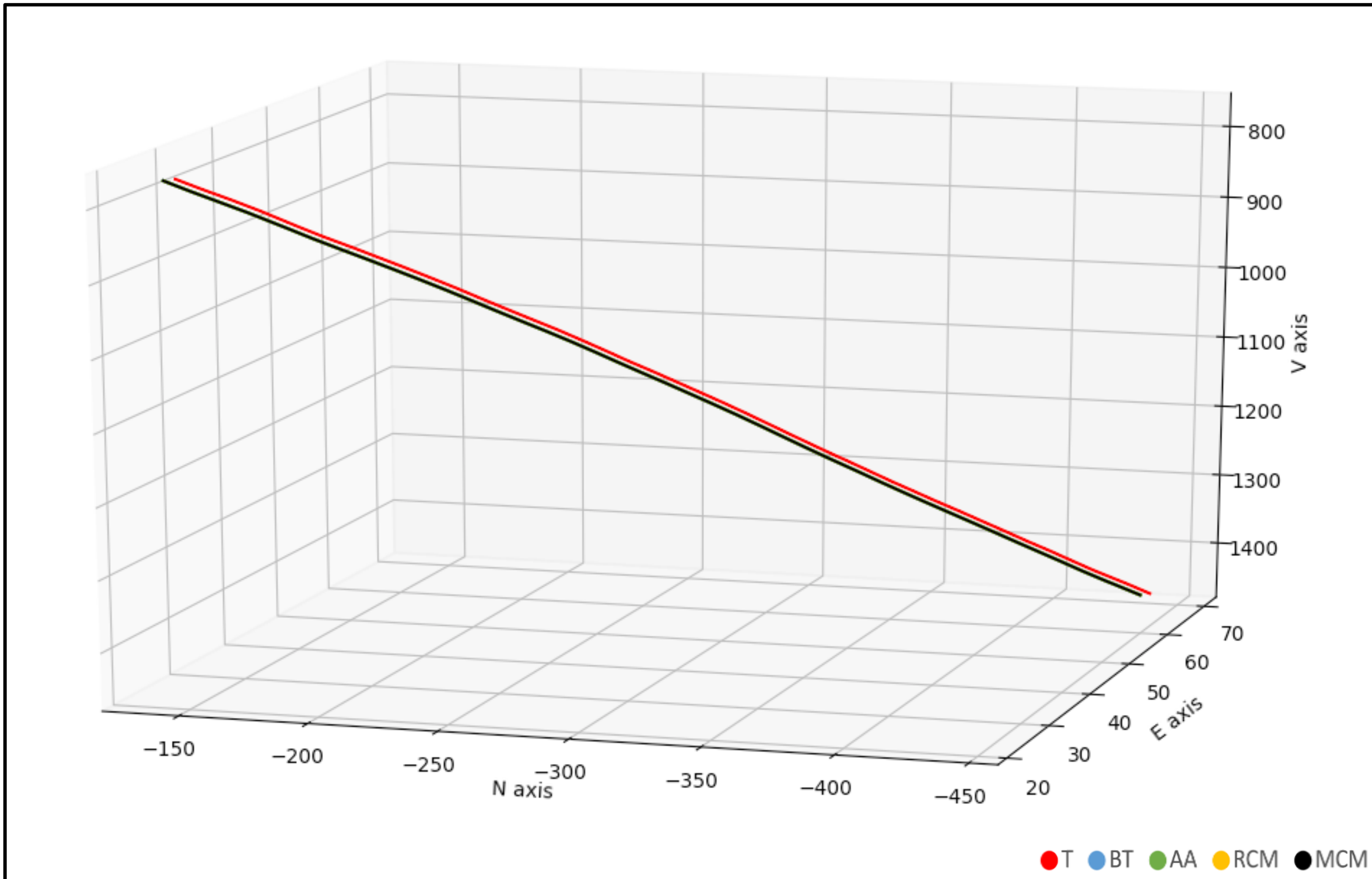


**Figure 5.11** Tangent Section of the Well S-2

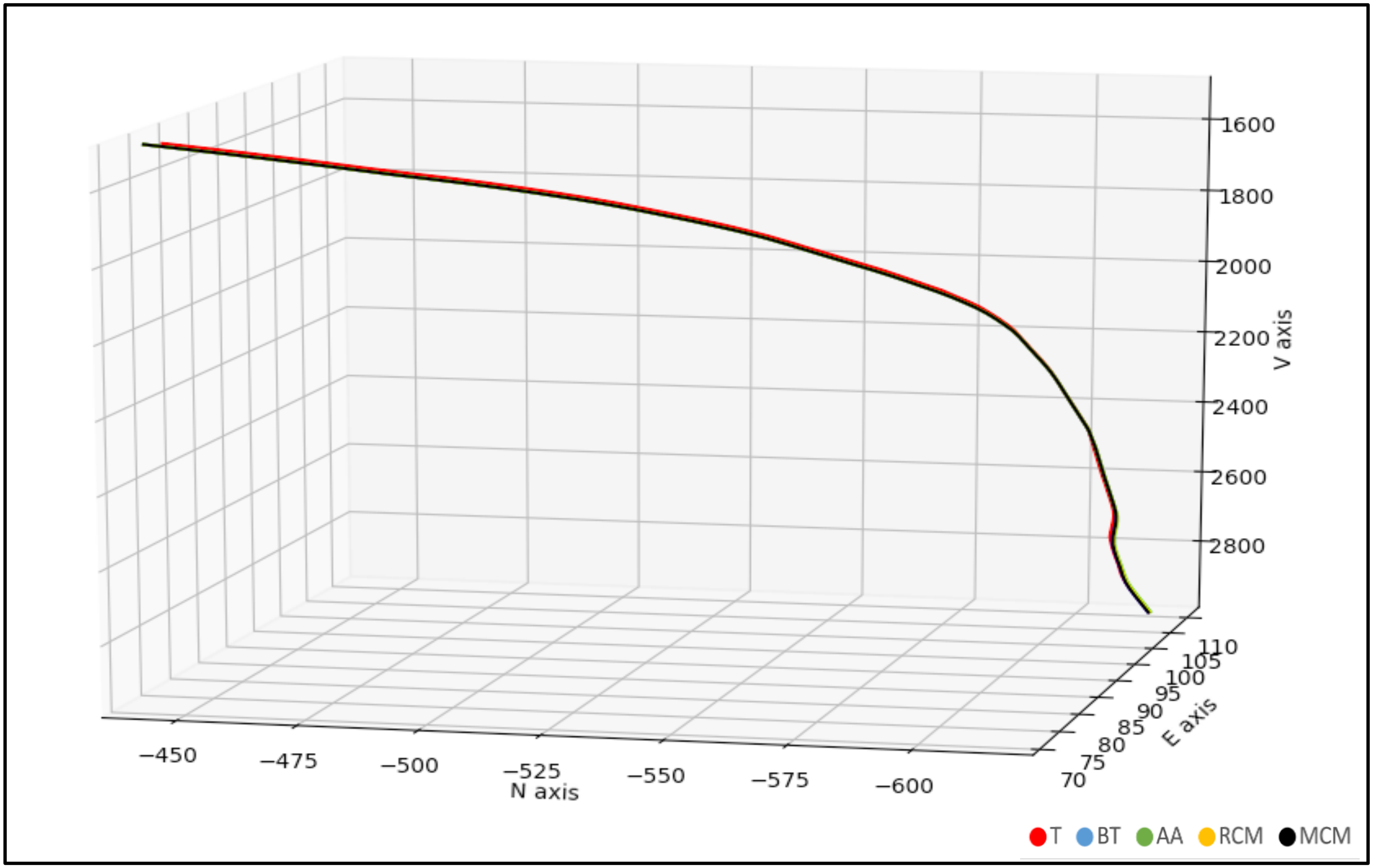


**Figure 5.12** Drop Section of the Well S-2

If we analyze DKO-1 and DKO-2 wells, the errors may seem a little more than the J type wells. However, it is not related with starting the kick-off deeper. Even though till the KOP, the hole is going vertical in theory, i.e. tangent; in reality this is not the case and the hole is continuously building, dropping, and turning with small degrees. Hence, just before KOP, some error is already accumulated. And after build section, the error is increasing as expected.

The last 2 wells, vertical types, have the maximum error of around 1 m for tangential method. The error comes from the unperfect nature of the drilled wells; that is, building, dropping, and turning with small degrees of the hole. We can say that with increasing asymmetry and depth, the error should increase. However, it would be satisfactory for most geothermal operators.

Although the numbers in the tables of summary results show the differences of each method at the last points of the wells, geothermal operator companies may desire to see them visually. For this purpose, following grid plots are prepared. Please see Figure 5.13-5.21.

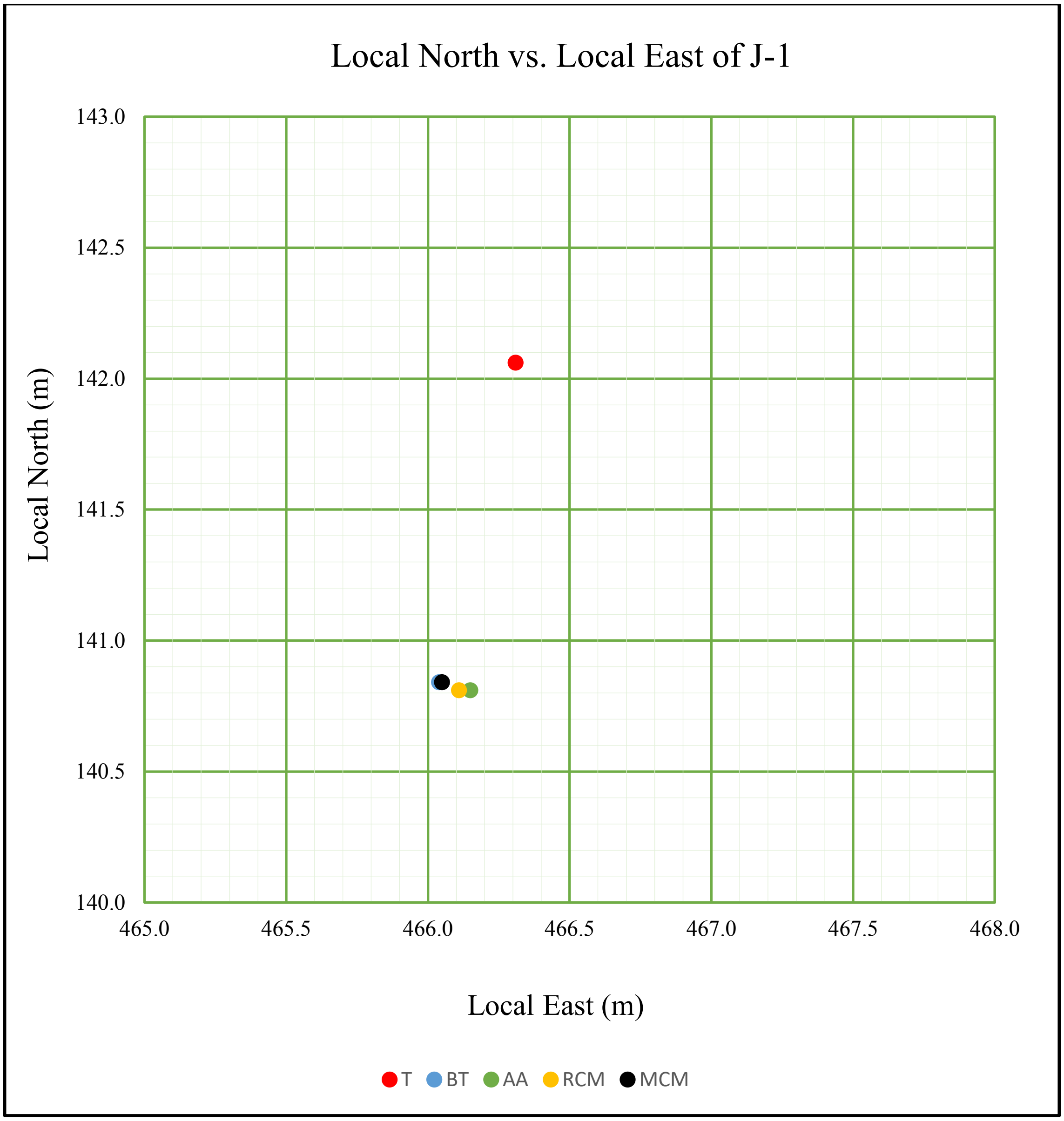


**Figure 5.13** Grid Plot of the Well J-1

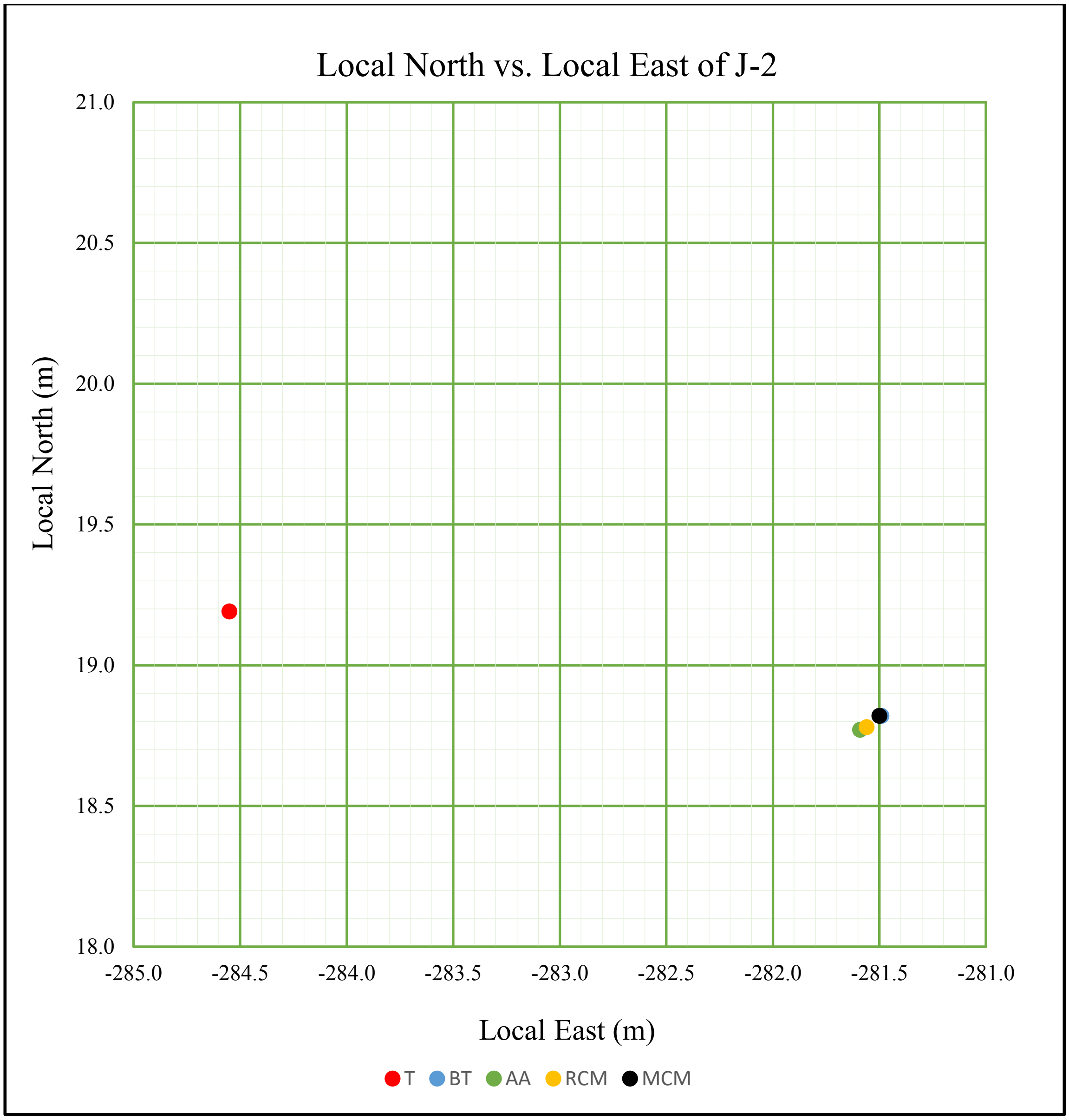


**Figure 5.14** Grid Plot of the Well J-2

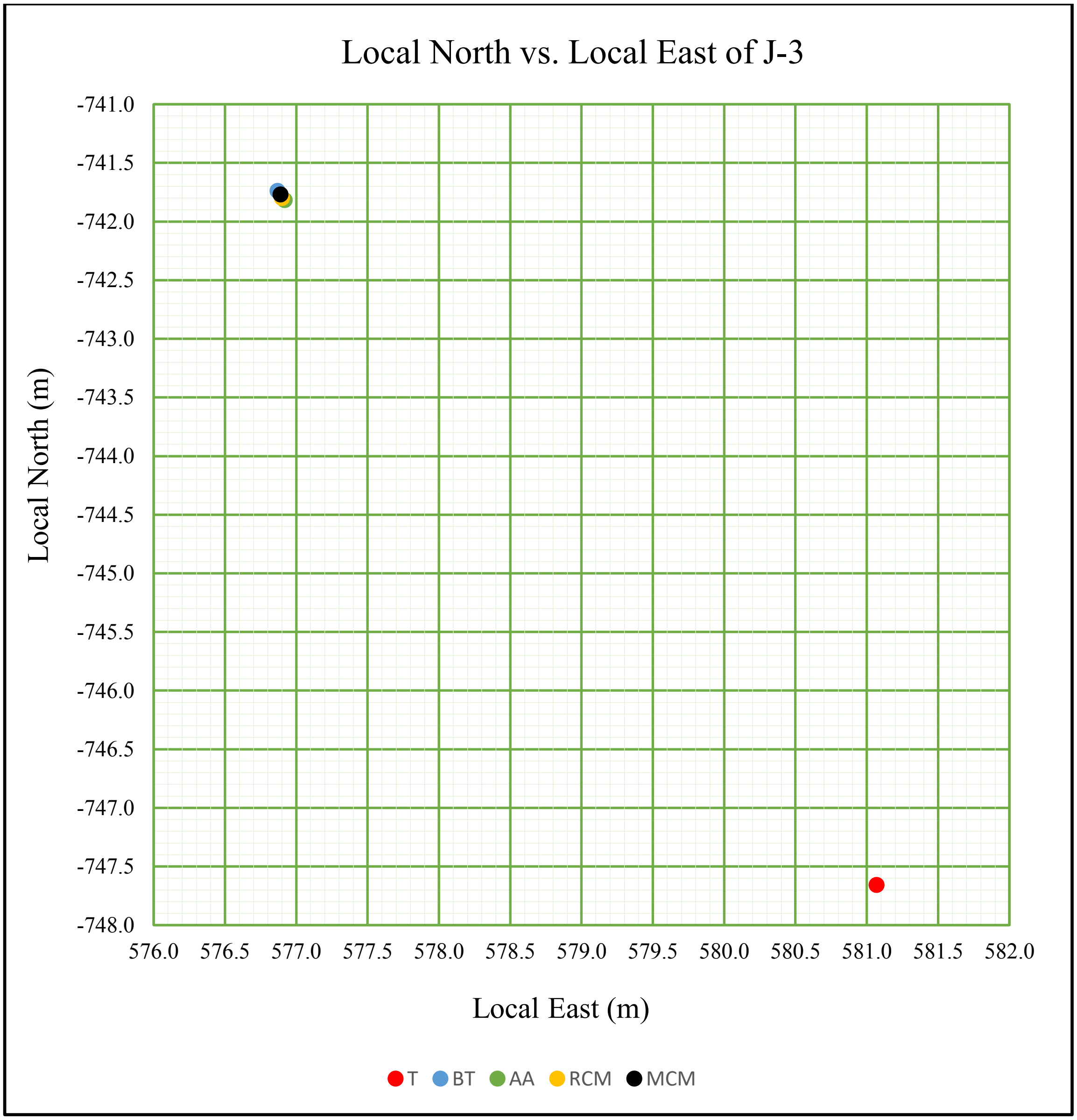


**Figure 5.15** Grid Plot of the Well J-3

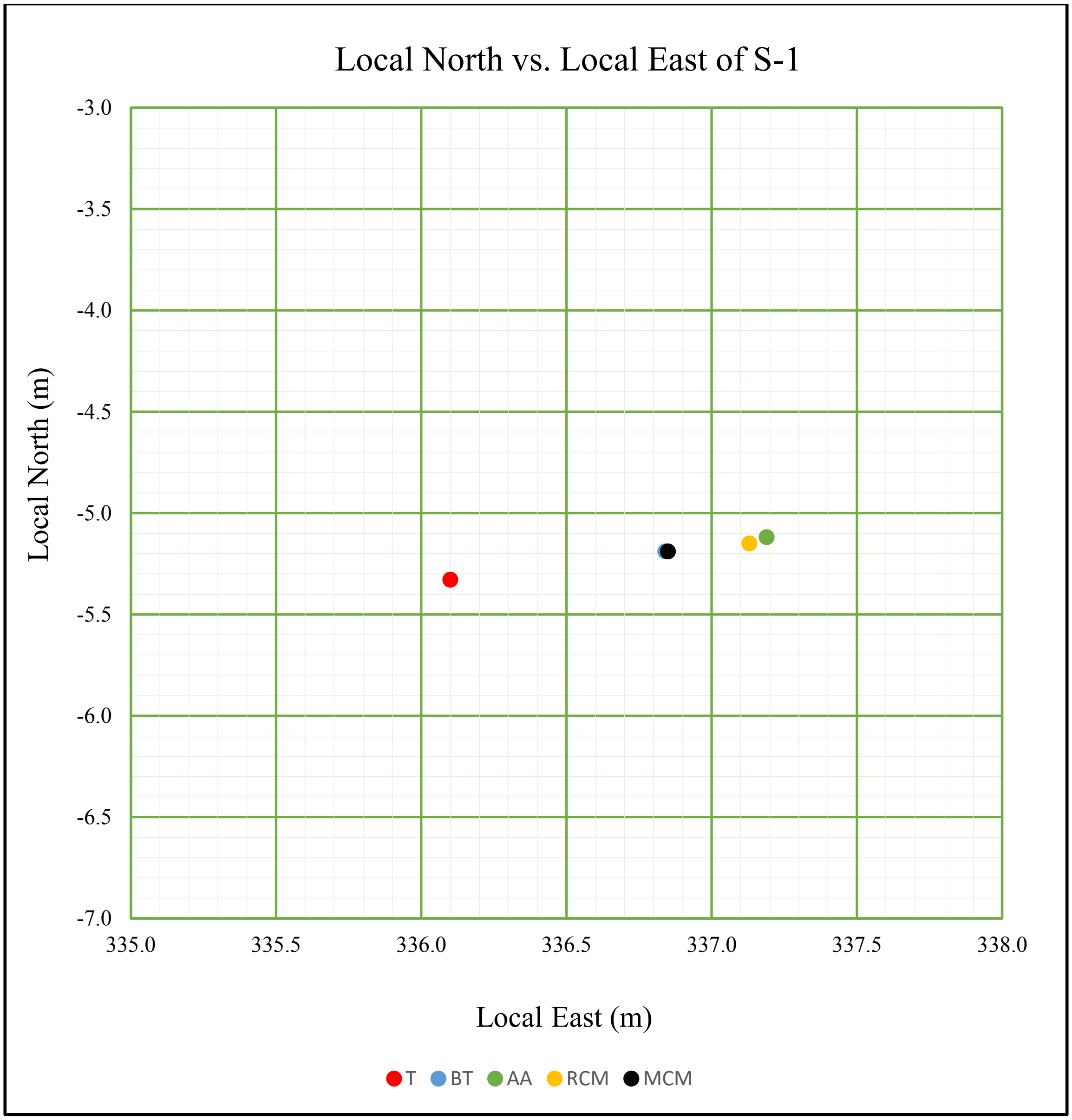


**Figure 5.16** Grid Plot of the Well S-1

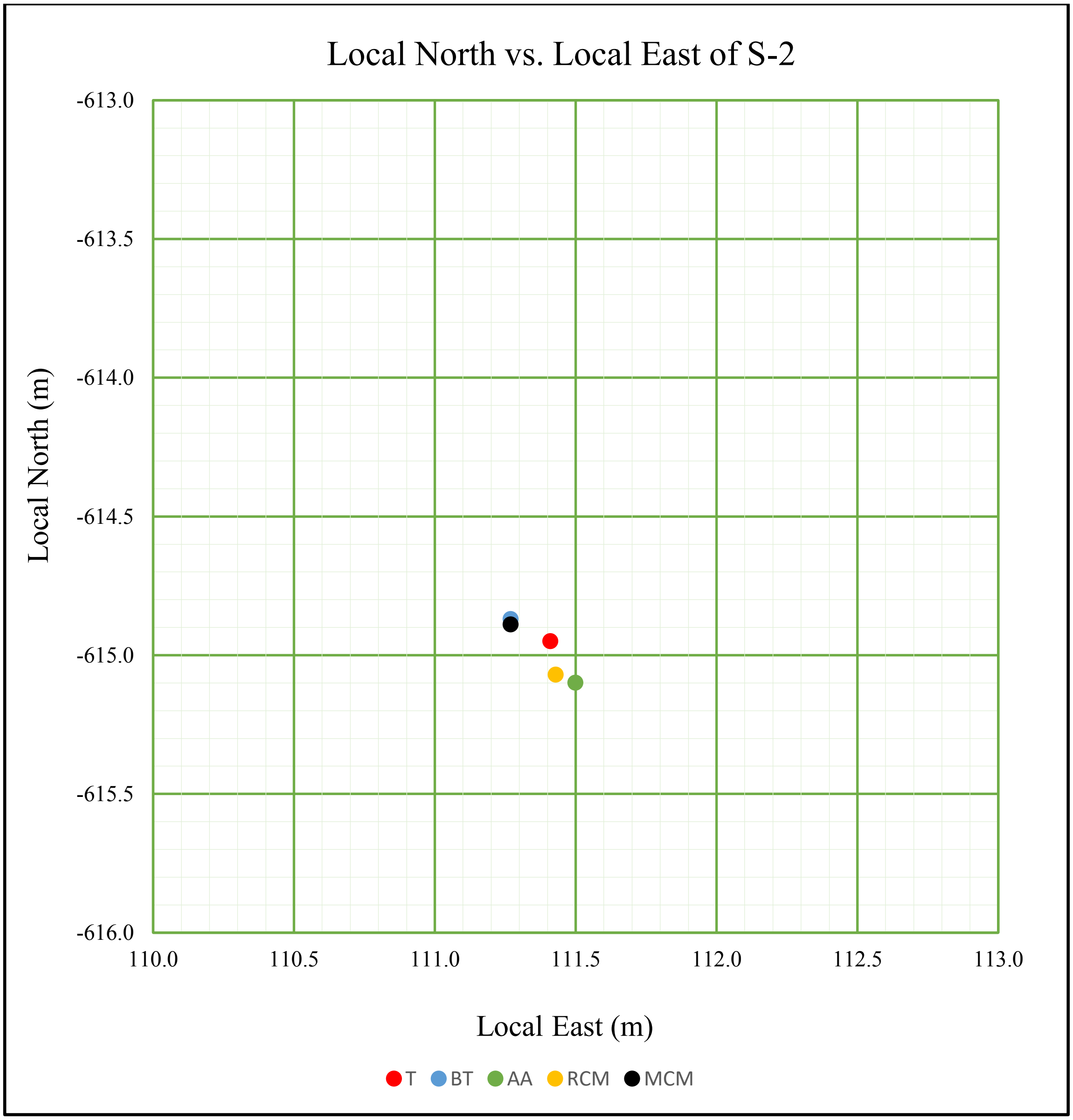


**Figure 5.17** Grid Plot of the Well S-2

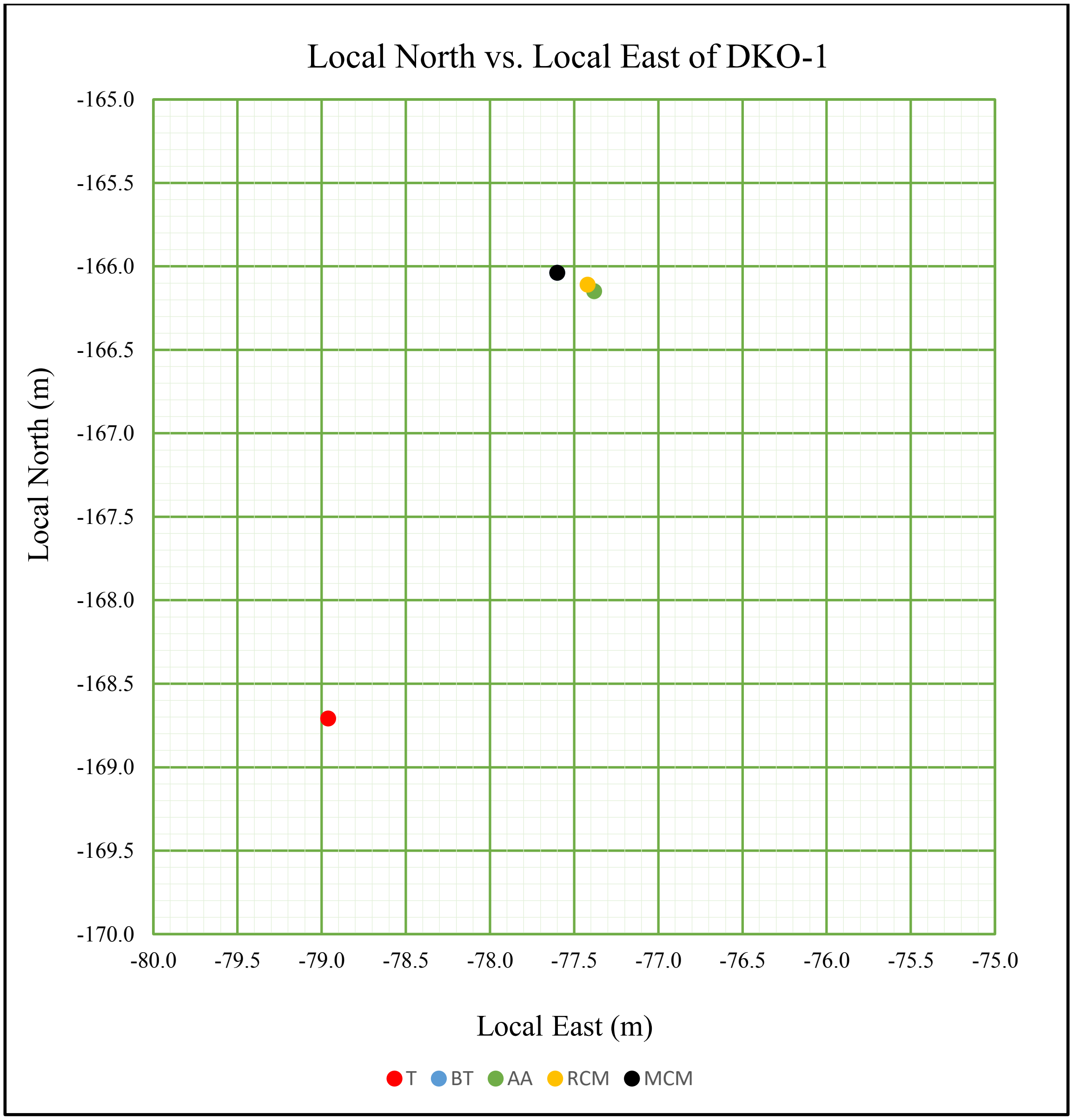


**Figure 5.18** Grid Plot of the Well DKO-1

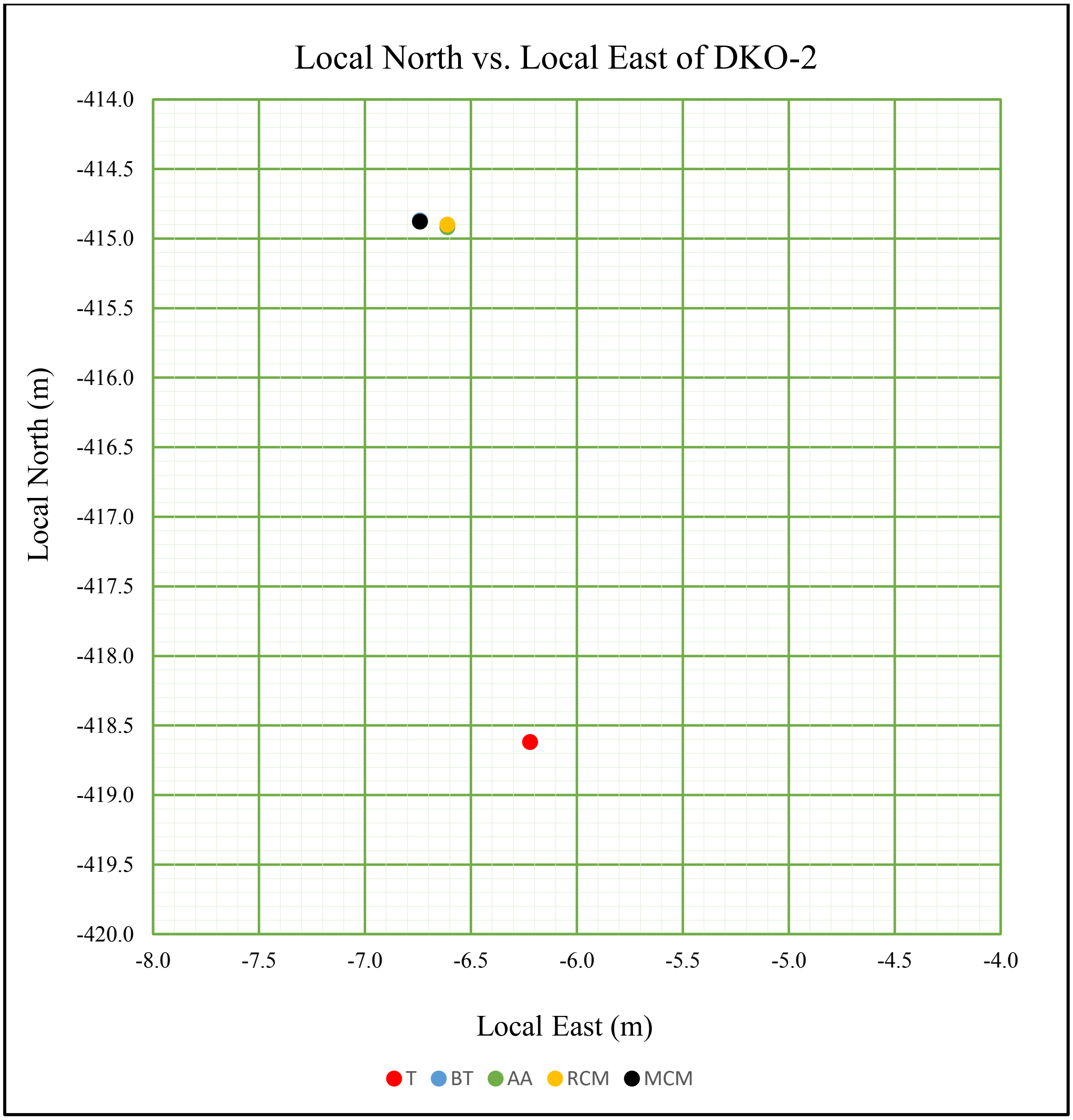


**Figure 5.19** Grid Plot of the Well DKO-2

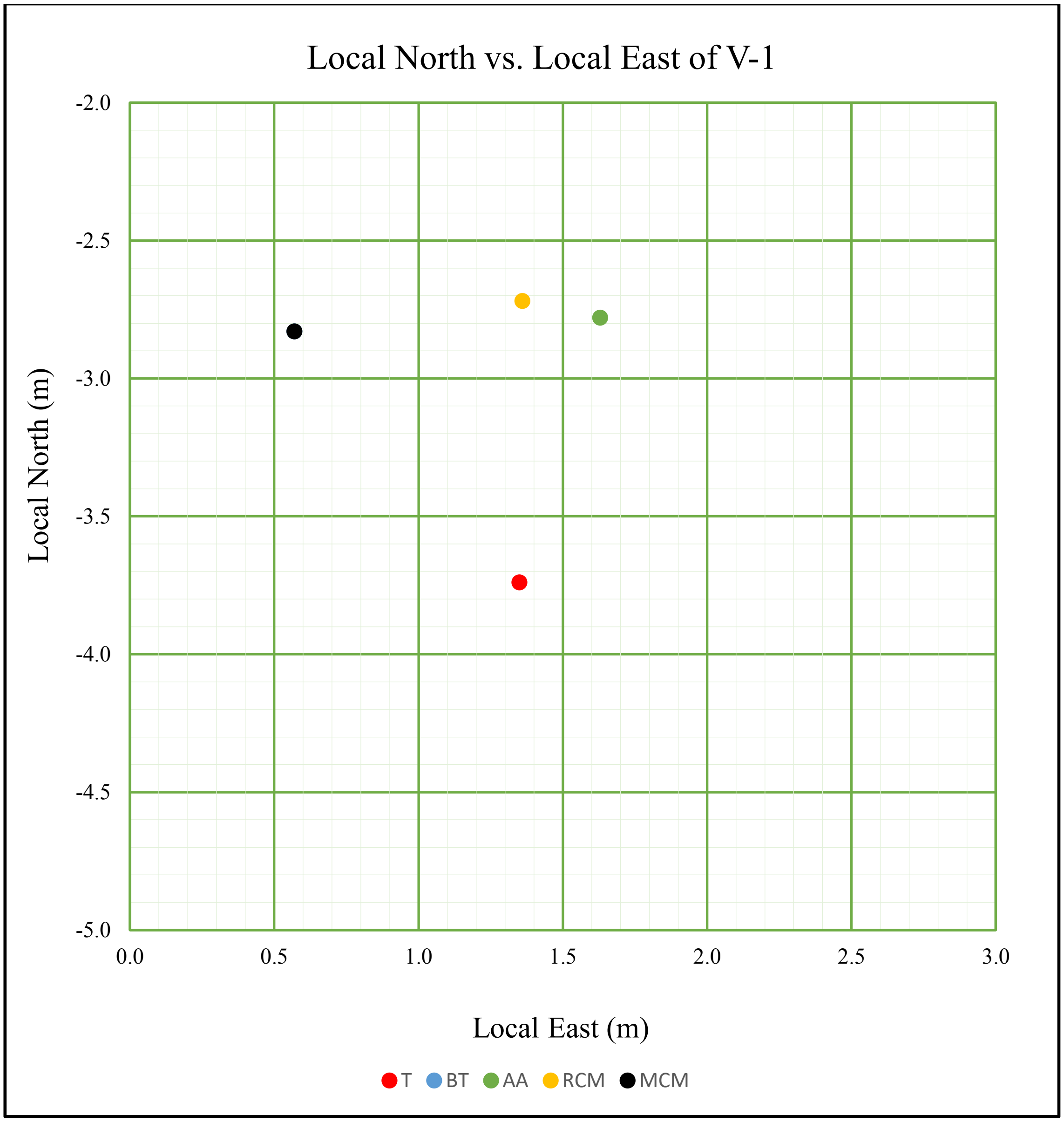


**Figure 5.20** Grid Plot of the Well V-1

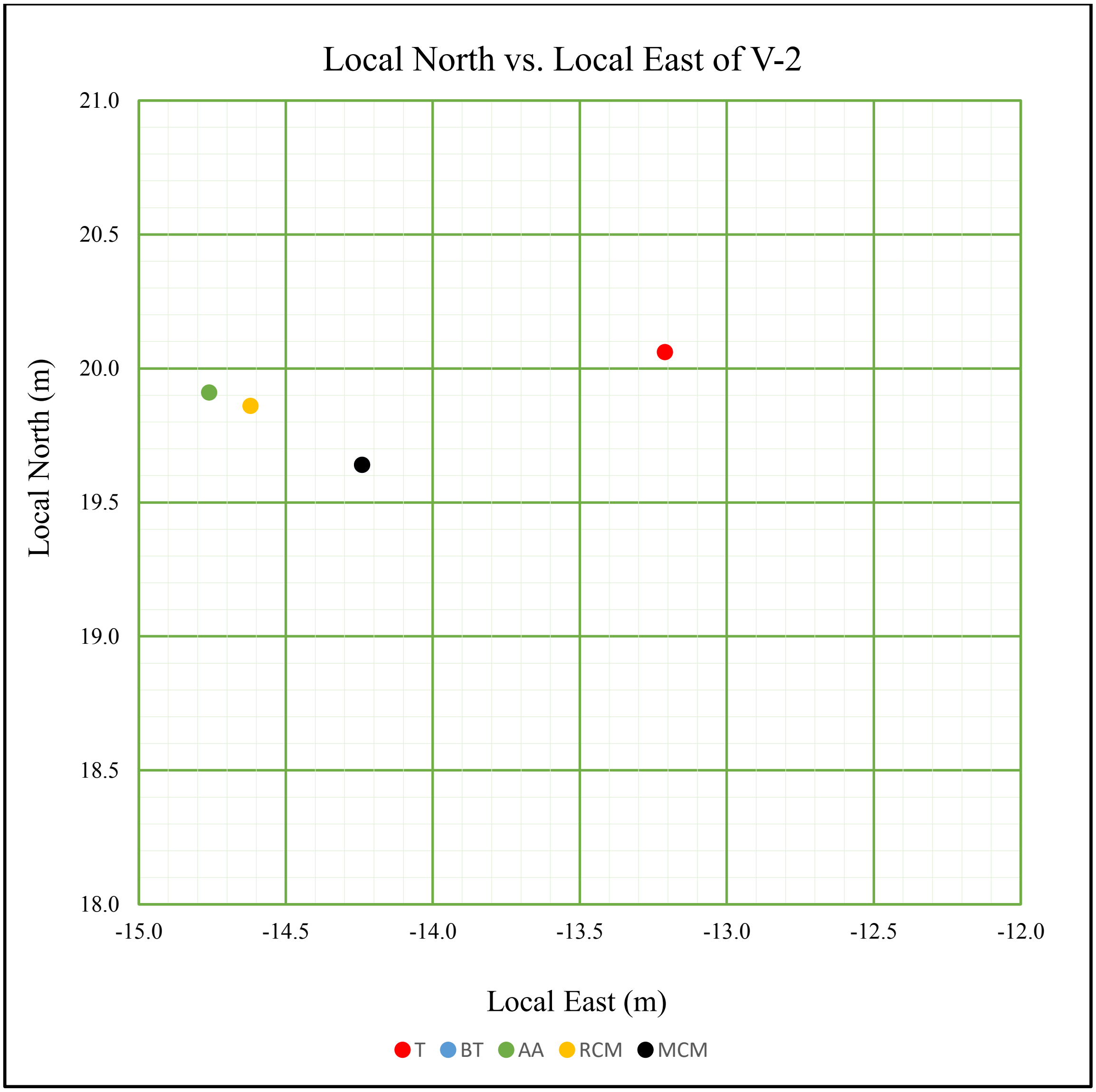


**Figure 5.21** Grid Plot of the Well V-2

**Important Note:** Throughout the thesis, and especially in this chapter, the "*error*" word is used frequently. These errors are calculated by considering the reference method as MCM, since it is widely accepted and industry standard for years. Nevertheless, the actual hole may not fit into MCM also. For a real minimization of error, which is not necessary for both geothermal and oil & gas wells for most of the time, every segment or curve of a well should be calculated according to its real expected shape. Thus, we should consider error as relative accuracy, based on MCM.

## 5.1 Error Analysis

Since the last point positions of the wells are relatively more important, summary results tables and grid plots were prepared for those points throughout this chapter. Here, root mean square (RMS) error analysis was employed to take into account all the survey points for each well, by taking the reference method as MCM. The last part of the python programming script is for RMS error analysis and calculations were made as such. And, following Table 5.17-5.25 were prepared accordingly.

As seen on the tables, all the methods except for tangential, shows a divergence of always less than 0.5 m for all 9 wells. As expected, a distinct separation of tangential one is seen on the Well J-3; less than 7 m. That is, although the methods other than tangential are quite satisfactory for our geothermal wells; tangential can also be acceptable under appropriate conditions.

**Table 5.17** RMS Analysis for the Well J-1

| **RMS Analysis for the Well J-1** | | | | |
|---|---|---|---|---|
| **METHOD** | TVD | Local N | Local E | VS |
| T | 0,13 | 0,36 | 1,23 | 1,26 |
| BT | 0,03 | 0,00 | 0,00 | 0,00 |
| AA | 0,02 | 0,06 | 0,04 | 0,03 |
| RCM | 0,02 | 0,05 | 0,03 | 0,02 |

**Table 5.18** RMS Analysis for the Well J-2

| **RMS Analysis for the Well J-2** | | | | |
|---|---|---|---|---|
| **METHOD** | TVD | Local N | Local E | VS |
| T | 0,37 | 0,28 | 2,42 | 2,43 |
| BT | 0,03 | 0,00 | 0,00 | 0,00 |
| AA | 0,01 | 0,03 | 0,07 | 0,07 |
| RCM | 0,02 | 0,02 | 0,05 | 0,05 |

**Table 5.19** RMS Analysis for the Well J-3

| RMS Analysis for the Well J-3 | | | | |
|---|---|---|---|---|
| **METHOD** | TVD | Local N | Local E | VS |
| T | 1,57 | 5,37 | 3,97 | 6,67 |
| BT | 0,06 | 0,02 | 0,01 | 0,02 |
| AA | 0,01 | 0,03 | 0,02 | 0,03 |
| RCM | 0,01 | 0,02 | 0,01 | 0,02 |

**Table 5.20** RMS Analysis for the Well S-1

| RMS Analysis for the Well S-1 | | | | |
|---|---|---|---|---|
| **METHOD** | TVD | Local N | Local E | VS |
| T | 0,16 | 0,67 | 1,04 | 1,05 |
| BT | 0,05 | 0,00 | 0,00 | 0,00 |
| AA | 0,03 | 0,10 | 0,17 | 0,17 |
| RCM | 0,04 | 0,07 | 0,14 | 0,13 |

**Table 5.21** RMS Analysis for the Well S-2

| RMS Analysis for the Well S-2 | | | | |
|---|---|---|---|---|
| **METHOD** | TVD | Local N | Local E | VS |
| T | 0,43 | 2,00 | 0,37 | 2,03 |
| BT | 0,05 | 0,01 | 0,00 | 0,01 |
| AA | 0,03 | 0,06 | 0,05 | 0,07 |
| RCM | 0,04 | 0,05 | 0,04 | 0,05 |

**Table 5.22** RMS Analysis for the Well DKO-1

| RMS Analysis for the Well DKO-1 | | | | |
|---|---|---|---|---|
| **METHOD** | TVD | Local N | Local E | VS |
| T | 0,21 | 1,75 | 0,88 | 1,96 |
| BT | 0,02 | 0,00 | 0,00 | 0,00 |
| AA | 0,00 | 0,07 | 0,17 | 0,01 |
| RCM | 0,00 | 0,05 | 0,14 | 0,02 |

**Table 5.23** RMS Analysis for the Well DKO-2

| RMS Analysis for the Well DKO-2 | | | | |
|---|---|---|---|---|
| **METHOD** | TVD | Local N | Local E | VS |
| T | 0,39 | 3,36 | 0,50 | 3,36 |
| BT | 0,02 | 0,00 | 0,00 | 0,00 |
| AA | 0,00 | 0,02 | 0,11 | 0,02 |
| RCM | 0,00 | 0,01 | 0,11 | 0,01 |

**Table 5.24** RMS Analysis for the Well V-1

| RMS Analysis for the Well V-1 | | | | |
|---|---|---|---|---|
| **METHOD** | TVD | Local N | Local E | VS |
| T | 0,03 | 0,58 | 0,73 | 0,58 |
| BT | 0,02 | 0,00 | 0,00 | 0,00 |
| AA | 0,01 | 0,14 | 0,47 | 0,14 |
| RCM | 0,01 | 0,14 | 0,36 | 0,14 |

**Table 5.25** RMS Analysis for the Well V-2

| RMS Analysis for the Well V-2 | | | | |
|---|---|---|---|---|
| **METHOD** | TVD | Local N | Local E | VS |
| T | 0,03 | 0,77 | 1,05 | 0,77 |
| BT | 0,02 | 0,00 | 0,00 | 0,00 |
| AA | 0,00 | 0,17 | 0,18 | 0,17 |
| RCM | 0,01 | 0,12 | 0,13 | 0,12 |

# CHAPTER 6

# CONCLUSIONS

This thesis work investigated relative accuracies of 5 different directional survey calculation methods which are tangential, balanced tangential, average angle, radius of curvature, and minimum curvature method, by taking the reference as MCM, for geothermal wells drilled in Aegean Part of Turkey. Our usual geothermal wells have the following properties:

- They are J-type, S-type and vertical; sometimes relatively DKO-type.
- S-type wells are mostly symmetrical.
- They are mostly 2D in shape; rarely 3D design. No designer wells, as in oil & gas industry.
- They have maximum of 2-3°/30 m doglegs for build & drop section. It means that they have long radius design.
- They usually have final MD of 1000-3000m; sometimes more than 4000 m.
- They have small-medium angles; maximum of around 45°.
- The targets are not a thin or multiple production zones far away from each other, as in oil & gas industry. Well TD is generally called after reaching high mud loss condition.
- They are drilled with only-inclination tools. Usually no need for gamma or any other LWD tools, which will decrease the importance of TVD accuracy.

For practical and fast application, a python programming code had been written which uses survey information (MD, Inc, Az) located in a .txt file, and vertical section azimuth as input; and it gives results or positions for each measured depth and method with its related 3D plots. To optimize what we are using, and what we actually need, 9 actual geothermal wells are picked; 3 J-type, 2 S-type, 2 DKO-type, and 2 vertical wells. Within well types, main changing parameter is inclination; besides, doglegs and depths. After getting outputs of the program and analyzing the last point positions of the wells, following conclusions are acquired:

- For J-type wells, with inclination, doglegs, and depths, the accuracies of the methods will be more pronounced. As its name implies, the tangential formula assumes a tangent hole, and it has the easiest calculation formulas to determine the position of a well in 3D space; while converting measured depth (MD), inclination (Inc), and azimuth (Az) to true vertical depth (TVD), north (N), and east (E) values. Although the tangential results will obviously diverge from the other 4 methods with increasing inclination, doglegs, and depths; the usual geothermal wells drilled in Turkey will keep this divergence maximum of around 10 m, which will satisfy most of the operator companies. In order to have a more realistic result, average angle method, the easiest one after tangential, can be utilized.
- For S-type wells, since they are behaving like a tangent section of a hole, with increasing symmetry, i.e. build and drop sections similarities with respect to doglegs and inclinations; which directional method is used is not significant for our usual geothermal wells.
- For DKO-type wells, the accuracy behavior of the methods is like J-type wells, except for some small addition of error may come from the vertical part because of the natural behavior of vertical sections, i.e. building, dropping, and turning with small amounts.
- For vertical wells, the error accumulates throughout a hole due to unperfect nature of actual wells as in vertical part of DKO-types. Although the error increases with increasing asymmetry and depth, the selected directional survey technique will not matter since our geothermal well needs are not very restricted about this subject.

# CHAPTER 7

# RECOMMENDATIONS

In view of especially the conclusions made in previous chapter and the complete thesis work, followings are recommended:

- Geothermal operators in Turkey, usually work with 3rd party directional drilling service companies. These companies are using again a 3rd party licensed directional drilling software for each well, i.e. software cost for each individual well. In these days, operators are willing to establish their own directional drilling departments to decrease the costs of directional operations. By taking into account the properties or needs of geothermal wells drilled in Aegean Part of Turkey, as specified in Conclusions chapter; operators may use a basic software, for their each well, depending on average angle, or even tangential method, to eliminate complicated formulas, while calculating the positions of each survey or interpolation depths. An only advanced software may be preferred for operator office. However, it is significant to add:
    - The industry standard CL should have maximum of 30 m while surveying, which will affect the accuracy of a method. Operators are already using CL of 10-30 m, they should continue like this, in order not to diverge the results of calculations methods from each other. Nevertheless, for the sake of another optimization study, to see the effect of survey frequency, some survey stations may be omitted, and calculations can be repeated. In the

literature there are studies for MCM; one can make these calculations for each method to meet the needs of a specific drilling field.

- If collision risk is present, extra precaution should be taken, keeping in mind that uncertainty due to measurement of surveying itself is much more than the preferred directional survey calculation method by a factor of 10 or even more, in general (Harvey et al., 1971).
- If license border is very limited, extra attention should be payed again.

▪ The script of written python programming code, used for this thesis work, is provided in Appendix. For further study, the program can be developed to calculate user-determined interpolation depth 3D-positions since operators sometimes need a position or positions data staying between survey points. Afterwards, the program can be upgraded to calculate distance between offset wells. However, this distance will be between center points of the wells. If conditions dictate, i.e. presence of collision risk case, one should add sensor uncertainty in calculations.

## REFERENCES


Adams, N. J., & Charrier, T. (1985). *Drilling Engineering: A Complete Well Planning Approach*.

Amorin, R., & Broni-Bediako, E. (2010). Application of Minimum Curvature Method to Wellpath Calculations. *Research Journal of Applied Sciences, Engineering and Technology*, *2*(7), 679–686.

Athumani, Z. (2018). *Directional Well Planning and Trajectory Design Calculations*.

Bourgoyne Jr., A. T., Millheim, K. K., Chenevert, M. E., & Young Jr., F. S. (1991). Applied Drilling Engineering. In J. F. Evers & D. S. Pye (Eds.), *SPE Textbook Series* (Vol. 2, Issue 2). Society of Petroleum Engineers.

Carden, R. S., & Grace, R. D. (2007). *Horizontal and Directional Drilling*. PetroSkills.

Chen, D. (2006). *Pretroleum Engineering Handbook: Drilling Engineering: Vol. II* (L. W. Lake & R. F. Mitchell (eds.)). Society of Petroleum Engineers.

Dipl.-Ing. Prassl, W. F. (2005). *Drilling Engineering*. Curtin University of Technology.

Dr. Mitchell, B. (1995). *Advanced Oil Well Drilling Engineering Handbook & Computer Programs* (10th ed.). Mitchell Engineering.

Dr. Stoner, M., & Reyes, D. D. (2019). *Directional Drilling Terms Defined*. https://www.makinhole.com/Glossary.htm

Farah, F. O. (2013). Directional Well Design, Trajectory and Survey Calculations, with a Case Study in Fiale, Asal Rift, Djibouti. *GEOTHERMAL TRAINING PROGRAMME*, *27*, 625–658. https://orkustofnun.is/gogn/unu-gtp-report/UNU-GTP-2013-27.pdf

Finger, J., & Blankenship, D. (2010). *Best Practices of Geothermal Drilling.pdf*.

Fruhwirth, R., & Lorbach, M. (1987). *Error Analysis Of Directional Survey Calculation Models* (p. 13). Society of Petroleum Engineers. https://doi.org/

Geomagnetism Canada, N. R. C. (2019). *Geomagnetism*. https://www.geomag.nrcan.gc.ca/

Harvey, R. P., Walstrom, J. E., & Eddy, H. D. (1971). A Mathematical Analysis of Errors in Directional Survey Calculations. *Journal of Petroleum Technology*, *23*(11), 1368–1374. https://doi.org/10.2118/3718-PA

Hassan, I. (2012). *Survey Interpolation: Software for Calculating Correct Well Path Between Survey Stations*. University of Stavanger.

Heriot-Watt University, I. of P. E. (2005). *Drilling Engineering*.

IADC. (2015). Evolution of directional drilling since 1900. *IADC Drilling Manual Excerpt*, 1–5. http://www.iadc.org/wp-content/uploads/2015/08/preview-dd.pdf

Inglis, T. (1987). Petroleum Engineering and Development Studies. In *Graham & Trotman* (Vol. 2).

Jamieson, A. (2012). *Introduction to Wellbore Positioning*. University of the Highlands & Islands. https://www.uhi.ac.uk/en/wellbore-positioning-download/

Kuru, E. (2014). *Advanced Drilling Engineering: Fundamentals of Directional Drilling* (Vol. 4).

Lubinski, A. (1961). Maximum Permissible Dog-Legs in Rotary Boreholes. *Journal of Petroleum Technology*, *13*(02), 175–194. https://www.onepetro.org/journal-paper/SPE-1543-G-PA

Lubinski, A. (1987). *Developments in Petroleum Engineering* (S. Miska (ed.)). Gulf Publishing Company.

Mian, M. A. (1992). *Petroleum Engineering: Handbook for the Practicing Engineer*. PennWell Publishing Company.

Mitchell, R. F., & Miska, S. Z. (2011). *Fundamentals of Drilling Engineering* (Vol. 12). Society of Petroleum Engineers.

Özbayoğlu, E. (2006). *PetE 322, Drilling Engineering–II: Directional Drilling*.

PetroSkills. (2019). *Introduction to Directional Drilling*. 01.05.2019. www.petroskills.com/blog/entry/00_totm/introduction-to-directional-drilling#.XeOnnJMzb_Q

Rabia, H. (2001). *Well Engineering & Construction*.

Schlumberger. (2019). *The Oilfield Glossary: Where the Oil Field Meets the Dictionary*. https://www.glossary.oilfield.slb.com/

Short, J. A. "Jim." (1993). *Petroleum Engineering Handbook*. Society of Petroleum Engineers.

Taylor, H. L., & Mason, M. C. (1972). A Systematic Approach to Well Surveying Calculations. *Society of Petroleum Engineers Journal*, *12*(06), 474–488. https://doi.org/10.2118/3362-PA

Walstrom, J. E., Harvey, R. P., & Eddy, H. D. (1972). A Comparison of Various Directional Survey Models and an Approach To Model Error Analysis. *Journal of Petroleum Technology*, *24*(08), 935–943. https://doi.org/10.2118/3379-PA

Wilson, G. J. (1968). An Improved Method for Computing Directional Surveys. *Journal of Petroleum Technology*, *20*(08), 871–876. https://doi.org/10.2118/1992-PA

## APPENDIX

### A. Survey Data of the Selected Wells

**Table A.1** Survey Data of the Well J-2

| | | |
|---|---|---|
| 0.00 | 0.00 | 274.08 |
| 5.20 | 0.00 | 274.08 |
| 77.10 | 0.22 | 274.08 |
| 106.80 | 0.73 | 199.44 |
| 126.50 | 2.01 | 220.29 |
| 145.60 | 3.23 | 229.11 |
| 164.70 | 3.62 | 233.14 |
| 183.80 | 3.77 | 243.95 |
| 202.80 | 4.03 | 248.94 |
| 222.00 | 4.20 | 250.09 |
| 241.20 | 4.61 | 250.32 |
| 260.30 | 4.54 | 256.75 |
| 279.50 | 4.73 | 262.91 |
| 298.70 | 5.75 | 260.67 |
| 318.10 | 6.85 | 259.80 |
| 337.30 | 8.50 | 261.25 |
| 356.40 | 8.76 | 264.70 |
| 375.60 | 9.06 | 267.91 |
| 394.90 | 9.43 | 274.12 |
| 414.20 | 10.64 | 275.17 |
| 433.40 | 11.63 | 274.88 |
| 452.80 | 12.69 | 274.87 |
| 472.10 | 13.02 | 273.77 |
| 491.50 | 12.65 | 271.60 |
| 510.70 | 13.20 | 270.31 |
| 529.90 | 13.58 | 271.92 |
| 549.10 | 14.20 | 272.76 |
| 568.30 | 14.48 | 274.23 |
| 587.50 | 15.07 | 275.13 |
| 606.70 | 15.18 | 273.34 |
| 625.90 | 14.99 | 274.53 |
| 645.10 | 14.97 | 276.21 |
| 664.30 | 15.25 | 275.60 |
| 683.50 | 14.91 | 273.68 |
| 702.70 | 15.19 | 272.82 |
| 721.90 | 15.08 | 272.86 |
| 750.20 | 14.26 | 269.87 |
| 769.30 | 14.47 | 273.99 |
| 788.50 | 15.39 | 281.27 |
| 817.20 | 17.16 | 285.90 |
| 836.40 | 17.40 | 283.63 |
| 855.60 | 17.50 | 280.94 |
| 874.80 | 17.50 | 279.22 |
| 894.20 | 17.26 | 277.55 |
| 913.40 | 17.16 | 277.15 |
| 932.50 | 17.02 | 277.18 |
| 951.70 | 17.03 | 276.46 |
| 970.90 | 17.42 | 273.44 |
| 990.00 | 17.62 | 273.41 |
| 1009.20 | 17.81 | 273.61 |
| 1028.60 | 17.85 | 273.80 |
| 1047.90 | 18.09 | 274.15 |
| 1067.10 | 17.95 | 273.84 |
| 1086.30 | 17.97 | 274.43 |
| 1109.60 | 17.87 | 275.02 |
| 1128.80 | 17.93 | 274.65 |
| 1148.00 | 17.85 | 274.79 |
| 1167.20 | 17.84 | 274.47 |
| 1186.40 | 18.43 | 275.24 |
| 1205.60 | 18.26 | 275.84 |
| 1224.80 | 17.66 | 276.52 |
| 1243.90 | 18.28 | 276.85 |
| 1263.20 | 17.91 | 276.96 |
| 1282.40 | 17.65 | 276.76 |
| 1301.70 | 17.78 | 276.97 |
| 1327.50 | 17.78 | 276.97 |

**Table A.2** Survey Data of the Well J-3

| | | |
|---|---|---|
| 0.00 | 0.00 | 153.95 |
| 6.70 | 0.00 | 153.95 |
| 176.70 | 0.57 | 153.95 |
| 196.90 | 1.44 | 149.16 |
| 225.10 | 2.98 | 142.85 |
| 253.50 | 4.30 | 139.46 |
| 281.90 | 5.94 | 138.46 |
| 310.20 | 8.21 | 140.29 |
| 338.60 | 10.89 | 141.51 |
| 366.90 | 13.69 | 143.63 |
| 395.20 | 16.23 | 141.65 |
| 423.60 | 18.51 | 140.64 |
| 451.70 | 20.42 | 139.30 |
| 480.10 | 22.30 | 140.03 |
| 508.20 | 23.38 | 139.82 |
| 537.60 | 25.39 | 141.04 |
| 566.00 | 25.50 | 141.55 |
| 594.60 | 24.76 | 140.91 |
| 622.90 | 24.89 | 142.36 |
| 651.40 | 25.94 | 144.54 |
| 679.90 | 26.10 | 145.59 |
| 707.60 | 25.31 | 144.89 |
| 736.10 | 25.28 | 144.90 |
| 764.40 | 25.66 | 146.23 |
| 792.90 | 25.78 | 144.36 |
| 822.10 | 26.79 | 144.30 |
| 850.50 | 26.18 | 143.60 |
| 881.20 | 24.94 | 142.28 |
| 905.90 | 24.43 | 141.89 |
| 934.10 | 24.98 | 142.73 |
| 962.70 | 26.52 | 145.34 |
| 991.20 | 26.90 | 146.20 |
| 1019.40 | 26.44 | 146.37 |
| 1047.90 | 27.27 | 146.47 |
| 1076.30 | 27.67 | 146.45 |
| 1104.80 | 27.31 | 146.29 |
| 1133.20 | 27.03 | 146.75 |
| 1161.70 | 26.79 | 146.82 |
| 1189.60 | 26.84 | 146.46 |
| 1218.40 | 28.04 | 146.11 |
| 1246.90 | 27.59 | 144.27 |
| 1275.30 | 27.29 | 142.64 |
| 1303.20 | 27.25 | 142.53 |
| 1332.40 | 26.58 | 142.79 |
| 1360.60 | 26.47 | 140.86 |
| 1388.70 | 25.84 | 140.67 |
| 1417.70 | 25.69 | 140.83 |
| 1446.00 | 25.45 | 139.97 |
| 1474.00 | 24.43 | 141.13 |
| 1502.30 | 24.37 | 142.15 |
| 1531.20 | 23.80 | 142.54 |
| 1559.50 | 23.25 | 142.14 |
| 1588.20 | 22.30 | 142.56 |
| 1616.60 | 22.37 | 143.86 |
| 1644.80 | 24.52 | 146.88 |
| 1673.30 | 26.54 | 145.12 |
| 1701.60 | 26.90 | 140.47 |
| 1715.00 | 26.98 | 138.34 |
| 1737.60 | 27.42 | 138.50 |
| 1761.30 | 27.78 | 138.78 |
| 1789.60 | 27.89 | 137.86 |
| 1817.70 | 28.34 | 139.86 |
| 1846.30 | 28.43 | 141.03 |
| 1874.90 | 28.71 | 141.01 |
| 1903.30 | 29.25 | 139.63 |
| 1931.60 | 29.38 | 142.27 |
| 1960.00 | 29.44 | 140.78 |
| 1988.10 | 29.95 | 140.39 |
| 2016.70 | 30.82 | 137.74 |
| 2044.90 | 32.82 | 136.45 |
| 2058.20 | 32.12 | 136.75 |
| 2077.70 | 32.16 | 135.55 |
| 2106.20 | 31.62 | 137.64 |
| 2134.60 | 31.70 | 140.19 |
| 2163.00 | 31.47 | 140.63 |
| 2191.60 | 32.06 | 141.29 |
| 2220.00 | 32.09 | 140.07 |
| 2248.30 | 31.64 | 140.25 |
| 2276.60 | 31.15 | 140.17 |
| 2305.20 | 30.74 | 141.52 |
| 2333.50 | 30.24 | 142.42 |
| 2361.90 | 29.27 | 143.45 |
| 2390.50 | 28.38 | 142.88 |
| 2412.00 | 27.39 | 142.30 |

**Table A.3** Survey Data of the Well S-1

| | | |
|---|---|---|
| 0 | 0 | 309.49 |
| 5.2 | 0 | 309.49 |
| 180.7 | 0.43 | 309.49 |
| 198.6 | 0.16 | 28.87 |
| 217.4 | 0.36 | 24.44 |
| 236.3 | 0.46 | 336.17 |
| 256.4 | 0.5 | 352.62 |
| 275.3 | 0.53 | 351.1 |
| 294.3 | 0.66 | 7.02 |
| 313.7 | 0.46 | 349.42 |
| 333.2 | 0.63 | 32.92 |
| 351.7 | 0.91 | 12.55 |
| 371.6 | 1.31 | 17.87 |
| 390.7 | 1.83 | 4.13 |
| 409.8 | 1.88 | 8.83 |
| 429.2 | 2.85 | 3.35 |
| 448.2 | 3.88 | 5.03 |
| 466.2 | 4.29 | 3.84 |
| 486.7 | 5.31 | 1.38 |
| 505.8 | 5.78 | 0.95 |
| 526 | 7.18 | 359.69 |
| 545.2 | 7.4 | 2.09 |
| 564.6 | 7.46 | 2.78 |
| 583.3 | 8.14 | 6.74 |
| 601.2 | 8.88 | 8.21 |
| 622.9 | 8.72 | 11.02 |
| 641.1 | 9.06 | 9.61 |
| 660.1 | 8.99 | 12.72 |
| 673.7 | 8.56 | 13.94 |
| 707.8 | 7.77 | 17.34 |
| 727.5 | 7.75 | 23.47 |
| 746.3 | 7.76 | 28.07 |
| 765.2 | 7.81 | 33.72 |
| 784.4 | 7.58 | 38.72 |
| 804 | 7.49 | 42.18 |
| 823.1 | 7.41 | 45.98 |
| 842.4 | 7.72 | 50.73 |
| 861 | 8.05 | 55.27 |
| 881 | 8.43 | 57.43 |
| 900.4 | 7.95 | 62.02 |
| 919 | 7.88 | 65.41 |
| 938.7 | 8.11 | 70.49 |
| 958 | 8.32 | 74.11 |
| 976.4 | 8.37 | 76.98 |
| 996.4 | 8.88 | 81.45 |
| 1016 | 8.57 | 84.99 |
| 1034.6 | 8.95 | 87.26 |
| 1054.5 | 9.05 | 91.29 |
| 1073.5 | 9.5 | 91.67 |
| 1092.5 | 9.64 | 92.73 |
| 1112.2 | 9.93 | 92.08 |
| 1131.7 | 10.01 | 90.27 |
| 1150.4 | 9.77 | 90.66 |
| 1169.6 | 10.12 | 92.83 |
| 1188.8 | 10.94 | 95.59 |
| 1207.9 | 10.85 | 96.9 |
| 1228.3 | 10.89 | 99.34 |
| 1246.8 | 10.85 | 100.2 |
| 1266 | 10.99 | 102.8 |
| 1285 | 11.54 | 106.41 |
| 1304.4 | 11.59 | 109.25 |
| 1323.8 | 11.65 | 109.62 |
| 1343.6 | 11.55 | 110.85 |
| 1362.1 | 11.81 | 110.75 |
| 1381.1 | 11.82 | 111.88 |
| 1401.3 | 11.95 | 112.05 |
| 1420.6 | 12.17 | 111.56 |
| 1439.4 | 12.43 | 111.85 |
| 1458.8 | 12.74 | 111.76 |
| 1478.2 | 13.15 | 112.5 |
| 1497.4 | 12.95 | 111.39 |
| 1516.5 | 12.29 | 110.71 |
| 1536 | 11.12 | 111.27 |
| 1555.3 | 11.05 | 109.23 |
| 1574.5 | 11.34 | 107.43 |
| 1593.7 | 11.61 | 108.06 |
| 1611.6 | 11.82 | 111.05 |
| 1632.3 | 11.65 | 110.41 |
| 1651.6 | 11.43 | 110.14 |
| 1670.9 | 11.62 | 109.89 |
| 1690.4 | 11.99 | 109.61 |
| 1709.6 | 12.08 | 110.64 |
| 1728.8 | 12.16 | 110.76 |
| 1748.7 | 12.36 | 111.78 |
| 1766.1 | 11.76 | 110.74 |
| 1785.8 | 11.2 | 107.7 |
| 1806 | 11.77 | 104.93 |
| 1826 | 11.89 | 99.38 |
| 1844.9 | 12.23 | 96.08 |
| 1863.7 | 11.95 | 96.71 |
| 1883 | 11.95 | 99.09 |
| 1902.7 | 11.64 | 101.09 |
| 1920.2 | 11.55 | 104.2 |
| 1940.7 | 11.93 | 105.51 |
| 1968.5 | 11.77 | 106.98 |
| 1988.8 | 12.28 | 106.68 |
| 2007.9 | 12.45 | 105.64 |
| 2026.4 | 12.5 | 106.1 |
| 2046.8 | 12.78 | 105.49 |
| 2066 | 13.1 | 105.71 |
| 2084.8 | 13.1 | 103.65 |
| 2104.6 | 12.7 | 99.17 |
| 2123.8 | 13.13 | 97.24 |
| 2142.5 | 13.27 | 97.18 |
| 2162.7 | 12.2 | 94.17 |
| 2181.7 | 12.32 | 93.83 |
| 2200.9 | 12.16 | 96.71 |
| 2220.3 | 12.61 | 98.07 |
| 2239.9 | 12.61 | 98.88 |
| 2258.4 | 12.84 | 98.46 |
| 2278.2 | 12.07 | 98.49 |
| 2297.8 | 11.78 | 103.25 |
| 2315.9 | 11.57 | 104.3 |
| 2336.1 | 11.26 | 105.59 |
| 2355 | 10.96 | 102.52 |
| 2373.6 | 10.12 | 102 |
| 2393.7 | 10.03 | 99.38 |
| 2413.2 | 9.75 | 97.81 |
| 2431.9 | 8.5 | 97.34 |
| 2451.7 | 7.64 | 94.09 |
| 2470.5 | 7.04 | 100.05 |
| 2489.5 | 6.97 | 98.95 |
| 2509.5 | 7.31 | 93.05 |
| 2528.5 | 7.45 | 91.8 |
| 2542.5 | 7.34 | 86.79 |
| 2564.8 | 7.16 | 82.03 |
| 2584.2 | 6.24 | 82.01 |
| 2603.1 | 6.66 | 86.03 |
| 2622.7 | 6.91 | 91.52 |
| 2642.3 | 6.34 | 92.49 |
| 2662.4 | 6.13 | 81.61 |
| 2680.4 | 5.3 | 74.93 |
| 2699 | 4.83 | 70.68 |
| 2718.8 | 4.56 | 58.24 |
| 2738.3 | 3.91 | 36.01 |
| 2757.4 | 4.73 | 16.97 |
| 2775.5 | 5.61 | 14.67 |
| 2796.2 | 6.78 | 7.31 |
| 2815.2 | 6.91 | 7.73 |
| 2834.8 | 4.74 | 16.29 |
| 2853.2 | 3.4 | 37.86 |
| 2872.2 | 2.27 | 42.35 |
| 2891.4 | 1.42 | 61.36 |
| 2911.9 | 1.39 | 119.36 |
| 2931.2 | 2.24 | 134.95 |
| 2949.9 | 2.48 | 144.88 |
| 2969 | 2.15 | 143.5 |
| 2987.9 | 2.4 | 161.37 |
| 3006.9 | 3.13 | 172.31 |
| 3026.3 | 2.78 | 184.92 |
| 3045.4 | 2.35 | 195.76 |
| 3064.3 | 2.09 | 194.6 |
| 3084 | 1.84 | 198.87 |
| 3102.5 | 1.54 | 201.16 |
| 3120.7 | 1.25 | 203.39 |
| 3140.5 | 1.26 | 221.23 |
| 3160.6 | 1.76 | 244.38 |
| 3179.6 | 2.18 | 256.4 |
| 3199.4 | 2.19 | 258.98 |
| 3218.7 | 2.03 | 259.88 |
| 3237.8 | 2.16 | 265.47 |
| 3257.2 | 3.14 | 280.72 |
| 3275.7 | 3.4 | 280.75 |
| 3295.1 | 3.33 | 274.16 |
| 3314.3 | 3.17 | 261.25 |
| 3333.9 | 3.44 | 246.85 |
| 3352.7 | 3.74 | 229.53 |
| 3373.2 | 3.17 | 217.11 |
| 3477 | 3.17 | 217.11 |

**Table A.4** Survey Data of the Well S-2

| | | |
|---|---|---|
| 0.00 | 0.00 | 151.98 |
| 6.90 | 0.00 | 151.98 |
| 10.00 | 0.06 | 151.98 |
| 20.00 | 0.13 | 189.77 |
| 30.00 | 0.07 | 194.63 |
| 40.00 | 0.08 | 312.07 |
| 50.00 | 0.16 | 226.78 |
| 60.00 | 0.08 | 173.07 |
| 70.00 | 0.12 | 136.79 |
| 79.00 | 0.16 | 147.45 |
| 129.60 | 0.23 | 164.20 |
| 139.00 | 0.32 | 165.57 |
| 148.30 | 0.58 | 164.83 |
| 157.70 | 0.51 | 187.99 |
| 167.00 | 0.33 | 163.83 |
| 176.60 | 0.61 | 183.94 |
| 186.00 | 0.41 | 168.19 |
| 193.00 | 0.54 | 161.89 |
| 202.00 | 0.55 | 147.16 |
| 212.00 | 0.71 | 174.54 |
| 221.00 | 0.67 | 154.69 |
| 249.00 | 0.77 | 162.58 |
| 289.20 | 2.10 | 156.53 |
| 298.80 | 2.74 | 157.63 |
| 307.70 | 3.31 | 156.79 |
| 317.00 | 4.05 | 160.82 |
| 326.40 | 4.57 | 158.58 |
| 335.70 | 5.22 | 162.92 |
| 345.10 | 5.82 | 164.22 |
| 354.40 | 6.26 | 167.73 |
| 363.90 | 6.88 | 171.43 |
| 373.30 | 7.63 | 172.69 |
| 382.70 | 8.35 | 172.81 |
| 392.00 | 8.91 | 173.60 |
| 401.30 | 9.56 | 174.47 |
| 420.00 | 11.15 | 173.56 |
| 438.80 | 12.55 | 174.04 |
| 457.30 | 13.90 | 174.59 |
| 475.90 | 14.88 | 174.71 |
| 485.30 | 15.33 | 173.87 |
| 504.00 | 16.61 | 174.36 |
| 522.80 | 17.48 | 172.23 |
| 541.50 | 18.31 | 171.25 |
| 560.20 | 19.85 | 171.14 |
| 579.50 | 21.47 | 170.03 |
| 606.80 | 23.40 | 170.78 |
| 625.50 | 23.06 | 170.45 |
| 653.60 | 22.29 | 170.84 |
| 672.50 | 23.01 | 171.08 |
| 693.00 | 22.90 | 170.87 |
| 717.90 | 22.04 | 172.83 |
| 736.00 | 22.26 | 172.06 |
| 754.00 | 22.81 | 172.17 |
| 774.00 | 22.84 | 171.48 |
| 792.00 | 23.42 | 170.00 |
| 810.00 | 23.42 | 169.02 |
| 829.00 | 24.10 | 168.78 |
| 849.00 | 23.77 | 169.42 |
| 877.00 | 22.50 | 169.52 |
| 894.70 | 22.73 | 169.05 |
| 914.50 | 23.40 | 168.38 |
| 932.00 | 23.30 | 168.98 |
| 951.00 | 23.08 | 168.71 |
| 970.00 | 23.02 | 169.24 |
| 989.00 | 23.51 | 170.13 |
| 1007.00 | 23.14 | 170.61 |
| 1026.50 | 23.20 | 170.26 |
| 1045.20 | 23.48 | 170.32 |
| 1063.90 | 23.50 | 170.18 |
| 1082.70 | 23.25 | 171.14 |
| 1101.20 | 23.03 | 171.32 |
| 1120.00 | 22.64 | 171.41 |
| 1138.50 | 23.37 | 171.04 |
| 1157.40 | 23.37 | 171.70 |
| 1176.10 | 23.41 | 171.84 |
| 1193.80 | 23.19 | 171.70 |
| 1213.50 | 23.07 | 172.25 |
| 1232.00 | 22.67 | 172.40 |
| 1250.00 | 22.71 | 172.56 |
| 1269.00 | 22.60 | 172.15 |
| 1288.00 | 22.79 | 172.08 |
| 1297.80 | 23.03 | 171.60 |
| 1316.50 | 23.06 | 172.24 |
| 1335.20 | 22.95 | 172.19 |
| 1353.90 | 22.98 | 171.33 |
| 1372.00 | 23.08 | 171.59 |
| 1391.00 | 23.53 | 171.35 |
| 1410.00 | 23.17 | 171.54 |
| 1428.70 | 23.02 | 171.19 |
| 1447.60 | 23.06 | 171.69 |
| 1466.20 | 23.18 | 170.87 |
| 1483.30 | 22.59 | 171.16 |
| 1503.00 | 22.76 | 171.18 |
| 1522.00 | 23.45 | 170.28 |
| 1531.00 | 23.64 | 170.31 |
| 1550.40 | 23.20 | 170.89 |
| 1569.10 | 23.41 | 170.54 |
| 1587.80 | 23.14 | 170.79 |
| 1606.00 | 23.00 | 170.86 |
| 1625.00 | 22.65 | 171.05 |
| 1644.00 | 21.96 | 170.77 |
| 1662.90 | 21.27 | 170.96 |
| 1681.60 | 21.25 | 169.97 |
| 1700.00 | 20.99 | 168.87 |
| 1719.00 | 20.53 | 169.51 |
| 1737.80 | 19.71 | 170.07 |
| 1756.50 | 18.95 | 170.22 |
| 1775.50 | 17.92 | 170.19 |
| 1794.00 | 17.09 | 170.64 |
| 1812.50 | 16.02 | 171.25 |
| 1831.30 | 15.30 | 170.36 |
| 1850.00 | 14.58 | 169.75 |
| 1868.60 | 13.87 | 169.53 |
| 1887.30 | 12.71 | 169.01 |
| 1906.00 | 11.70 | 168.80 |
| 1912.00 | 11.29 | 169.98 |
| 1933.70 | 10.75 | 168.81 |
| 1942.50 | 10.47 | 170.59 |
| 1962.70 | 10.67 | 168.42 |
| 1979.10 | 10.39 | 169.31 |
| 1998.90 | 10.36 | 167.97 |
| 2017.60 | 10.07 | 167.04 |
| 2036.40 | 8.45 | 163.65 |
| 2055.00 | 8.60 | 165.17 |
| 2072.80 | 8.58 | 165.58 |
| 2091.60 | 7.80 | 160.23 |
| 2111.40 | 6.58 | 160.86 |
| 2130.10 | 6.65 | 160.52 |
| 2148.80 | 6.02 | 159.10 |
| 2167.50 | 5.38 | 164.12 |
| 2185.20 | 5.09 | 164.32 |
| 2205.17 | 4.83 | 166.40 |
| 2222.50 | 4.49 | 168.19 |
| 2241.50 | 3.47 | 173.14 |
| 2260.80 | 3.89 | 175.94 |
| 2278.70 | 4.15 | 180.95 |
| 2298.40 | 4.16 | 177.92 |
| 2317.10 | 3.93 | 179.42 |
| 2335.80 | 3.26 | 174.85 |
| 2354.50 | 2.75 | 174.46 |
| 2373.10 | 2.69 | 174.24 |
| 2391.90 | 2.43 | 173.20 |
| 2429.30 | 2.86 | 176.47 |
| 2447.90 | 2.77 | 177.40 |
| 2466.70 | 2.40 | 167.77 |
| 2485.70 | 2.45 | 168.81 |
| 2494.90 | 2.36 | 168.40 |
| 2504.20 | 2.11 | 177.00 |
| 2550.90 | 2.02 | 196.81 |
| 2569.50 | 2.03 | 194.88 |
| 2589.20 | 1.87 | 193.84 |
| 2606.90 | 1.82 | 191.97 |
| 2625.60 | 1.77 | 189.26 |
| 2644.30 | 1.74 | 183.29 |
| 2663.00 | 1.58 | 182.98 |
| 2681.70 | 1.51 | 179.27 |
| 2700.40 | 1.37 | 174.48 |
| 2719.10 | 0.83 | 143.81 |
| 2737.70 | 1.33 | 63.51 |
| 2756.40 | 2.56 | 46.70 |
| 2775.20 | 2.96 | 43.05 |
| 2794.00 | 2.34 | 40.29 |
| 2812.80 | 1.70 | 34.70 |
| 2840.80 | 1.62 | 72.65 |
| 2860.00 | 2.11 | 72.22 |
| 2877.70 | 1.59 | 87.05 |
| 2896.80 | 1.33 | 111.35 |
| 2915.50 | 1.26 | 119.41 |
| 2934.20 | 1.11 | 104.52 |
| 2952.70 | 2.07 | 77.44 |
| 2981.00 | 2.52 | 81.87 |
| 3009.70 | 2.18 | 105.81 |
| 3037.70 | 2.20 | 126.38 |
| 3065.10 | 2.23 | 133.50 |
| 3101.00 | 2.23 | 133.50 |

**Table A.5** Survey Data of the Well DKO-1

| | | |
|---|---|---|
| 0 | 0 | 338.11 |
| 5.6 | 0 | 338.11 |
| 51.2 | 0.1 | 338.11 |
| 101.2 | 0.06 | 342.26 |
| 151.2 | 0.1 | 52.83 |
| 201.2 | 0.11 | 53.1 |
| 251.2 | 0.18 | 51.23 |
| 301.2 | 0.23 | 59.86 |
| 351.2 | 0.21 | 73.68 |
| 401.2 | 0.25 | 67.49 |
| 451.2 | 0.24 | 50.1 |
| 501.2 | 0.36 | 61.58 |
| 551.2 | 0.44 | 58.93 |
| 601.2 | 0.45 | 68.44 |
| 651.2 | 0.5 | 62.61 |
| 701.2 | 0.46 | 61.89 |
| 751.2 | 0.56 | 84.73 |
| 801.2 | 0.54 | 90.12 |
| 851.2 | 0.71 | 87.24 |
| 901.2 | 0.52 | 108.99 |
| 951.2 | 0.59 | 102.26 |
| 1001.2 | 0.67 | 107.41 |
| 1051.2 | 0.68 | 90 |
| 1101.2 | 0.56 | 90.12 |
| 1151.2 | 0.55 | 80.17 |
| 1201.2 | 0.4 | 97.98 |
| 1251.2 | 0.35 | 128.58 |
| 1301.2 | 0.34 | 100.26 |
| 1351.2 | 0.34 | 149.75 |
| 1401.2 | 0.42 | 147.58 |
| 1451.2 | 0.41 | 174.13 |
| 1501.2 | 0.43 | 161.96 |
| 1551.2 | 1.56 | 195.81 |
| 1601.2 | 2.75 | 205.57 |
| 1646 | 2.096 | 204.24 |
| 1663 | 4.01 | 203.92 |
| 1680 | 4.73 | 204.38 |
| 1697 | 6.19 | 210.6 |
| 1714.6 | 7.36 | 209.58 |
| 1743.3 | 7.39 | 209.97 |
| 1772.5 | 9.52 | 206.62 |
| 1802.9 | 11.63 | 203.63 |
| 1830 | 11.9 | 207.04 |
| 1858.7 | 11.65 | 204.76 |
| 1887.2 | 11.93 | 206.92 |
| 1916.4 | 11.43 | 208.53 |
| 1945.2 | 12.11 | 206.77 |
| 1974.1 | 12 | 208.07 |
| 2003.1 | 11.26 | 206.63 |
| 2031.8 | 11.58 | 207.12 |
| 2060.2 | 11.29 | 206.77 |
| 2089.6 | 12.56 | 207.58 |
| 2118.4 | 11.64 | 208.04 |
| 2146.7 | 11.83 | 206.08 |
| 2185.4 | 13.9 | 204 |
| 2224.5 | 12.43 | 205.88 |
| 2253.4 | 13.45 | 207.67 |
| 2281.4 | 12.11 | 207.58 |
| 2329.6 | 12.74 | 209.6 |
| 2358.5 | 12.75 | 209.19 |
| 2387.3 | 12.35 | 209.36 |
| 2416.5 | 12.79 | 210.7 |
| 2445 | 12.48 | 210.46 |
| 2473.7 | 12.66 | 210.23 |
| 2502.9 | 12.13 | 209.09 |
| 2541.4 | 11.59 | 208.13 |
| 2575.1 | 11.83 | 207.55 |

**Table A.6** Survey Data of the Well DKO-2

| | | |
|---|---|---|
| 0.00 | 0.00 | 122.61 |
| 6.70 | 0.00 | 122.61 |
| 149.20 | 0.08 | 122.61 |
| 299.20 | 0.09 | 122.61 |
| 449.20 | 0.57 | 122.61 |
| 598.00 | 0.97 | 122.61 |
| 748.30 | 0.60 | 122.61 |
| 910.30 | 0.62 | 122.61 |
| 938.40 | 0.87 | 157.71 |
| 967.00 | 2.11 | 171.12 |
| 995.60 | 3.95 | 179.03 |
| 1024.30 | 4.29 | 181.11 |
| 1052.80 | 4.63 | 182.58 |
| 1081.20 | 6.33 | 187.32 |
| 1109.70 | 7.95 | 190.80 |
| 1137.80 | 9.04 | 186.87 |
| 1166.30 | 10.21 | 185.31 |
| 1195.00 | 11.37 | 183.88 |
| 1224.00 | 12.46 | 183.39 |
| 1252.80 | 13.47 | 183.20 |
| 1280.70 | 13.31 | 182.51 |
| 1309.20 | 13.36 | 184.13 |
| 1337.60 | 13.51 | 183.77 |
| 1366.10 | 13.35 | 182.91 |
| 1395.00 | 13.44 | 184.27 |
| 1423.30 | 13.60 | 183.73 |
| 1451.60 | 13.79 | 184.87 |
| 1480.60 | 13.62 | 184.17 |
| 1508.70 | 13.67 | 183.85 |
| 1537.50 | 13.71 | 184.20 |
| 1565.90 | 13.63 | 183.90 |
| 1594.10 | 13.32 | 184.81 |
| 1622.90 | 13.21 | 185.00 |
| 1651.20 | 12.52 | 184.09 |
| 1679.90 | 12.68 | 184.50 |
| 1708.20 | 13.11 | 183.45 |
| 1736.50 | 12.92 | 182.67 |
| 1765.10 | 13.32 | 182.88 |
| 1792.60 | 13.52 | 184.54 |
| 1822.40 | 14.19 | 182.01 |
| 1850.40 | 13.87 | 183.16 |
| 1878.80 | 14.16 | 182.36 |
| 1907.50 | 14.81 | 183.60 |
| 1935.40 | 14.86 | 184.89 |
| 1964.20 | 15.22 | 183.27 |
| 1992.60 | 15.68 | 183.09 |
| 2021.70 | 16.15 | 183.04 |
| 2051.40 | 16.40 | 185.48 |
| 2080.00 | 15.79 | 183.81 |
| 2108.30 | 15.18 | 182.88 |
| 2136.80 | 14.00 | 179.14 |
| 2164.10 | 13.01 | 174.37 |
| 2192.60 | 12.21 | 172.40 |
| 2221.20 | 12.35 | 172.02 |
| 2250.00 | 13.12 | 171.56 |
| 2278.40 | 13.09 | 171.76 |
| 2306.80 | 13.53 | 172.86 |
| 2335.30 | 13.80 | 174.54 |
| 2363.30 | 13.68 | 181.00 |
| 2392.10 | 14.16 | 183.57 |
| 2421.20 | 14.12 | 183.17 |
| 2449.30 | 14.20 | 183.05 |
| 2478.10 | 14.42 | 183.41 |
| 2505.90 | 14.26 | 181.87 |
| 2536.20 | 14.23 | 180.18 |
| 2562.70 | 13.95 | 178.20 |
| 2591.20 | 14.13 | 177.32 |
| 2618.80 | 14.04 | 177.44 |
| 2653.00 | 13.84 | 178.72 |
| 2676.90 | 13.76 | 180.87 |
| 2706.00 | 13.64 | 183.21 |
| 2734.70 | 13.63 | 183.41 |
| 2763.10 | 13.64 | 180.42 |
| 2808.00 | 13.64 | 180.42 |

**Table A.7** Survey Data of the Well V-1

| | | |
|---|---|---|
| 0 | 0 | 127.25 |
| 6.1 | 0 | 127.25 |
| 119.6 | 1.13 | 127.25 |
| 138.8 | 1.09 | 126.77 |
| 157.8 | 0.98 | 121.29 |
| 176 | 0.9 | 110.13 |
| 192.4 | 1.08 | 103.38 |
| 216 | 0.98 | 107.47 |
| 230.6 | 1 | 103.61 |
| 252.9 | 0.25 | 11.95 |
| 271.7 | 0.87 | 318.06 |
| 291.3 | 0.86 | 334.16 |
| 310.3 | 0.91 | 338.31 |
| 329.6 | 0.81 | 332.71 |
| 348.4 | 0.94 | 354.5 |
| 367.6 | 0.7 | 6.19 |
| 386.5 | 0.54 | 358.69 |
| 405.5 | 0.96 | 322.82 |
| 424.5 | 1.19 | 301.98 |
| 444 | 1.24 | 314.47 |
| 463.3 | 1.06 | 319.24 |
| 482.3 | 0.95 | 299.07 |
| 500.7 | 0.73 | 282.72 |
| 529.5 | 0.64 | 229.82 |
| 548.4 | 0.72 | 239.22 |
| 567.5 | 0.85 | 234.6 |
| 587 | 0.49 | 231.7 |
| 606 | 0.46 | 219.91 |
| 620.4 | 0.47 | 204.75 |
| 651.1 | 0.25 | 212.55 |
| 671 | 0.44 | 171.14 |
| 689.9 | 0.6 | 144.66 |
| 709.1 | 0.71 | 164.13 |
| 728.5 | 0.89 | 161.13 |
| 747 | 1.11 | 168.07 |
| 765.7 | 1.22 | 169.79 |
| 785.2 | 1.08 | 168.3 |
| 804.3 | 0.68 | 172.31 |
| 823.1 | 0.64 | 164.18 |
| 861.7 | 0.44 | 146.38 |
| 881 | 0.35 | 135 |
| 899.2 | 0.43 | 94.45 |
| 918.5 | 0.4 | 116.6 |
| 937.5 | 0.57 | 147.71 |
| 956.8 | 0.7 | 165.59 |
| 975.3 | 0.72 | 203.67 |
| 994.7 | 0.74 | 270.66 |
| 1014 | 0.97 | 290.9 |
| 1033.3 | 0.92 | 276.22 |
| 1051.2 | 0.97 | 275.31 |
| 1070.3 | 0.52 | 282.64 |
| 1089.4 | 0.37 | 298.36 |
| 1108.6 | 0.3 | 288.23 |
| 1127.7 | 0.43 | 303.58 |
| 1146.9 | 0.56 | 332.01 |
| 1165.5 | 1.17 | 5.65 |
| 1184.5 | 1.01 | 14.04 |
| 1203.9 | 0.87 | 9.42 |
| 1221.9 | 0.49 | 24.56 |
| 1241 | 0.35 | 33.06 |
| 1260.2 | 0.1 | 72.84 |
| 1279.6 | 0.29 | 180.47 |
| 1297.5 | 0.56 | 150.19 |
| 1316.6 | 0.59 | 134.55 |
| 1345.3 | 0.77 | 137.96 |
| 1364 | 1.14 | 157.9 |
| 1382.4 | 0.63 | 160.11 |
| 1401.8 | 0.45 | 57.02 |
| 1420.1 | 0.99 | 14.41 |
| 1439.8 | 1.71 | 9.72 |
| 1458.9 | 0.63 | 47.09 |
| 1477.7 | 2.07 | 183.17 |
| 1497.5 | 2.61 | 186.44 |
| 1516.5 | 1.42 | 170.6 |
| 1535.5 | 0.9 | 46.83 |
| 1554.4 | 2.01 | 11.19 |
| 1573.6 | 2.13 | 9.91 |
| 1592.9 | 1.75 | 0.06 |
| 1612.4 | 2.39 | 331.24 |
| 1631.3 | 1.96 | 321.33 |
| 1649.6 | 0.87 | 300.39 |
| 1668.6 | 0.58 | 277.73 |
| 1687.4 | 0.71 | 248.03 |
| 1706.5 | 1.11 | 232.12 |
| 1727.4 | 0.67 | 206.31 |
| 1745.9 | 0.55 | 211.9 |
| 1760.9 | 0.17 | 163.55 |
| 1784.3 | 0.39 | 30.1 |
| 1802.9 | 0.32 | 353.6 |
| 1821.2 | 0.5 | 340.94 |
| 1840.6 | 0.33 | 338.98 |
| 1858.8 | 0.76 | 1.01 |
| 1877.9 | 0.67 | 2.18 |
| 1898.1 | 0.48 | 171.04 |
| 1915.9 | 1.39 | 168.75 |
| 1935 | 2.05 | 166.43 |
| 1953.8 | 1.97 | 152.67 |
| 1973.2 | 2.18 | 142.18 |
| 1993 | 2.42 | 145.66 |
| 2011.6 | 2.24 | 175.54 |

**Table A.8** Survey Data of the Well V-2

| | | |
|---|---|---|
| 0 | 0 | 63.02 |
| 112 | 0.16 | 63.02 |
| 369.45 | 0.35 | 63.02 |
| 629.5 | 0.7 | 63.02 |
| 812.08 | 0.76 | 63.02 |
| 843.45 | 0.77 | 66.12 |
| 869.7 | 0.79 | 64.2 |
| 897.92 | 0.77 | 48.01 |
| 927.42 | 0.78 | 58.37 |
| 953.86 | 0.67 | 59.07 |
| 983.79 | 0.78 | 58.24 |
| 1013.23 | 0.74 | 64.96 |
| 1040.87 | 0.65 | 56.93 |
| 1066.7 | 0.51 | 58.1 |
| 1098.1 | 0.74 | 62.49 |
| 1125.9 | 0.52 | 61.46 |
| 1155.5 | 0.71 | 54.58 |
| 1183.3 | 0.76 | 38.87 |
| 1214.2 | 0.57 | 27.77 |
| 1243.3 | 0.52 | 26.43 |
| 1271.4 | 0.44 | 7.53 |
| 1299.51 | 0.6 | 21.3 |
| 1330.45 | 0.56 | 33.46 |
| 1359.05 | 0.4 | 27.55 |
| 1388.27 | 0.55 | 32.18 |
| 1416.2 | 0.4 | 32.97 |
| 1444.99 | 0.47 | 28.54 |
| 1465.9 | 0.33 | 22.94 |
| 1503 | 0.42 | 8.65 |
| 1531.9 | 0.48 | 7.8 |
| 1560.79 | 0.47 | 359.2 |
| 1589 | 0.7 | 2.91 |
| 1615.5 | 0.63 | 357.54 |
| 1646.9 | 0.47 | 319.88 |
| 1676.1 | 0.39 | 259.73 |
| 1705.6 | 0.52 | 263.6 |
| 1733.82 | 0.91 | 256.51 |
| 1761.3 | 0.92 | 255.91 |
| 1791.1 | 1.38 | 257.2 |
| 1820.9 | 1.42 | 261.97 |
| 1849.27 | 1.27 | 264.53 |
| 1877.95 | 1.17 | 266.02 |
| 1905.3 | 1.35 | 275.96 |
| 1933 | 1.49 | 286.72 |
| 1965.1 | 2.11 | 293.44 |
| 1978 | 2.18 | 294.55 |
| 2014.7 | 3.55 | 292.66 |
| 2028.6 | 3.88 | 293.38 |
| 2056.9 | 3.75 | 293.57 |
| 2086.2 | 3.61 | 293.89 |
| 2115 | 2.89 | 299.01 |
| 2143.6 | 2.52 | 297.79 |
| 2171.7 | 1.9 | 307.39 |
| 2199.8 | 1.8 | 317.85 |
| 2228.8 | 1.72 | 307.21 |
| 2258.8 | 1.45 | 2.17 |
| 2287.5 | 1.82 | 28.23 |
| 2317.8 | 2.87 | 37.88 |
| 2346.5 | 3.79 | 38.93 |
| 2375.5 | 3.99 | 40.29 |
| 2403.8 | 4.07 | 26.42 |
| 2430.8 | 4.64 | 14.67 |
| 2462.2 | 4.46 | 9 |
| 2490.4 | 3.33 | 340.26 |
| 2518.7 | 3.41 | 317.84 |
| 2547.1 | 3.55 | 295.26 |
| 2575 | 4.24 | 251.22 |
| 2605.8 | 1.54 | 263.47 |
| 2633.9 | 0.55 | 203.14 |
| 2661.8 | 1.68 | 212.8 |
| 2691.7 | 1.83 | 219.45 |
| 2721 | 3.23 | 218.12 |
| 2748.7 | 3.07 | 212.64 |
| 2777.2 | 1.38 | 218.22 |
| 2807.9 | 1.2 | 238.47 |
| 2837.6 | 1.65 | 242.55 |
| 2864.9 | 2.13 | 251.34 |
| 2893.7 | 2.93 | 207.53 |
| 2921.6 | 2.83 | 181.87 |
| 2949.5 | 2.11 | 179.96 |
| 2981.7 | 1.15 | 204.37 |
| 3000 | 1.15 | 204.37 |

## B. The Python Programming Code Output Screen Shots of the Well J-1

**Table B.1** The Results of Balanced Tangential Method for the Well J-1 (1/7)

```
*********************************************Balanced_Tangential*********************************************
```

| Survey No | MD | Inc | Az | CL | TVD | Local N | Local E | DLS | VS |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 180.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2 | 5.20 | 0.00 | 180.00 | 5.20 | 5.20 | 0.00 | 0.00 | 0.00 | 0.00 |
| 3 | 112.00 | 0.10 | 180.00 | 106.80 | 112.00 | -0.09 | 0.00 | 0.03 | -0.02 |
| 4 | 133.00 | 0.13 | 360.00 | 21.00 | 133.00 | -0.09 | 0.00 | 0.33 | -0.02 |
| 5 | 152.00 | 0.10 | 129.09 | 19.00 | 152.00 | -0.08 | 0.01 | 0.33 | -0.01 |
| 6 | 171.90 | 0.07 | 137.57 | 19.90 | 171.90 | -0.10 | 0.03 | 0.05 | 0.01 |
| 7 | 188.90 | 0.13 | 225.60 | 17.00 | 188.90 | -0.12 | 0.03 | 0.26 | -0.00 |
| 8 | 207.30 | 0.19 | 82.55 | 18.40 | 207.30 | -0.13 | 0.04 | 0.50 | 0.01 |
| 9 | 226.10 | 0.65 | 116.94 | 18.80 | 226.10 | -0.17 | 0.17 | 0.81 | 0.12 |
| 10 | 245.40 | 1.14 | 94.60 | 19.30 | 245.40 | -0.24 | 0.46 | 0.92 | 0.39 |
| 11 | 264.85 | 1.97 | 95.93 | 19.45 | 264.84 | -0.29 | 0.98 | 1.28 | 0.89 |
| 12 | 284.02 | 3.08 | 88.71 | 19.17 | 283.99 | -0.31 | 1.83 | 1.80 | 1.70 |
| 13 | 302.56 | 4.23 | 87.58 | 18.54 | 302.49 | -0.27 | 3.01 | 1.86 | 2.86 |
| 14 | 322.00 | 5.63 | 84.08 | 19.44 | 321.86 | -0.14 | 4.67 | 2.21 | 4.50 |
| 15 | 341.40 | 6.29 | 83.37 | 19.40 | 341.15 | 0.08 | 6.67 | 1.03 | 6.50 |
| 16 | 360.27 | 7.02 | 81.14 | 18.87 | 359.89 | 0.38 | 8.84 | 1.23 | 8.67 |
| 17 | 379.20 | 7.48 | 79.20 | 18.93 | 378.67 | 0.79 | 11.19 | 0.83 | 11.06 |
| 18 | 399.50 | 7.83 | 76.90 | 20.30 | 398.79 | 1.35 | 13.84 | 0.69 | 13.76 |
| 19 | 418.50 | 7.61 | 75.37 | 19.00 | 417.62 | 1.96 | 16.32 | 0.48 | 16.31 |
| 20 | 437.20 | 7.64 | 76.27 | 18.70 | 436.15 | 2.57 | 18.72 | 0.20 | 18.79 |
| 21 | 456.20 | 8.28 | 78.70 | 19.00 | 454.97 | 3.13 | 21.29 | 1.14 | 21.42 |
| 22 | 476.63 | 8.45 | 79.73 | 20.43 | 475.18 | 3.69 | 24.21 | 0.33 | 24.39 |
| 23 | 495.64 | 8.51 | 78.18 | 19.01 | 493.99 | 4.23 | 26.96 | 0.37 | 27.19 |
| 24 | 514.87 | 8.78 | 76.31 | 19.23 | 513.00 | 4.86 | 29.78 | 0.61 | 30.08 |
| 25 | 534.10 | 9.20 | 75.88 | 19.23 | 531.99 | 5.59 | 32.70 | 0.66 | 33.08 |

**Table B.2** The Results of Balanced Tangential Method for the Well J-1 (2/7)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 26 | 553.20 | 9.14 | 74.90 | 19.10 | 550.85 | 6.36 | 35.64 | 0.26 | 36.13 |
| 27 | 572.75 | 9.31 | 75.08 | 19.55 | 570.14 | 7.17 | 38.67 | 0.26 | 39.26 |
| 28 | 591.62 | 9.25 | 74.92 | 18.87 | 588.77 | 7.95 | 41.61 | 0.10 | 42.30 |
| 29 | 611.11 | 9.27 | 73.36 | 19.49 | 608.00 | 8.81 | 44.62 | 0.39 | 45.44 |
| 30 | 630.30 | 9.19 | 74.52 | 19.19 | 626.94 | 9.66 | 47.58 | 0.32 | 48.51 |
| 31 | 649.70 | 8.92 | 74.46 | 19.40 | 646.10 | 10.48 | 50.52 | 0.42 | 51.56 |
| 32 | 669.10 | 9.02 | 75.12 | 19.40 | 665.27 | 11.27 | 53.44 | 0.22 | 54.59 |
| 33 | 688.13 | 9.46 | 74.25 | 19.03 | 684.05 | 12.08 | 56.39 | 0.73 | 57.64 |
| 34 | 707.55 | 9.44 | 73.54 | 19.42 | 703.20 | 12.96 | 59.45 | 0.18 | 60.83 |
| 35 | 729.90 | 9.28 | 72.79 | 22.35 | 725.26 | 14.02 | 62.93 | 0.27 | 64.46 |
| 36 | 746.27 | 9.08 | 72.42 | 16.37 | 741.42 | 14.80 | 65.42 | 0.38 | 67.07 |
| 37 | 765.62 | 9.07 | 73.33 | 19.35 | 760.53 | 15.70 | 68.34 | 0.22 | 70.11 |
| 38 | 784.99 | 9.00 | 73.48 | 19.37 | 779.66 | 16.57 | 71.26 | 0.11 | 73.15 |
| 39 | 804.15 | 8.71 | 73.77 | 19.16 | 798.59 | 17.40 | 74.09 | 0.46 | 76.10 |
| 40 | 822.94 | 8.88 | 73.02 | 18.79 | 817.16 | 18.22 | 76.84 | 0.33 | 78.97 |
| 41 | 842.26 | 8.90 | 75.28 | 19.32 | 836.24 | 19.03 | 79.71 | 0.54 | 81.95 |
| 42 | 861.70 | 8.96 | 77.90 | 19.44 | 855.45 | 19.73 | 82.65 | 0.63 | 84.97 |
| 43 | 881.05 | 8.85 | 78.39 | 19.35 | 874.56 | 20.35 | 85.58 | 0.21 | 87.96 |
| 44 | 900.05 | 8.71 | 77.42 | 19.00 | 893.34 | 20.96 | 88.41 | 0.32 | 90.86 |
| 45 | 919.92 | 8.49 | 77.20 | 19.87 | 912.99 | 21.61 | 91.31 | 0.34 | 93.83 |
| 46 | 939.20 | 8.36 | 77.11 | 19.28 | 932.06 | 22.24 | 94.07 | 0.20 | 96.65 |
| 47 | 958.60 | 8.23 | 76.43 | 19.40 | 951.26 | 22.88 | 96.79 | 0.25 | 99.45 |
| 48 | 998.40 | 7.49 | 76.80 | 39.80 | 990.68 | 24.14 | 102.08 | 0.56 | 104.90 |
| 49 | 1018.15 | 8.20 | 77.42 | 19.75 | 1010.25 | 24.74 | 104.71 | 1.09 | 107.59 |
| 50 | 1038.20 | 8.67 | 77.83 | 20.05 | 1030.08 | 25.37 | 107.59 | 0.71 | 110.53 |
| 51 | 1057.50 | 8.65 | 78.11 | 19.30 | 1049.16 | 25.97 | 110.43 | 0.07 | 113.43 |
| 52 | 1075.90 | 8.56 | 75.70 | 18.40 | 1067.35 | 26.60 | 113.11 | 0.61 | 116.19 |

**Table B.3** The Results of Balanced Tangential Method for the Well J-1 (3/7)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 53 | 1095.39 | 8.52 | 74.49 | 19.49 | 1086.63 | 27.34 | 115.90 | 0.28 | 119.08 |
| 54 | 1113.84 | 8.62 | 73.72 | 18.45 | 1104.87 | 28.09 | 118.55 | 0.25 | 121.83 |
| 55 | 1133.14 | 8.80 | 72.09 | 19.30 | 1123.95 | 28.95 | 121.34 | 0.47 | 124.75 |
| 56 | 1152.40 | 8.31 | 70.51 | 19.26 | 1142.99 | 29.87 | 124.06 | 0.85 | 127.60 |
| 57 | 1172.01 | 8.00 | 71.15 | 19.61 | 1162.41 | 30.79 | 126.68 | 0.49 | 130.37 |
| 58 | 1191.40 | 7.96 | 71.49 | 19.39 | 1181.61 | 31.65 | 129.23 | 0.10 | 133.05 |
| 59 | 1210.58 | 7.73 | 70.09 | 19.18 | 1200.61 | 32.51 | 131.71 | 0.47 | 135.66 |
| 60 | 1230.01 | 7.29 | 69.93 | 19.43 | 1219.87 | 33.38 | 134.09 | 0.68 | 138.18 |
| 61 | 1248.35 | 7.40 | 69.21 | 18.34 | 1238.06 | 34.19 | 136.29 | 0.23 | 140.51 |
| 62 | 1267.80 | 7.09 | 69.92 | 19.45 | 1257.36 | 35.05 | 138.59 | 0.50 | 142.95 |
| 63 | 1287.50 | 7.06 | 68.50 | 19.70 | 1276.91 | 35.91 | 140.86 | 0.27 | 145.36 |
| 64 | 1306.55 | 6.85 | 69.27 | 19.05 | 1295.82 | 36.74 | 143.01 | 0.36 | 147.64 |
| 65 | 1325.60 | 7.14 | 70.72 | 19.05 | 1314.72 | 37.54 | 145.19 | 0.53 | 149.95 |
| 66 | 1344.50 | 7.17 | 73.48 | 18.90 | 1333.48 | 38.26 | 147.43 | 0.55 | 152.30 |
| 67 | 1364.47 | 7.01 | 73.16 | 19.97 | 1353.29 | 38.97 | 149.79 | 0.25 | 154.76 |
| 68 | 1382.60 | 7.03 | 72.06 | 18.13 | 1371.29 | 39.63 | 151.90 | 0.22 | 156.97 |
| 69 | 1402.15 | 6.84 | 72.02 | 19.55 | 1390.70 | 40.36 | 154.15 | 0.29 | 159.33 |
| 70 | 1422.25 | 6.85 | 71.53 | 20.10 | 1410.65 | 41.11 | 156.42 | 0.09 | 161.71 |
| 71 | 1441.53 | 6.74 | 71.55 | 19.28 | 1429.80 | 41.83 | 158.59 | 0.17 | 163.99 |
| 72 | 1460.96 | 6.82 | 71.70 | 19.43 | 1449.09 | 42.55 | 160.76 | 0.13 | 166.27 |
| 73 | 1480.19 | 7.74 | 72.49 | 19.23 | 1468.16 | 43.30 | 163.08 | 1.44 | 168.71 |
| 74 | 1499.03 | 8.46 | 73.53 | 18.84 | 1486.82 | 44.07 | 165.62 | 1.17 | 171.36 |
| 75 | 1517.80 | 9.36 | 71.61 | 18.77 | 1505.36 | 44.95 | 168.39 | 1.51 | 174.26 |
| 76 | 1536.70 | 10.15 | 70.96 | 18.90 | 1523.99 | 45.98 | 171.43 | 1.27 | 177.45 |
| 77 | 1556.10 | 10.82 | 72.51 | 19.40 | 1543.06 | 47.08 | 174.78 | 1.12 | 180.97 |
| 78 | 1576.32 | 11.63 | 75.94 | 20.22 | 1562.89 | 48.15 | 178.57 | 1.56 | 184.90 |
| 79 | 1595.69 | 12.32 | 78.04 | 19.37 | 1581.84 | 49.05 | 182.48 | 1.26 | 188.92 |

**Table B.4** The Results of Balanced Tangential Method for the Well J-1 (4/7)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 80 | 1614.77 | 12.73 | 79.35 | 19.08 | 1600.47 | 49.86 | 186.54 | 0.78 | 193.05 |
| 81 | 1633.50 | 12.70 | 79.57 | 18.73 | 1618.74 | 50.61 | 190.59 | 0.09 | 197.17 |
| 82 | 1653.40 | 12.85 | 78.68 | 19.90 | 1638.15 | 51.44 | 194.91 | 0.37 | 201.56 |
| 83 | 1672.09 | 12.61 | 77.10 | 18.69 | 1656.38 | 52.31 | 198.94 | 0.68 | 205.68 |
| 84 | 1691.85 | 12.20 | 76.30 | 19.76 | 1675.68 | 53.28 | 203.07 | 0.67 | 209.92 |
| 85 | 1711.27 | 11.79 | 76.44 | 19.42 | 1694.67 | 54.23 | 206.99 | 0.63 | 213.96 |
| 86 | 1729.70 | 11.21 | 76.82 | 18.43 | 1712.73 | 55.08 | 210.57 | 0.95 | 217.63 |
| 87 | 1749.10 | 10.54 | 78.69 | 19.40 | 1731.78 | 55.86 | 214.14 | 1.17 | 221.29 |
| 88 | 1769.01 | 10.45 | 79.94 | 19.91 | 1751.36 | 56.53 | 217.71 | 0.37 | 224.91 |
| 89 | 1788.30 | 10.60 | 80.28 | 19.29 | 1770.32 | 57.14 | 221.18 | 0.25 | 228.43 |
| 90 | 1806.80 | 10.74 | 79.80 | 18.50 | 1788.50 | 57.73 | 224.55 | 0.27 | 231.84 |
| 91 | 1826.98 | 10.33 | 78.93 | 20.18 | 1808.34 | 58.41 | 228.18 | 0.65 | 235.53 |
| 92 | 1845.13 | 10.69 | 78.73 | 18.15 | 1826.19 | 59.05 | 231.43 | 0.60 | 238.83 |
| 93 | 1864.30 | 11.07 | 78.99 | 19.17 | 1845.02 | 59.75 | 234.98 | 0.60 | 242.45 |
| 94 | 1884.02 | 11.08 | 79.44 | 19.72 | 1864.37 | 60.46 | 238.70 | 0.13 | 246.23 |
| 95 | 1903.77 | 11.01 | 79.44 | 19.75 | 1883.75 | 61.16 | 242.42 | 0.11 | 250.01 |
| 96 | 1922.75 | 10.43 | 79.65 | 18.98 | 1902.40 | 61.80 | 245.89 | 0.92 | 253.53 |
| 97 | 1941.45 | 10.16 | 80.00 | 18.70 | 1920.80 | 62.39 | 249.18 | 0.44 | 256.87 |
| 98 | 1961.75 | 9.62 | 81.66 | 20.30 | 1940.80 | 62.94 | 252.62 | 0.90 | 260.34 |
| 99 | 1981.15 | 9.10 | 82.85 | 19.40 | 1959.94 | 63.37 | 255.75 | 0.86 | 263.48 |
| 100 | 1999.95 | 8.87 | 80.94 | 18.80 | 1978.51 | 63.78 | 258.65 | 0.60 | 266.40 |
| 101 | 2018.66 | 8.48 | 75.67 | 18.71 | 1997.00 | 64.35 | 261.41 | 1.42 | 269.22 |
| 102 | 2037.87 | 8.41 | 73.78 | 19.21 | 2016.01 | 65.09 | 264.14 | 0.45 | 272.04 |
| 103 | 2057.66 | 7.99 | 73.78 | 19.79 | 2035.59 | 65.88 | 266.85 | 0.64 | 274.86 |
| 104 | 2076.90 | 8.25 | 70.08 | 19.24 | 2054.64 | 66.73 | 269.43 | 0.91 | 277.57 |
| 105 | 2095.98 | 8.89 | 65.80 | 19.08 | 2073.51 | 67.80 | 272.06 | 1.42 | 280.38 |
| 106 | 2115.82 | 9.31 | 64.46 | 19.84 | 2093.10 | 69.12 | 274.91 | 0.71 | 283.46 |

**Table B.5** The Results of Balanced Tangential Method for the Well J-1 (5/7)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 107 | 2134.69 | 9.45 | 63.20 | 18.87 | 2111.71 | 70.47 | 277.67 | 0.40 | 286.46 |
| 108 | 2153.82 | 9.23 | 62.40 | 19.13 | 2130.59 | 71.89 | 280.43 | 0.40 | 289.48 |
| 109 | 2173.95 | 9.88 | 63.26 | 20.13 | 2150.44 | 73.42 | 283.40 | 0.99 | 292.73 |
| 110 | 2193.25 | 9.84 | 68.00 | 19.30 | 2169.46 | 74.78 | 286.41 | 1.26 | 295.98 |
| 111 | 2212.60 | 8.84 | 71.85 | 19.35 | 2188.55 | 75.86 | 289.35 | 1.83 | 299.10 |
| 112 | 2231.73 | 8.47 | 74.84 | 19.13 | 2207.46 | 76.69 | 292.11 | 0.91 | 301.97 |
| 113 | 2250.62 | 8.35 | 75.48 | 18.89 | 2226.15 | 77.40 | 294.78 | 0.24 | 304.74 |
| 114 | 2257.39 | 8.42 | 76.36 | 6.77 | 2232.85 | 77.64 | 295.74 | 0.65 | 305.72 |
| 115 | 2291.55 | 8.70 | 75.68 | 34.16 | 2266.63 | 78.87 | 300.67 | 0.26 | 310.81 |
| 116 | 2309.98 | 8.78 | 73.74 | 18.43 | 2284.84 | 79.61 | 303.37 | 0.50 | 313.61 |
| 117 | 2329.15 | 8.89 | 75.15 | 19.17 | 2303.78 | 80.39 | 306.21 | 0.38 | 316.55 |
| 118 | 2349.15 | 8.60 | 81.03 | 20.00 | 2323.55 | 81.02 | 309.18 | 1.41 | 319.58 |
| 119 | 2368.82 | 8.05 | 81.16 | 19.67 | 2343.01 | 81.46 | 311.99 | 0.84 | 322.42 |
| 120 | 2389.12 | 6.97 | 81.16 | 20.30 | 2363.14 | 81.87 | 314.62 | 1.60 | 325.06 |
| 121 | 2407.15 | 7.13 | 79.82 | 18.03 | 2381.03 | 82.24 | 316.80 | 0.38 | 327.27 |
| 122 | 2426.50 | 7.77 | 77.10 | 19.35 | 2400.22 | 82.74 | 319.25 | 1.13 | 329.78 |
| 123 | 2444.95 | 7.58 | 74.61 | 18.45 | 2418.50 | 83.34 | 321.64 | 0.62 | 332.24 |
| 124 | 2464.60 | 7.46 | 75.03 | 19.65 | 2437.98 | 84.02 | 324.13 | 0.20 | 334.81 |
| 125 | 2484.05 | 7.40 | 75.29 | 19.45 | 2457.27 | 84.66 | 326.56 | 0.11 | 337.33 |
| 126 | 2503.53 | 7.31 | 75.29 | 19.48 | 2476.59 | 85.29 | 328.97 | 0.14 | 339.82 |
| 127 | 2523.41 | 8.42 | 71.28 | 19.88 | 2496.28 | 86.08 | 331.57 | 1.87 | 342.53 |
| 128 | 2542.46 | 9.17 | 70.50 | 19.05 | 2515.11 | 87.04 | 334.32 | 1.20 | 345.43 |
| 129 | 2560.67 | 8.77 | 70.15 | 18.21 | 2533.10 | 87.99 | 337.00 | 0.67 | 348.26 |
| 130 | 2579.25 | 8.30 | 73.75 | 18.58 | 2551.47 | 88.85 | 339.62 | 1.15 | 351.01 |
| 131 | 2599.30 | 7.94 | 71.14 | 20.05 | 2571.32 | 89.70 | 342.32 | 0.77 | 353.83 |
| 132 | 2618.70 | 7.72 | 70.69 | 19.40 | 2590.54 | 90.57 | 344.81 | 0.35 | 356.46 |
| 133 | 2637.90 | 7.06 | 70.56 | 19.20 | 2609.58 | 91.39 | 347.14 | 1.03 | 358.92 |

**Table B.6** The Results of Balanced Tangential Method for the Well J-1 (6/7)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 134 | 2656.80 | 7.10 | 71.12 | 18.90 | 2628.33 | 92.15 | 349.34 | 0.13 | 361.24 |
| 135 | 2677.79 | 7.85 | 81.40 | 20.99 | 2649.14 | 92.78 | 351.99 | 2.19 | 363.96 |
| 136 | 2695.69 | 8.09 | 83.22 | 17.90 | 2666.87 | 93.12 | 354.45 | 0.58 | 366.43 |
| 137 | 2714.60 | 7.51 | 81.10 | 18.91 | 2685.61 | 93.46 | 356.99 | 1.03 | 368.98 |
| 138 | 2734.80 | 6.79 | 78.64 | 20.20 | 2705.65 | 93.90 | 359.46 | 1.16 | 371.49 |
| 139 | 2753.30 | 6.57 | 76.31 | 18.50 | 2724.02 | 94.37 | 361.56 | 0.57 | 373.64 |
| 140 | 2772.70 | 6.32 | 79.06 | 19.40 | 2743.30 | 94.83 | 363.69 | 0.61 | 375.82 |
| 141 | 2792.20 | 6.36 | 80.62 | 19.50 | 2762.68 | 95.21 | 365.81 | 0.27 | 377.96 |
| 142 | 2811.90 | 6.54 | 80.88 | 19.70 | 2782.26 | 95.57 | 367.99 | 0.28 | 380.17 |
| 143 | 2831.00 | 6.90 | 79.85 | 19.10 | 2801.23 | 95.94 | 370.20 | 0.60 | 382.40 |
| 144 | 2850.10 | 7.00 | 79.32 | 19.10 | 2820.19 | 96.36 | 372.47 | 0.19 | 384.71 |
| 145 | 2869.20 | 7.55 | 75.63 | 19.10 | 2839.13 | 96.89 | 374.83 | 1.13 | 387.12 |
| 146 | 2889.10 | 7.67 | 71.92 | 19.90 | 2858.86 | 97.63 | 377.36 | 0.76 | 389.76 |
| 147 | 2907.10 | 8.29 | 71.99 | 18.00 | 2876.68 | 98.40 | 379.74 | 1.03 | 392.25 |
| 148 | 2927.00 | 7.94 | 76.84 | 19.90 | 2896.38 | 99.16 | 382.44 | 1.16 | 395.05 |
| 149 | 2946.20 | 8.15 | 84.40 | 19.20 | 2915.39 | 99.59 | 385.08 | 1.68 | 397.73 |
| 150 | 2965.50 | 8.26 | 86.78 | 19.30 | 2934.50 | 99.80 | 387.83 | 0.55 | 400.44 |
| 151 | 2985.20 | 8.06 | 88.76 | 19.70 | 2954.00 | 99.91 | 390.62 | 0.53 | 403.18 |
| 152 | 3004.60 | 8.12 | 87.84 | 19.40 | 2973.20 | 99.99 | 393.35 | 0.22 | 405.85 |
| 153 | 3023.20 | 8.17 | 83.25 | 18.60 | 2991.62 | 100.20 | 395.98 | 1.05 | 408.45 |
| 154 | 3041.00 | 8.33 | 81.29 | 17.80 | 3009.23 | 100.54 | 398.51 | 0.55 | 410.99 |
| 155 | 3062.20 | 8.03 | 80.24 | 21.20 | 3030.22 | 101.03 | 401.48 | 0.47 | 413.99 |
| 156 | 3081.00 | 7.55 | 77.11 | 18.80 | 3048.84 | 101.52 | 403.98 | 1.02 | 416.54 |
| 157 | 3100.60 | 8.34 | 70.04 | 19.60 | 3068.25 | 102.30 | 406.57 | 1.92 | 419.24 |
| 158 | 3119.80 | 8.69 | 71.09 | 19.20 | 3087.24 | 103.24 | 409.26 | 0.60 | 422.07 |
| 159 | 3139.40 | 8.77 | 69.53 | 19.60 | 3106.61 | 104.24 | 412.06 | 0.38 | 425.03 |
| 160 | 3158.60 | 8.60 | 68.25 | 19.20 | 3125.59 | 105.29 | 414.76 | 0.40 | 427.90 |

**Table B.7** The Results of Balanced Tangential Method for the Well J-1 (7/7)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 161 | 3178.10 | 8.94 | 72.37 | 19.50 | 3144.87 | 106.29 | 417.56 | 1.10 | 430.86 |
| 162 | 3196.90 | 8.55 | 68.96 | 18.80 | 3163.45 | 107.23 | 420.26 | 1.03 | 433.70 |
| 163 | 3216.30 | 8.29 | 64.56 | 19.40 | 3182.64 | 108.35 | 422.86 | 1.07 | 436.50 |
| 164 | 3235.10 | 8.64 | 64.78 | 18.80 | 3201.23 | 109.53 | 425.37 | 0.56 | 439.22 |
| 165 | 3254.70 | 8.66 | 68.29 | 19.60 | 3220.61 | 110.71 | 428.07 | 0.81 | 442.12 |
| 166 | 3274.00 | 8.13 | 68.13 | 19.30 | 3239.70 | 111.75 | 430.68 | 0.82 | 444.91 |
| 167 | 3294.00 | 7.66 | 65.76 | 20.00 | 3259.51 | 112.83 | 433.21 | 0.86 | 447.62 |
| 168 | 3313.20 | 7.41 | 66.80 | 19.20 | 3278.55 | 113.84 | 435.52 | 0.44 | 450.10 |
| 169 | 3332.60 | 7.94 | 63.91 | 19.40 | 3297.77 | 114.92 | 437.87 | 1.01 | 452.65 |
| 170 | 3351.60 | 8.14 | 64.24 | 19.00 | 3316.59 | 116.08 | 440.26 | 0.32 | 455.24 |
| 171 | 3370.10 | 8.24 | 67.37 | 18.50 | 3334.90 | 117.16 | 442.66 | 0.74 | 457.84 |
| 172 | 3390.00 | 8.23 | 62.04 | 19.90 | 3354.59 | 118.38 | 445.24 | 1.15 | 460.63 |
| 173 | 3409.40 | 8.76 | 57.94 | 19.40 | 3373.78 | 119.81 | 447.72 | 1.24 | 463.38 |
| 174 | 3428.70 | 8.89 | 56.93 | 19.30 | 3392.85 | 121.41 | 450.21 | 0.31 | 466.18 |
| 175 | 3447.70 | 8.65 | 54.78 | 19.00 | 3411.63 | 123.03 | 452.61 | 0.64 | 468.90 |
| 176 | 3467.10 | 8.45 | 50.48 | 19.40 | 3430.81 | 124.78 | 454.90 | 1.04 | 471.54 |
| 177 | 3486.40 | 8.48 | 46.49 | 19.30 | 3449.90 | 126.66 | 457.03 | 0.91 | 474.05 |
| 178 | 3505.60 | 8.40 | 41.88 | 19.20 | 3468.90 | 128.68 | 458.99 | 1.06 | 476.44 |
| 179 | 3525.00 | 8.10 | 37.73 | 19.40 | 3488.09 | 130.82 | 460.77 | 1.03 | 478.68 |
| 180 | 3544.30 | 8.20 | 33.87 | 19.30 | 3507.20 | 133.04 | 462.37 | 0.86 | 480.76 |
| 181 | 3563.70 | 8.07 | 28.07 | 19.40 | 3526.40 | 135.39 | 463.78 | 1.28 | 482.70 |
| 182 | 3582.90 | 8.26 | 22.85 | 19.20 | 3545.41 | 137.85 | 464.95 | 1.20 | 484.42 |
| 183 | 3605.00 | 8.32 | 17.17 | 22.10 | 3567.28 | 140.84 | 466.04 | 1.11 | 486.19 |

**Table B.8** The Results of Average Angle Method for the Well J-1 (1/7)

**************************************************Average_Angle*****************************************************

| Survey No | MD | Inc | Az | CL | TVD | Local N | Local E | DLS | VS |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 180.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2 | 5.20 | 0.00 | 180.00 | 5.20 | 5.20 | 0.00 | 0.00 | 0.00 | 0.00 |
| 3 | 112.00 | 0.10 | 180.00 | 106.80 | 112.00 | -0.09 | 0.00 | 0.03 | -0.02 |
| 4 | 133.00 | 0.13 | 360.00 | 21.00 | 133.00 | -0.09 | -0.04 | 0.33 | -0.06 |
| 5 | 152.00 | 0.10 | 129.09 | 19.00 | 152.00 | -0.08 | -0.01 | 0.33 | -0.03 |
| 6 | 171.90 | 0.07 | 137.57 | 19.90 | 171.90 | -0.10 | 0.01 | 0.05 | -0.01 |
| 7 | 188.90 | 0.13 | 225.60 | 17.00 | 188.90 | -0.13 | 0.01 | 0.26 | -0.02 |
| 8 | 207.30 | 0.19 | 82.55 | 18.40 | 207.30 | -0.17 | 0.04 | 0.50 | -0.01 |
| 9 | 226.10 | 0.65 | 116.94 | 18.80 | 226.10 | -0.20 | 0.17 | 0.81 | 0.12 |
| 10 | 245.40 | 1.14 | 94.60 | 19.30 | 245.40 | -0.28 | 0.46 | 0.92 | 0.38 |
| 11 | 264.85 | 1.97 | 95.93 | 19.45 | 264.84 | -0.33 | 0.99 | 1.28 | 0.88 |
| 12 | 284.02 | 3.08 | 88.71 | 19.17 | 283.99 | -0.36 | 1.83 | 1.80 | 1.69 |
| 13 | 302.56 | 4.23 | 87.58 | 18.54 | 302.49 | -0.32 | 3.01 | 1.86 | 2.85 |
| 14 | 322.00 | 5.63 | 84.08 | 19.44 | 321.86 | -0.20 | 4.68 | 2.21 | 4.49 |
| 15 | 341.40 | 6.29 | 83.37 | 19.40 | 341.16 | 0.02 | 6.68 | 1.03 | 6.49 |
| 16 | 360.27 | 7.02 | 81.14 | 18.87 | 359.90 | 0.31 | 8.85 | 1.23 | 8.67 |
| 17 | 379.20 | 7.48 | 79.20 | 18.93 | 378.68 | 0.72 | 11.20 | 0.83 | 11.05 |
| 18 | 399.50 | 7.83 | 76.90 | 20.30 | 398.80 | 1.28 | 13.85 | 0.69 | 13.75 |
| 19 | 418.50 | 7.61 | 75.37 | 19.00 | 417.63 | 1.89 | 16.32 | 0.48 | 16.30 |
| 20 | 437.20 | 7.64 | 76.27 | 18.70 | 436.16 | 2.50 | 18.73 | 0.20 | 18.79 |
| 21 | 456.20 | 8.28 | 78.70 | 19.00 | 454.98 | 3.07 | 21.30 | 1.14 | 21.42 |
| 22 | 476.63 | 8.45 | 79.73 | 20.43 | 475.19 | 3.63 | 24.22 | 0.33 | 24.38 |
| 23 | 495.64 | 8.51 | 78.18 | 19.01 | 493.99 | 4.16 | 26.97 | 0.37 | 27.18 |
| 24 | 514.87 | 8.78 | 76.31 | 19.23 | 513.00 | 4.80 | 29.79 | 0.61 | 30.07 |
| 25 | 534.10 | 9.20 | 75.88 | 19.23 | 532.00 | 5.52 | 32.71 | 0.66 | 33.08 |

**Table B.9** The Results of Average Angle Method for the Well J-1 (2/7)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 26 | 553.20 | 9.14 | 74.90 | 19.10 | 550.85 | 6.29 | 35.65 | 0.26 | 36.12 |
| 27 | 572.75 | 9.31 | 75.08 | 19.55 | 570.15 | 7.10 | 38.68 | 0.26 | 39.26 |
| 28 | 591.62 | 9.25 | 74.92 | 18.87 | 588.77 | 7.89 | 41.62 | 0.10 | 42.30 |
| 29 | 611.11 | 9.27 | 73.36 | 19.49 | 608.01 | 8.75 | 44.63 | 0.39 | 45.43 |
| 30 | 630.30 | 9.19 | 74.52 | 19.19 | 626.95 | 9.60 | 47.59 | 0.32 | 48.51 |
| 31 | 649.70 | 8.92 | 74.46 | 19.40 | 646.11 | 10.42 | 50.53 | 0.42 | 51.56 |
| 32 | 669.10 | 9.02 | 75.12 | 19.40 | 665.27 | 11.21 | 53.45 | 0.22 | 54.58 |
| 33 | 688.13 | 9.46 | 74.25 | 19.03 | 684.05 | 12.02 | 56.40 | 0.73 | 57.64 |
| 34 | 707.55 | 9.44 | 73.54 | 19.42 | 703.21 | 12.90 | 59.46 | 0.18 | 60.82 |
| 35 | 729.90 | 9.28 | 72.79 | 22.35 | 725.26 | 13.95 | 62.94 | 0.27 | 64.45 |
| 36 | 746.27 | 9.08 | 72.42 | 16.37 | 741.42 | 14.74 | 65.44 | 0.38 | 67.06 |
| 37 | 765.62 | 9.07 | 73.33 | 19.35 | 760.53 | 15.63 | 68.35 | 0.22 | 70.11 |
| 38 | 784.99 | 9.00 | 73.48 | 19.37 | 779.66 | 16.50 | 71.27 | 0.11 | 73.15 |
| 39 | 804.15 | 8.71 | 73.77 | 19.16 | 798.59 | 17.33 | 74.10 | 0.46 | 76.09 |
| 40 | 822.94 | 8.88 | 73.02 | 18.79 | 817.16 | 18.16 | 76.85 | 0.33 | 78.96 |
| 41 | 842.26 | 8.90 | 75.28 | 19.32 | 836.25 | 18.97 | 79.72 | 0.54 | 81.95 |
| 42 | 861.70 | 8.96 | 77.90 | 19.44 | 855.45 | 19.67 | 82.66 | 0.63 | 84.96 |
| 43 | 881.05 | 8.85 | 78.39 | 19.35 | 874.57 | 20.29 | 85.59 | 0.21 | 87.96 |
| 44 | 900.05 | 8.71 | 77.42 | 19.00 | 893.35 | 20.89 | 88.43 | 0.32 | 90.86 |
| 45 | 919.92 | 8.49 | 77.20 | 19.87 | 912.99 | 21.55 | 91.32 | 0.34 | 93.83 |
| 46 | 939.20 | 8.36 | 77.11 | 19.28 | 932.07 | 22.17 | 94.08 | 0.20 | 96.65 |
| 47 | 958.60 | 8.23 | 76.43 | 19.40 | 951.26 | 22.81 | 96.80 | 0.25 | 99.45 |
| 48 | 998.40 | 7.49 | 76.80 | 39.80 | 990.69 | 24.07 | 102.10 | 0.56 | 104.89 |
| 49 | 1018.15 | 8.20 | 77.42 | 19.75 | 1010.25 | 24.68 | 104.73 | 1.09 | 107.59 |
| 50 | 1038.20 | 8.67 | 77.83 | 20.05 | 1030.09 | 25.31 | 107.60 | 0.71 | 110.53 |
| 51 | 1057.50 | 8.65 | 78.11 | 19.30 | 1049.17 | 25.91 | 110.44 | 0.07 | 113.43 |
| 52 | 1075.90 | 8.56 | 75.70 | 18.40 | 1067.36 | 26.54 | 113.12 | 0.61 | 116.19 |

**Table B.10** The Results of Average Angle Method for the Well J-1 (3/7)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 53 | 1095.39 | 8.52 | 74.49 | 19.49 | 1086.63 | 27.28 | 115.92 | 0.28 | 119.08 |
| 54 | 1113.84 | 8.62 | 73.72 | 18.45 | 1104.88 | 28.03 | 118.56 | 0.25 | 121.83 |
| 55 | 1133.14 | 8.80 | 72.09 | 19.30 | 1123.96 | 28.89 | 121.36 | 0.47 | 124.74 |
| 56 | 1152.40 | 8.31 | 70.51 | 19.26 | 1143.00 | 29.81 | 124.07 | 0.85 | 127.60 |
| 57 | 1172.01 | 8.00 | 71.15 | 19.61 | 1162.41 | 30.72 | 126.70 | 0.49 | 130.37 |
| 58 | 1191.40 | 7.96 | 71.49 | 19.39 | 1181.62 | 31.59 | 129.25 | 0.10 | 133.05 |
| 59 | 1210.58 | 7.73 | 70.09 | 19.18 | 1200.62 | 32.45 | 131.72 | 0.47 | 135.66 |
| 60 | 1230.01 | 7.29 | 69.93 | 19.43 | 1219.88 | 33.32 | 134.11 | 0.68 | 138.18 |
| 61 | 1248.35 | 7.40 | 69.21 | 18.34 | 1238.07 | 34.13 | 136.30 | 0.23 | 140.51 |
| 62 | 1267.80 | 7.09 | 69.92 | 19.45 | 1257.36 | 34.99 | 138.60 | 0.50 | 142.95 |
| 63 | 1287.50 | 7.06 | 68.50 | 19.70 | 1276.91 | 35.85 | 140.87 | 0.27 | 145.36 |
| 64 | 1306.55 | 6.85 | 69.27 | 19.05 | 1295.82 | 36.68 | 143.02 | 0.36 | 147.64 |
| 65 | 1325.60 | 7.14 | 70.72 | 19.05 | 1314.73 | 37.48 | 145.20 | 0.53 | 149.95 |
| 66 | 1344.50 | 7.17 | 73.48 | 18.90 | 1333.48 | 38.20 | 147.44 | 0.55 | 152.30 |
| 67 | 1364.47 | 7.01 | 73.16 | 19.97 | 1353.30 | 38.91 | 149.80 | 0.25 | 154.76 |
| 68 | 1382.60 | 7.03 | 72.06 | 18.13 | 1371.30 | 39.57 | 151.92 | 0.22 | 156.97 |
| 69 | 1402.15 | 6.84 | 72.02 | 19.55 | 1390.70 | 40.30 | 154.16 | 0.29 | 159.33 |
| 70 | 1422.25 | 6.85 | 71.53 | 20.10 | 1410.66 | 41.05 | 156.44 | 0.09 | 161.72 |
| 71 | 1441.53 | 6.74 | 71.55 | 19.28 | 1429.80 | 41.77 | 158.60 | 0.17 | 163.99 |
| 72 | 1460.96 | 6.82 | 71.70 | 19.43 | 1449.10 | 42.49 | 160.78 | 0.13 | 166.28 |
| 73 | 1480.19 | 7.74 | 72.49 | 19.23 | 1468.17 | 43.24 | 163.10 | 1.44 | 168.71 |
| 74 | 1499.03 | 8.46 | 73.53 | 18.84 | 1486.83 | 44.02 | 165.64 | 1.17 | 171.36 |
| 75 | 1517.80 | 9.36 | 71.61 | 18.77 | 1505.37 | 44.89 | 168.41 | 1.51 | 174.26 |
| 76 | 1536.70 | 10.15 | 70.96 | 18.90 | 1524.00 | 45.92 | 171.44 | 1.27 | 177.45 |
| 77 | 1556.10 | 10.82 | 72.51 | 19.40 | 1543.07 | 47.02 | 174.80 | 1.12 | 180.97 |
| 78 | 1576.32 | 11.63 | 75.94 | 20.22 | 1562.91 | 48.09 | 178.58 | 1.56 | 184.90 |
| 79 | 1595.69 | 12.32 | 78.04 | 19.37 | 1581.85 | 49.00 | 182.50 | 1.26 | 188.92 |

**Table B.11** The Results of Average Angle Method for the Well J-1 (4/7)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 80 | 1614.77 | 12.73 | 79.35 | 19.08 | 1600.48 | 49.81 | 186.56 | 0.78 | 193.05 |
| 81 | 1633.50 | 12.70 | 79.57 | 18.73 | 1618.75 | 50.56 | 190.61 | 0.09 | 197.17 |
| 82 | 1653.40 | 12.85 | 78.68 | 19.90 | 1638.16 | 51.39 | 194.93 | 0.37 | 201.56 |
| 83 | 1672.09 | 12.61 | 77.10 | 18.69 | 1656.39 | 52.26 | 198.96 | 0.68 | 205.68 |
| 84 | 1691.85 | 12.20 | 76.30 | 19.76 | 1675.69 | 53.23 | 203.09 | 0.67 | 209.93 |
| 85 | 1711.27 | 11.79 | 76.44 | 19.42 | 1694.68 | 54.18 | 207.01 | 0.63 | 213.96 |
| 86 | 1729.70 | 11.21 | 76.82 | 18.43 | 1712.74 | 55.03 | 210.59 | 0.95 | 217.64 |
| 87 | 1749.10 | 10.54 | 78.69 | 19.40 | 1731.79 | 55.81 | 214.16 | 1.17 | 221.30 |
| 88 | 1769.01 | 10.45 | 79.94 | 19.91 | 1751.37 | 56.48 | 217.73 | 0.37 | 224.92 |
| 89 | 1788.30 | 10.60 | 80.28 | 19.29 | 1770.34 | 57.09 | 221.20 | 0.25 | 228.43 |
| 90 | 1806.80 | 10.74 | 79.80 | 18.50 | 1788.52 | 57.68 | 224.57 | 0.27 | 231.85 |
| 91 | 1826.98 | 10.33 | 78.93 | 20.18 | 1808.36 | 58.36 | 228.20 | 0.65 | 235.53 |
| 92 | 1845.13 | 10.69 | 78.73 | 18.15 | 1826.20 | 59.00 | 231.45 | 0.60 | 238.84 |
| 93 | 1864.30 | 11.07 | 78.99 | 19.17 | 1845.03 | 59.70 | 235.00 | 0.60 | 242.45 |
| 94 | 1884.02 | 11.08 | 79.44 | 19.72 | 1864.38 | 60.41 | 238.72 | 0.13 | 246.24 |
| 95 | 1903.77 | 11.01 | 79.44 | 19.75 | 1883.76 | 61.10 | 242.44 | 0.11 | 250.02 |
| 96 | 1922.75 | 10.43 | 79.65 | 18.98 | 1902.41 | 61.74 | 245.91 | 0.92 | 253.54 |
| 97 | 1941.45 | 10.16 | 80.00 | 18.70 | 1920.81 | 62.33 | 249.20 | 0.44 | 256.87 |
| 98 | 1961.75 | 9.62 | 81.66 | 20.30 | 1940.81 | 62.89 | 252.64 | 0.90 | 260.35 |
| 99 | 1981.15 | 9.10 | 82.85 | 19.40 | 1959.95 | 63.32 | 255.77 | 0.86 | 263.49 |
| 100 | 1999.95 | 8.87 | 80.94 | 18.80 | 1978.52 | 63.73 | 258.67 | 0.60 | 266.41 |
| 101 | 2018.66 | 8.48 | 75.67 | 18.71 | 1997.02 | 64.30 | 261.44 | 1.42 | 269.23 |
| 102 | 2037.87 | 8.41 | 73.78 | 19.21 | 2016.02 | 65.05 | 264.16 | 0.45 | 272.05 |
| 103 | 2057.66 | 7.99 | 73.78 | 19.79 | 2035.61 | 65.83 | 266.87 | 0.64 | 274.87 |
| 104 | 2076.90 | 8.25 | 70.08 | 19.24 | 2054.65 | 66.68 | 269.45 | 0.91 | 277.58 |
| 105 | 2095.98 | 8.89 | 65.80 | 19.08 | 2073.52 | 67.74 | 272.09 | 1.42 | 280.39 |
| 106 | 2115.82 | 9.31 | 64.46 | 19.84 | 2093.11 | 69.06 | 274.93 | 0.71 | 283.47 |

**Table B.12** The Results of Average Angle Method for the Well J-1 (5/7)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 107 | 2134.69 | 9.45 | 63.20 | 18.87 | 2111.73 | 70.42 | 277.69 | 0.40 | 286.48 |
| 108 | 2153.82 | 9.23 | 62.40 | 19.13 | 2130.61 | 71.84 | 280.46 | 0.40 | 289.50 |
| 109 | 2173.95 | 9.88 | 63.26 | 20.13 | 2150.46 | 73.37 | 283.43 | 0.99 | 292.75 |
| 110 | 2193.25 | 9.84 | 68.00 | 19.30 | 2169.47 | 74.73 | 286.44 | 1.26 | 296.00 |
| 111 | 2212.60 | 8.84 | 71.85 | 19.35 | 2188.56 | 75.81 | 289.39 | 1.83 | 299.12 |
| 112 | 2231.73 | 8.47 | 74.84 | 19.13 | 2207.48 | 76.63 | 292.15 | 0.91 | 301.99 |
| 113 | 2250.62 | 8.35 | 75.48 | 18.89 | 2226.16 | 77.34 | 294.82 | 0.24 | 304.76 |
| 114 | 2257.39 | 8.42 | 76.36 | 6.77 | 2232.86 | 77.58 | 295.78 | 0.65 | 305.74 |
| 115 | 2291.55 | 8.70 | 75.68 | 34.16 | 2266.64 | 78.81 | 300.71 | 0.26 | 310.83 |
| 116 | 2309.98 | 8.78 | 73.74 | 18.43 | 2284.86 | 79.55 | 303.41 | 0.50 | 313.63 |
| 117 | 2329.15 | 8.89 | 75.15 | 19.17 | 2303.80 | 80.34 | 306.25 | 0.38 | 316.57 |
| 118 | 2349.15 | 8.60 | 81.03 | 20.00 | 2323.57 | 80.96 | 309.22 | 1.41 | 319.61 |
| 119 | 2368.82 | 8.05 | 81.16 | 19.67 | 2343.03 | 81.40 | 312.04 | 0.84 | 322.45 |
| 120 | 2389.12 | 6.97 | 81.16 | 20.30 | 2363.16 | 81.81 | 314.66 | 1.60 | 325.09 |
| 121 | 2407.15 | 7.13 | 79.82 | 18.03 | 2381.05 | 82.18 | 316.84 | 0.38 | 327.30 |
| 122 | 2426.50 | 7.77 | 77.10 | 19.35 | 2400.24 | 82.68 | 319.30 | 1.13 | 329.80 |
| 123 | 2444.95 | 7.58 | 74.61 | 18.45 | 2418.52 | 83.28 | 321.69 | 0.62 | 332.27 |
| 124 | 2464.60 | 7.46 | 75.03 | 19.65 | 2438.00 | 83.96 | 324.17 | 0.20 | 334.84 |
| 125 | 2484.05 | 7.40 | 75.29 | 19.45 | 2457.29 | 84.60 | 326.60 | 0.11 | 337.35 |
| 126 | 2503.53 | 7.31 | 75.29 | 19.48 | 2476.61 | 85.23 | 329.01 | 0.14 | 339.85 |
| 127 | 2523.41 | 8.42 | 71.28 | 19.88 | 2496.30 | 86.02 | 331.62 | 1.87 | 342.56 |
| 128 | 2542.46 | 9.17 | 70.50 | 19.05 | 2515.13 | 86.97 | 334.37 | 1.20 | 345.47 |
| 129 | 2560.67 | 8.77 | 70.15 | 18.21 | 2533.11 | 87.92 | 337.04 | 0.67 | 348.29 |
| 130 | 2579.25 | 8.30 | 73.75 | 18.58 | 2551.49 | 88.78 | 339.67 | 1.15 | 351.04 |
| 131 | 2599.30 | 7.94 | 71.14 | 20.05 | 2571.34 | 89.63 | 342.37 | 0.77 | 353.87 |
| 132 | 2618.70 | 7.72 | 70.69 | 19.40 | 2590.56 | 90.50 | 344.86 | 0.35 | 356.50 |
| 133 | 2637.90 | 7.06 | 70.56 | 19.20 | 2609.60 | 91.32 | 347.19 | 1.03 | 358.96 |

**Table B.13** The Results of Average Angle Method for the Well J-1 (6/7)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 134 | 2656.80 | 7.10 | 71.12 | 18.90 | 2628.35 | 92.08 | 349.39 | 0.13 | 361.27 |
| 135 | 2677.79 | 7.85 | 81.40 | 20.99 | 2649.16 | 92.73 | 352.05 | 2.19 | 364.01 |
| 136 | 2695.69 | 8.09 | 83.22 | 17.90 | 2666.89 | 93.06 | 354.51 | 0.58 | 366.47 |
| 137 | 2714.60 | 7.51 | 81.10 | 18.91 | 2685.63 | 93.41 | 357.05 | 1.03 | 369.03 |
| 138 | 2734.80 | 6.79 | 78.64 | 20.20 | 2705.67 | 93.85 | 359.52 | 1.16 | 371.53 |
| 139 | 2753.30 | 6.57 | 76.31 | 18.50 | 2724.04 | 94.32 | 361.62 | 0.57 | 373.69 |
| 140 | 2772.70 | 6.32 | 79.06 | 19.40 | 2743.32 | 94.79 | 363.75 | 0.61 | 375.86 |
| 141 | 2792.20 | 6.36 | 80.62 | 19.50 | 2762.70 | 95.17 | 365.87 | 0.27 | 378.01 |
| 142 | 2811.90 | 6.54 | 80.88 | 19.70 | 2782.28 | 95.52 | 368.06 | 0.28 | 380.22 |
| 143 | 2831.00 | 6.90 | 79.85 | 19.10 | 2801.25 | 95.90 | 370.26 | 0.60 | 382.45 |
| 144 | 2850.10 | 7.00 | 79.32 | 19.10 | 2820.21 | 96.31 | 372.53 | 0.19 | 384.75 |
| 145 | 2869.20 | 7.55 | 75.63 | 19.10 | 2839.15 | 96.84 | 374.89 | 1.13 | 387.17 |
| 146 | 2889.10 | 7.67 | 71.92 | 19.90 | 2858.88 | 97.57 | 377.42 | 0.76 | 389.81 |
| 147 | 2907.10 | 8.29 | 71.99 | 18.00 | 2876.70 | 98.35 | 379.80 | 1.03 | 392.30 |
| 148 | 2927.00 | 7.94 | 76.84 | 19.90 | 2896.40 | 99.10 | 382.51 | 1.16 | 395.10 |
| 149 | 2946.20 | 8.15 | 84.40 | 19.20 | 2915.41 | 99.54 | 385.16 | 1.68 | 397.78 |
| 150 | 2965.50 | 8.26 | 86.78 | 19.30 | 2934.52 | 99.75 | 387.90 | 0.55 | 400.50 |
| 151 | 2985.20 | 8.06 | 88.76 | 19.70 | 2954.02 | 99.86 | 390.70 | 0.53 | 403.24 |
| 152 | 3004.60 | 8.12 | 87.84 | 19.40 | 2973.22 | 99.94 | 393.43 | 0.22 | 405.91 |
| 153 | 3023.20 | 8.17 | 83.25 | 18.60 | 2991.64 | 100.15 | 396.05 | 1.05 | 408.51 |
| 154 | 3041.00 | 8.33 | 81.29 | 17.80 | 3009.25 | 100.49 | 398.58 | 0.55 | 411.05 |
| 155 | 3062.20 | 8.03 | 80.24 | 21.20 | 3030.24 | 100.97 | 401.56 | 0.47 | 414.06 |
| 156 | 3081.00 | 7.55 | 77.11 | 18.80 | 3048.86 | 101.47 | 404.06 | 1.02 | 416.60 |
| 157 | 3100.60 | 8.34 | 70.04 | 19.60 | 3068.27 | 102.24 | 406.66 | 1.92 | 419.31 |
| 158 | 3119.80 | 8.69 | 71.09 | 19.20 | 3087.26 | 103.19 | 409.34 | 0.60 | 422.14 |
| 159 | 3139.40 | 8.77 | 69.53 | 19.60 | 3106.64 | 104.19 | 412.14 | 0.38 | 425.10 |
| 160 | 3158.60 | 8.60 | 68.25 | 19.20 | 3125.62 | 105.23 | 414.84 | 0.40 | 427.97 |

**Table B.14** The Results of Average Angle Method for the Well J-1 (7/7)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 161 | 3178.10 | 8.94 | 72.37 | 19.50 | 3144.89 | 106.24 | 417.64 | 1.10 | 430.93 |
| 162 | 3196.90 | 8.55 | 68.96 | 18.80 | 3163.47 | 107.18 | 420.34 | 1.03 | 433.78 |
| 163 | 3216.30 | 8.29 | 64.56 | 19.40 | 3182.66 | 108.30 | 422.95 | 1.07 | 436.58 |
| 164 | 3235.10 | 8.64 | 64.78 | 18.80 | 3201.26 | 109.49 | 425.45 | 0.56 | 439.29 |
| 165 | 3254.70 | 8.66 | 68.29 | 19.60 | 3220.63 | 110.66 | 428.16 | 0.81 | 442.20 |
| 166 | 3274.00 | 8.13 | 68.13 | 19.30 | 3239.73 | 111.71 | 430.77 | 0.82 | 444.99 |
| 167 | 3294.00 | 7.66 | 65.76 | 20.00 | 3259.54 | 112.78 | 433.30 | 0.86 | 447.70 |
| 168 | 3313.20 | 7.41 | 66.80 | 19.20 | 3278.57 | 113.79 | 435.61 | 0.44 | 450.18 |
| 169 | 3332.60 | 7.94 | 63.91 | 19.40 | 3297.80 | 114.88 | 437.96 | 1.01 | 452.72 |
| 170 | 3351.60 | 8.14 | 64.24 | 19.00 | 3316.61 | 116.04 | 440.35 | 0.32 | 455.32 |
| 171 | 3370.10 | 8.24 | 67.37 | 18.50 | 3334.92 | 117.12 | 442.75 | 0.74 | 457.91 |
| 172 | 3390.00 | 8.23 | 62.04 | 19.90 | 3354.62 | 118.33 | 445.33 | 1.15 | 460.71 |
| 173 | 3409.40 | 8.76 | 57.94 | 19.40 | 3373.80 | 119.77 | 447.81 | 1.24 | 463.46 |
| 174 | 3428.70 | 8.89 | 56.93 | 19.30 | 3392.87 | 121.36 | 450.31 | 0.31 | 466.26 |
| 175 | 3447.70 | 8.65 | 54.78 | 19.00 | 3411.65 | 122.99 | 452.71 | 0.64 | 468.98 |
| 176 | 3467.10 | 8.45 | 50.48 | 19.40 | 3430.84 | 124.74 | 455.00 | 1.04 | 471.62 |
| 177 | 3486.40 | 8.48 | 46.49 | 19.30 | 3449.93 | 126.62 | 457.13 | 0.91 | 474.14 |
| 178 | 3505.60 | 8.40 | 41.88 | 19.20 | 3468.92 | 128.64 | 459.09 | 1.06 | 476.53 |
| 179 | 3525.00 | 8.10 | 37.73 | 19.40 | 3488.12 | 130.78 | 460.87 | 1.03 | 478.77 |
| 180 | 3544.30 | 8.20 | 33.87 | 19.30 | 3507.22 | 133.00 | 462.47 | 0.86 | 480.85 |
| 181 | 3563.70 | 8.07 | 28.07 | 19.40 | 3526.43 | 135.35 | 463.89 | 1.28 | 482.79 |
| 182 | 3582.90 | 8.26 | 22.85 | 19.20 | 3545.43 | 137.82 | 465.06 | 1.20 | 484.52 |
| 183 | 3605.00 | 8.32 | 17.17 | 22.10 | 3567.30 | 140.81 | 466.15 | 1.11 | 486.29 |

**Table B.15** The Results of Radius of Curvature Method for the Well J-1 (1/7)

`********************************************Radius_of_Curvature_Method********************************************`

| Survey No | MD | Inc | Az | CL | TVD | Local N | Local E | DLS | VS |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 180.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2 | 5.20 | 0.00 | 180.00 | 5.20 | 5.20 | 0.00 | 0.00 | 0.00 | 0.00 |
| 3 | 112.00 | 0.10 | 180.00 | 106.80 | 112.00 | -0.09 | 0.00 | 0.03 | -0.02 |
| 4 | 133.00 | 0.13 | 360.00 | 21.00 | 133.00 | -0.09 | -0.03 | 0.33 | -0.05 |
| 5 | 152.00 | 0.10 | 129.09 | 19.00 | 152.00 | -0.08 | 0.00 | 0.33 | -0.02 |
| 6 | 171.90 | 0.07 | 137.57 | 19.90 | 171.90 | -0.10 | 0.02 | 0.05 | -0.00 |
| 7 | 188.90 | 0.13 | 225.60 | 17.00 | 188.90 | -0.13 | 0.02 | 0.26 | -0.01 |
| 8 | 207.30 | 0.19 | 82.55 | 18.40 | 207.30 | -0.16 | 0.04 | 0.50 | -0.00 |
| 9 | 226.10 | 0.65 | 116.94 | 18.80 | 226.10 | -0.19 | 0.17 | 0.81 | 0.12 |
| 10 | 245.40 | 1.14 | 94.60 | 19.30 | 245.40 | -0.27 | 0.46 | 0.92 | 0.38 |
| 11 | 264.85 | 1.97 | 95.93 | 19.45 | 264.84 | -0.32 | 0.99 | 1.28 | 0.88 |
| 12 | 284.02 | 3.08 | 88.71 | 19.17 | 283.99 | -0.35 | 1.83 | 1.80 | 1.69 |
| 13 | 302.56 | 4.23 | 87.58 | 18.54 | 302.49 | -0.31 | 3.01 | 1.86 | 2.85 |
| 14 | 322.00 | 5.63 | 84.08 | 19.44 | 321.86 | -0.19 | 4.68 | 2.21 | 4.50 |
| 15 | 341.40 | 6.29 | 83.37 | 19.40 | 341.16 | 0.03 | 6.68 | 1.03 | 6.49 |
| 16 | 360.27 | 7.02 | 81.14 | 18.87 | 359.90 | 0.33 | 8.85 | 1.23 | 8.67 |
| 17 | 379.20 | 7.48 | 79.20 | 18.93 | 378.68 | 0.73 | 11.20 | 0.83 | 11.05 |
| 18 | 399.50 | 7.83 | 76.90 | 20.30 | 398.80 | 1.29 | 13.84 | 0.69 | 13.75 |
| 19 | 418.50 | 7.61 | 75.37 | 19.00 | 417.62 | 1.90 | 16.32 | 0.48 | 16.31 |
| 20 | 437.20 | 7.64 | 76.27 | 18.70 | 436.16 | 2.51 | 18.73 | 0.20 | 18.79 |
| 21 | 456.20 | 8.28 | 78.70 | 19.00 | 454.97 | 3.08 | 21.30 | 1.14 | 21.42 |
| 22 | 476.63 | 8.45 | 79.73 | 20.43 | 475.19 | 3.64 | 24.22 | 0.33 | 24.38 |
| 23 | 495.64 | 8.51 | 78.18 | 19.01 | 493.99 | 4.18 | 26.97 | 0.37 | 27.18 |
| 24 | 514.87 | 8.78 | 76.31 | 19.23 | 513.00 | 4.81 | 29.79 | 0.61 | 30.07 |
| 25 | 534.10 | 9.20 | 75.88 | 19.23 | 531.99 | 5.54 | 32.70 | 0.66 | 33.08 |

**Table B.16** The Results of Radius of Curvature Method for the Well J-1 (2/7)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 26 | 553.20 | 9.14 | 74.90 | 19.10 | 550.85 | 6.30 | 35.65 | 0.26 | 36.12 |
| 27 | 572.75 | 9.31 | 75.08 | 19.55 | 570.15 | 7.12 | 38.68 | 0.26 | 39.26 |
| 28 | 591.62 | 9.25 | 74.92 | 18.87 | 588.77 | 7.90 | 41.62 | 0.10 | 42.30 |
| 29 | 611.11 | 9.27 | 73.36 | 19.49 | 608.01 | 8.76 | 44.63 | 0.39 | 45.43 |
| 30 | 630.30 | 9.19 | 74.52 | 19.19 | 626.95 | 9.61 | 47.59 | 0.32 | 48.51 |
| 31 | 649.70 | 8.92 | 74.46 | 19.40 | 646.11 | 10.43 | 50.53 | 0.42 | 51.56 |
| 32 | 669.10 | 9.02 | 75.12 | 19.40 | 665.27 | 11.22 | 53.45 | 0.22 | 54.58 |
| 33 | 688.13 | 9.46 | 74.25 | 19.03 | 684.05 | 12.03 | 56.40 | 0.73 | 57.64 |
| 34 | 707.55 | 9.44 | 73.54 | 19.42 | 703.21 | 12.91 | 59.46 | 0.18 | 60.82 |
| 35 | 729.90 | 9.28 | 72.79 | 22.35 | 725.26 | 13.97 | 62.94 | 0.27 | 64.45 |
| 36 | 746.27 | 9.08 | 72.42 | 16.37 | 741.42 | 14.75 | 65.43 | 0.38 | 67.06 |
| 37 | 765.62 | 9.07 | 73.33 | 19.35 | 760.53 | 15.65 | 68.35 | 0.22 | 70.11 |
| 38 | 784.99 | 9.00 | 73.48 | 19.37 | 779.66 | 16.51 | 71.26 | 0.11 | 73.15 |
| 39 | 804.15 | 8.71 | 73.77 | 19.16 | 798.59 | 17.35 | 74.09 | 0.46 | 76.09 |
| 40 | 822.94 | 8.88 | 73.02 | 18.79 | 817.16 | 18.17 | 76.85 | 0.33 | 78.96 |
| 41 | 842.26 | 8.90 | 75.28 | 19.32 | 836.25 | 18.98 | 79.72 | 0.54 | 81.95 |
| 42 | 861.70 | 8.96 | 77.90 | 19.44 | 855.45 | 19.68 | 82.65 | 0.63 | 84.96 |
| 43 | 881.05 | 8.85 | 78.39 | 19.35 | 874.57 | 20.30 | 85.59 | 0.21 | 87.96 |
| 44 | 900.05 | 8.71 | 77.42 | 19.00 | 893.35 | 20.90 | 88.42 | 0.32 | 90.86 |
| 45 | 919.92 | 8.49 | 77.20 | 19.87 | 912.99 | 21.56 | 91.32 | 0.34 | 93.83 |
| 46 | 939.20 | 8.36 | 77.11 | 19.28 | 932.06 | 22.19 | 94.07 | 0.20 | 96.65 |
| 47 | 958.60 | 8.23 | 76.43 | 19.40 | 951.26 | 22.83 | 96.80 | 0.25 | 99.45 |
| 48 | 998.40 | 7.49 | 76.80 | 39.80 | 990.69 | 24.09 | 102.09 | 0.56 | 104.89 |
| 49 | 1018.15 | 8.20 | 77.42 | 19.75 | 1010.25 | 24.69 | 104.72 | 1.09 | 107.59 |
| 50 | 1038.20 | 8.67 | 77.83 | 20.05 | 1030.09 | 25.32 | 107.59 | 0.71 | 110.53 |
| 51 | 1057.50 | 8.65 | 78.11 | 19.30 | 1049.17 | 25.92 | 110.44 | 0.07 | 113.43 |
| 52 | 1075.90 | 8.56 | 75.70 | 18.40 | 1067.36 | 26.55 | 113.12 | 0.61 | 116.18 |

**Table B.17** The Results of Radius of Curvature Method for the Well J-1 (3/7)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 53 | 1095.39 | 8.52 | 74.49 | 19.49 | 1086.63 | 27.29 | 115.91 | 0.28 | 119.08 |
| 54 | 1113.84 | 8.62 | 73.72 | 18.45 | 1104.88 | 28.04 | 118.56 | 0.25 | 121.83 |
| 55 | 1133.14 | 8.80 | 72.09 | 19.30 | 1123.95 | 28.90 | 121.35 | 0.47 | 124.74 |
| 56 | 1152.40 | 8.31 | 70.51 | 19.26 | 1143.00 | 29.82 | 124.07 | 0.85 | 127.60 |
| 57 | 1172.01 | 8.00 | 71.15 | 19.61 | 1162.41 | 30.74 | 126.69 | 0.49 | 130.37 |
| 58 | 1191.40 | 7.96 | 71.49 | 19.39 | 1181.61 | 31.60 | 129.24 | 0.10 | 133.05 |
| 59 | 1210.58 | 7.73 | 70.09 | 19.18 | 1200.61 | 32.46 | 131.72 | 0.47 | 135.66 |
| 60 | 1230.01 | 7.29 | 69.93 | 19.43 | 1219.88 | 33.33 | 134.10 | 0.68 | 138.18 |
| 61 | 1248.35 | 7.40 | 69.21 | 18.34 | 1238.07 | 34.15 | 136.30 | 0.23 | 140.51 |
| 62 | 1267.80 | 7.09 | 69.92 | 19.45 | 1257.36 | 35.00 | 138.60 | 0.50 | 142.95 |
| 63 | 1287.50 | 7.06 | 68.50 | 19.70 | 1276.91 | 35.86 | 140.87 | 0.27 | 145.35 |
| 64 | 1306.55 | 6.85 | 69.27 | 19.05 | 1295.82 | 36.69 | 143.02 | 0.36 | 147.64 |
| 65 | 1325.60 | 7.14 | 70.72 | 19.05 | 1314.73 | 37.49 | 145.20 | 0.53 | 149.95 |
| 66 | 1344.50 | 7.17 | 73.48 | 18.90 | 1333.48 | 38.21 | 147.44 | 0.55 | 152.30 |
| 67 | 1364.47 | 7.01 | 73.16 | 19.97 | 1353.30 | 38.92 | 149.80 | 0.25 | 154.76 |
| 68 | 1382.60 | 7.03 | 72.06 | 18.13 | 1371.29 | 39.58 | 151.91 | 0.22 | 156.97 |
| 69 | 1402.15 | 6.84 | 72.02 | 19.55 | 1390.70 | 40.31 | 154.16 | 0.29 | 159.32 |
| 70 | 1422.25 | 6.85 | 71.53 | 20.10 | 1410.66 | 41.06 | 156.43 | 0.09 | 161.71 |
| 71 | 1441.53 | 6.74 | 71.55 | 19.28 | 1429.80 | 41.78 | 158.60 | 0.17 | 163.99 |
| 72 | 1460.96 | 6.82 | 71.70 | 19.43 | 1449.10 | 42.50 | 160.77 | 0.13 | 166.27 |
| 73 | 1480.19 | 7.74 | 72.49 | 19.23 | 1468.17 | 43.25 | 163.09 | 1.44 | 168.70 |
| 74 | 1499.03 | 8.46 | 73.53 | 18.84 | 1486.82 | 44.03 | 165.63 | 1.17 | 171.35 |
| 75 | 1517.80 | 9.36 | 71.61 | 18.77 | 1505.37 | 44.90 | 168.41 | 1.51 | 174.26 |
| 76 | 1536.70 | 10.15 | 70.96 | 18.90 | 1523.99 | 45.93 | 171.44 | 1.27 | 177.45 |
| 77 | 1556.10 | 10.82 | 72.51 | 19.40 | 1543.07 | 47.03 | 174.79 | 1.12 | 180.97 |
| 78 | 1576.32 | 11.63 | 75.94 | 20.22 | 1562.90 | 48.10 | 178.58 | 1.56 | 184.90 |
| 79 | 1595.69 | 12.32 | 78.04 | 19.37 | 1581.85 | 49.01 | 182.49 | 1.26 | 188.92 |

**Table B.18** The Results of Radius of Curvature Method for the Well J-1 (4/7)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 80 | 1614.77 | 12.73 | 79.35 | 19.08 | 1600.48 | 49.82 | 186.55 | 0.78 | 193.05 |
| 81 | 1633.50 | 12.70 | 79.57 | 18.73 | 1618.75 | 50.57 | 190.60 | 0.09 | 197.17 |
| 82 | 1653.40 | 12.85 | 78.68 | 19.90 | 1638.15 | 51.40 | 194.93 | 0.37 | 201.56 |
| 83 | 1672.09 | 12.61 | 77.10 | 18.69 | 1656.38 | 52.27 | 198.95 | 0.68 | 205.68 |
| 84 | 1691.85 | 12.20 | 76.30 | 19.76 | 1675.68 | 53.24 | 203.08 | 0.67 | 209.92 |
| 85 | 1711.27 | 11.79 | 76.44 | 19.42 | 1694.68 | 54.19 | 207.01 | 0.63 | 213.96 |
| 86 | 1729.70 | 11.21 | 76.82 | 18.43 | 1712.74 | 55.04 | 210.58 | 0.95 | 217.63 |
| 87 | 1749.10 | 10.54 | 78.69 | 19.40 | 1731.79 | 55.82 | 214.16 | 1.17 | 221.29 |
| 88 | 1769.01 | 10.45 | 79.94 | 19.91 | 1751.37 | 56.49 | 217.72 | 0.37 | 224.91 |
| 89 | 1788.30 | 10.60 | 80.28 | 19.29 | 1770.33 | 57.10 | 221.19 | 0.25 | 228.43 |
| 90 | 1806.80 | 10.74 | 79.80 | 18.50 | 1788.51 | 57.69 | 224.57 | 0.27 | 231.85 |
| 91 | 1826.98 | 10.33 | 78.93 | 20.18 | 1808.35 | 58.37 | 228.19 | 0.65 | 235.53 |
| 92 | 1845.13 | 10.69 | 78.73 | 18.15 | 1826.20 | 59.01 | 231.44 | 0.60 | 238.84 |
| 93 | 1864.30 | 11.07 | 78.99 | 19.17 | 1845.02 | 59.71 | 234.99 | 0.60 | 242.45 |
| 94 | 1884.02 | 11.08 | 79.44 | 19.72 | 1864.38 | 60.42 | 238.71 | 0.13 | 246.23 |
| 95 | 1903.77 | 11.01 | 79.44 | 19.75 | 1883.76 | 61.11 | 242.43 | 0.11 | 250.01 |
| 96 | 1922.75 | 10.43 | 79.65 | 18.98 | 1902.41 | 61.75 | 245.90 | 0.92 | 253.54 |
| 97 | 1941.45 | 10.16 | 80.00 | 18.70 | 1920.81 | 62.35 | 249.19 | 0.44 | 256.87 |
| 98 | 1961.75 | 9.62 | 81.66 | 20.30 | 1940.81 | 62.90 | 252.63 | 0.90 | 260.35 |
| 99 | 1981.15 | 9.10 | 82.85 | 19.40 | 1959.95 | 63.33 | 255.76 | 0.86 | 263.48 |
| 100 | 1999.95 | 8.87 | 80.94 | 18.80 | 1978.52 | 63.74 | 258.67 | 0.60 | 266.40 |
| 101 | 2018.66 | 8.48 | 75.67 | 18.71 | 1997.01 | 64.31 | 261.43 | 1.42 | 269.22 |
| 102 | 2037.87 | 8.41 | 73.78 | 19.21 | 2016.01 | 65.06 | 264.15 | 0.45 | 272.04 |
| 103 | 2057.66 | 7.99 | 73.78 | 19.79 | 2035.60 | 65.84 | 266.86 | 0.64 | 274.86 |
| 104 | 2076.90 | 8.25 | 70.08 | 19.24 | 2054.65 | 66.69 | 269.44 | 0.91 | 277.57 |
| 105 | 2095.98 | 8.89 | 65.80 | 19.08 | 2073.52 | 67.75 | 272.08 | 1.42 | 280.39 |
| 106 | 2115.82 | 9.31 | 64.46 | 19.84 | 2093.11 | 69.07 | 274.93 | 0.71 | 283.47 |

**Table B.19** The Results of Radius of Curvature Method for the Well J-1 (5/7)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 107 | 2134.69 | 9.45 | 63.20 | 18.87 | 2111.72 | 70.43 | 277.69 | 0.40 | 286.47 |
| 108 | 2153.82 | 9.23 | 62.40 | 19.13 | 2130.60 | 71.85 | 280.45 | 0.40 | 289.49 |
| 109 | 2173.95 | 9.88 | 63.26 | 20.13 | 2150.45 | 73.37 | 283.42 | 0.99 | 292.74 |
| 110 | 2193.25 | 9.84 | 68.00 | 19.30 | 2169.47 | 74.74 | 286.43 | 1.26 | 295.99 |
| 111 | 2212.60 | 8.84 | 71.85 | 19.35 | 2188.56 | 75.82 | 289.38 | 1.83 | 299.11 |
| 112 | 2231.73 | 8.47 | 74.84 | 19.13 | 2207.47 | 76.64 | 292.14 | 0.91 | 301.99 |
| 113 | 2250.62 | 8.35 | 75.48 | 18.89 | 2226.16 | 77.35 | 294.81 | 0.24 | 304.75 |
| 114 | 2257.39 | 8.42 | 76.36 | 6.77 | 2232.86 | 77.59 | 295.76 | 0.65 | 305.74 |
| 115 | 2291.55 | 8.70 | 75.68 | 34.16 | 2266.64 | 78.82 | 300.70 | 0.26 | 310.82 |
| 116 | 2309.98 | 8.78 | 73.74 | 18.43 | 2284.85 | 79.56 | 303.40 | 0.50 | 313.62 |
| 117 | 2329.15 | 8.89 | 75.15 | 19.17 | 2303.79 | 80.34 | 306.24 | 0.38 | 316.56 |
| 118 | 2349.15 | 8.60 | 81.03 | 20.00 | 2323.56 | 80.97 | 309.21 | 1.41 | 319.60 |
| 119 | 2368.82 | 8.05 | 81.16 | 19.67 | 2343.02 | 81.41 | 312.02 | 0.84 | 322.44 |
| 120 | 2389.12 | 6.97 | 81.16 | 20.30 | 2363.15 | 81.82 | 314.64 | 1.60 | 325.08 |
| 121 | 2407.15 | 7.13 | 79.82 | 18.03 | 2381.04 | 82.19 | 316.83 | 0.38 | 327.29 |
| 122 | 2426.50 | 7.77 | 77.10 | 19.35 | 2400.23 | 82.69 | 319.29 | 1.13 | 329.79 |
| 123 | 2444.95 | 7.58 | 74.61 | 18.45 | 2418.51 | 83.29 | 321.67 | 0.62 | 332.26 |
| 124 | 2464.60 | 7.46 | 75.03 | 19.65 | 2438.00 | 83.96 | 324.16 | 0.20 | 334.83 |
| 125 | 2484.05 | 7.40 | 75.29 | 19.45 | 2457.28 | 84.61 | 326.59 | 0.11 | 337.34 |
| 126 | 2503.53 | 7.31 | 75.29 | 19.48 | 2476.60 | 85.24 | 329.00 | 0.14 | 339.84 |
| 127 | 2523.41 | 8.42 | 71.28 | 19.88 | 2496.29 | 86.02 | 331.60 | 1.87 | 342.55 |
| 128 | 2542.46 | 9.17 | 70.50 | 19.05 | 2515.12 | 86.98 | 334.36 | 1.20 | 345.45 |
| 129 | 2560.67 | 8.77 | 70.15 | 18.21 | 2533.11 | 87.93 | 337.03 | 0.67 | 348.28 |
| 130 | 2579.25 | 8.30 | 73.75 | 18.58 | 2551.48 | 88.79 | 339.65 | 1.15 | 351.03 |
| 131 | 2599.30 | 7.94 | 71.14 | 20.05 | 2571.33 | 89.64 | 342.35 | 0.77 | 353.85 |
| 132 | 2618.70 | 7.72 | 70.69 | 19.40 | 2590.55 | 90.51 | 344.85 | 0.35 | 356.49 |
| 133 | 2637.90 | 7.06 | 70.56 | 19.20 | 2609.59 | 91.32 | 347.18 | 1.03 | 358.94 |

**Table B.20** The Results of Radius of Curvature Method for the Well J-1 (6/7)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 134 | 2656.80 | 7.10 | 71.12 | 18.90 | 2628.35 | 92.09 | 349.38 | 0.13 | 361.26 |
| 135 | 2677.79 | 7.85 | 81.40 | 20.99 | 2649.16 | 92.74 | 352.03 | 2.19 | 363.99 |
| 136 | 2695.69 | 8.09 | 83.22 | 17.90 | 2666.89 | 93.07 | 354.49 | 0.58 | 366.46 |
| 137 | 2714.60 | 7.51 | 81.10 | 18.91 | 2685.62 | 93.42 | 357.03 | 1.03 | 369.01 |
| 138 | 2734.80 | 6.79 | 78.64 | 20.20 | 2705.66 | 93.86 | 359.50 | 1.16 | 371.52 |
| 139 | 2753.30 | 6.57 | 76.31 | 18.50 | 2724.04 | 94.33 | 361.61 | 0.57 | 373.67 |
| 140 | 2772.70 | 6.32 | 79.06 | 19.40 | 2743.31 | 94.79 | 363.73 | 0.61 | 375.85 |
| 141 | 2792.20 | 6.36 | 80.62 | 19.50 | 2762.70 | 95.17 | 365.85 | 0.27 | 378.00 |
| 142 | 2811.90 | 6.54 | 80.88 | 19.70 | 2782.27 | 95.53 | 368.04 | 0.28 | 380.20 |
| 143 | 2831.00 | 6.90 | 79.85 | 19.10 | 2801.24 | 95.90 | 370.24 | 0.60 | 382.43 |
| 144 | 2850.10 | 7.00 | 79.32 | 19.10 | 2820.20 | 96.32 | 372.51 | 0.19 | 384.74 |
| 145 | 2869.20 | 7.55 | 75.63 | 19.10 | 2839.15 | 96.84 | 374.87 | 1.13 | 387.15 |
| 146 | 2889.10 | 7.67 | 71.92 | 19.90 | 2858.87 | 97.58 | 377.40 | 0.76 | 389.79 |
| 147 | 2907.10 | 8.29 | 71.99 | 18.00 | 2876.70 | 98.35 | 379.78 | 1.03 | 392.28 |
| 148 | 2927.00 | 7.94 | 76.84 | 19.90 | 2896.40 | 99.11 | 382.48 | 1.16 | 395.09 |
| 149 | 2946.20 | 8.15 | 84.40 | 19.20 | 2915.41 | 99.55 | 385.13 | 1.68 | 397.76 |
| 150 | 2965.50 | 8.26 | 86.78 | 19.30 | 2934.51 | 99.76 | 387.88 | 0.55 | 400.48 |
| 151 | 2985.20 | 8.06 | 88.76 | 19.70 | 2954.01 | 99.87 | 390.67 | 0.53 | 403.22 |
| 152 | 3004.60 | 8.12 | 87.84 | 19.40 | 2973.22 | 99.95 | 393.40 | 0.22 | 405.89 |
| 153 | 3023.20 | 8.17 | 83.25 | 18.60 | 2991.63 | 100.15 | 396.03 | 1.05 | 408.49 |
| 154 | 3041.00 | 8.33 | 81.29 | 17.80 | 3009.25 | 100.50 | 398.56 | 0.55 | 411.03 |
| 155 | 3062.20 | 8.03 | 80.24 | 21.20 | 3030.23 | 100.98 | 401.54 | 0.47 | 414.03 |
| 156 | 3081.00 | 7.55 | 77.11 | 18.80 | 3048.86 | 101.48 | 404.04 | 1.02 | 416.58 |
| 157 | 3100.60 | 8.34 | 70.04 | 19.60 | 3068.27 | 102.25 | 406.63 | 1.92 | 419.28 |
| 158 | 3119.80 | 8.69 | 71.09 | 19.20 | 3087.26 | 103.19 | 409.31 | 0.60 | 422.11 |
| 159 | 3139.40 | 8.77 | 69.53 | 19.60 | 3106.63 | 104.19 | 412.11 | 0.38 | 425.07 |
| 160 | 3158.60 | 8.60 | 68.25 | 19.20 | 3125.61 | 105.24 | 414.82 | 0.40 | 427.95 |

**Table B.21** The Results of Radius of Curvature Method for the Well J-1 (7/7)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 161 | 3178.10 | 8.94 | 72.37 | 19.50 | 3144.88 | 106.24 | 417.62 | 1.10 | 430.91 |
| 162 | 3196.90 | 8.55 | 68.96 | 18.80 | 3163.46 | 107.19 | 420.31 | 1.03 | 433.75 |
| 163 | 3216.30 | 8.29 | 64.56 | 19.40 | 3182.65 | 108.31 | 422.92 | 1.07 | 436.55 |
| 164 | 3235.10 | 8.64 | 64.78 | 18.80 | 3201.25 | 109.49 | 425.43 | 0.56 | 439.26 |
| 165 | 3254.70 | 8.66 | 68.29 | 19.60 | 3220.63 | 110.66 | 428.13 | 0.81 | 442.17 |
| 166 | 3274.00 | 8.13 | 68.13 | 19.30 | 3239.72 | 111.71 | 430.75 | 0.82 | 444.96 |
| 167 | 3294.00 | 7.66 | 65.76 | 20.00 | 3259.53 | 112.79 | 433.27 | 0.86 | 447.67 |
| 168 | 3313.20 | 7.41 | 66.80 | 19.20 | 3278.56 | 113.80 | 435.58 | 0.44 | 450.15 |
| 169 | 3332.60 | 7.94 | 63.91 | 19.40 | 3297.79 | 114.88 | 437.93 | 1.01 | 452.70 |
| 170 | 3351.60 | 8.14 | 64.24 | 19.00 | 3316.60 | 116.04 | 440.32 | 0.32 | 455.29 |
| 171 | 3370.10 | 8.24 | 67.37 | 18.50 | 3334.91 | 117.12 | 442.73 | 0.74 | 457.89 |
| 172 | 3390.00 | 8.23 | 62.04 | 19.90 | 3354.61 | 118.34 | 445.30 | 1.15 | 460.68 |
| 173 | 3409.40 | 8.76 | 57.94 | 19.40 | 3373.80 | 119.77 | 447.78 | 1.24 | 463.43 |
| 174 | 3428.70 | 8.89 | 56.93 | 19.30 | 3392.87 | 121.37 | 450.28 | 0.31 | 466.23 |
| 175 | 3447.70 | 8.65 | 54.78 | 19.00 | 3411.64 | 122.99 | 452.68 | 0.64 | 468.95 |
| 176 | 3467.10 | 8.45 | 50.48 | 19.40 | 3430.83 | 124.74 | 454.97 | 1.04 | 471.59 |
| 177 | 3486.40 | 8.48 | 46.49 | 19.30 | 3449.92 | 126.62 | 457.09 | 0.91 | 474.11 |
| 178 | 3505.60 | 8.40 | 41.88 | 19.20 | 3468.91 | 128.64 | 459.06 | 1.06 | 476.50 |
| 179 | 3525.00 | 8.10 | 37.73 | 19.40 | 3488.11 | 130.78 | 460.84 | 1.03 | 478.74 |
| 180 | 3544.30 | 8.20 | 33.87 | 19.30 | 3507.22 | 133.00 | 462.44 | 0.86 | 480.82 |
| 181 | 3563.70 | 8.07 | 28.07 | 19.40 | 3526.42 | 135.35 | 463.85 | 1.28 | 482.76 |
| 182 | 3582.90 | 8.26 | 22.85 | 19.20 | 3545.43 | 137.82 | 465.02 | 1.20 | 484.48 |
| 183 | 3605.00 | 8.32 | 17.17 | 22.10 | 3567.29 | 140.81 | 466.11 | 1.11 | 486.26 |

**Table B.22** The Results of Minimum Curvature Method for the Well J-1 (1/7)

*********************************************Minimum_Curvature_Method*********************************************

| Survey No | MD | Inc | Az | CL | TVD | Local N | Local E | DLS | VS |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 180.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2 | 5.20 | 0.00 | 180.00 | 5.20 | 5.20 | 0.00 | 0.00 | 0.00 | 0.00 |
| 3 | 112.00 | 0.10 | 180.00 | 106.80 | 112.00 | -0.09 | 0.00 | 0.03 | -0.02 |
| 4 | 133.00 | 0.13 | 360.00 | 21.00 | 133.00 | -0.09 | 0.00 | 0.33 | -0.02 |
| 5 | 152.00 | 0.10 | 129.09 | 19.00 | 152.00 | -0.08 | 0.01 | 0.33 | -0.01 |
| 6 | 171.90 | 0.07 | 137.57 | 19.90 | 171.90 | -0.10 | 0.03 | 0.05 | 0.01 |
| 7 | 188.90 | 0.13 | 225.60 | 17.00 | 188.90 | -0.12 | 0.03 | 0.26 | -0.00 |
| 8 | 207.30 | 0.19 | 82.55 | 18.40 | 207.30 | -0.13 | 0.04 | 0.50 | 0.01 |
| 9 | 226.10 | 0.65 | 116.94 | 18.80 | 226.10 | -0.17 | 0.17 | 0.81 | 0.12 |
| 10 | 245.40 | 1.14 | 94.60 | 19.30 | 245.40 | -0.24 | 0.46 | 0.92 | 0.39 |
| 11 | 264.85 | 1.97 | 95.93 | 19.45 | 264.84 | -0.29 | 0.98 | 1.28 | 0.89 |
| 12 | 284.02 | 3.08 | 88.71 | 19.17 | 283.99 | -0.31 | 1.83 | 1.80 | 1.70 |
| 13 | 302.56 | 4.23 | 87.58 | 18.54 | 302.50 | -0.27 | 3.01 | 1.86 | 2.86 |
| 14 | 322.00 | 5.63 | 84.08 | 19.44 | 321.86 | -0.14 | 4.67 | 2.21 | 4.50 |
| 15 | 341.40 | 6.29 | 83.37 | 19.40 | 341.16 | 0.08 | 6.67 | 1.03 | 6.50 |
| 16 | 360.27 | 7.02 | 81.14 | 18.87 | 359.90 | 0.38 | 8.84 | 1.23 | 8.67 |
| 17 | 379.20 | 7.48 | 79.20 | 18.93 | 378.68 | 0.79 | 11.19 | 0.83 | 11.06 |
| 18 | 399.50 | 7.83 | 76.90 | 20.30 | 398.80 | 1.35 | 13.84 | 0.69 | 13.76 |
| 19 | 418.50 | 7.61 | 75.37 | 19.00 | 417.63 | 1.96 | 16.32 | 0.48 | 16.31 |
| 20 | 437.20 | 7.64 | 76.27 | 18.70 | 436.16 | 2.57 | 18.72 | 0.20 | 18.79 |
| 21 | 456.20 | 8.28 | 78.70 | 19.00 | 454.98 | 3.13 | 21.29 | 1.14 | 21.42 |
| 22 | 476.63 | 8.45 | 79.73 | 20.43 | 475.19 | 3.69 | 24.21 | 0.33 | 24.39 |
| 23 | 495.64 | 8.51 | 78.18 | 19.01 | 494.00 | 4.23 | 26.96 | 0.37 | 27.19 |
| 24 | 514.87 | 8.78 | 76.31 | 19.23 | 513.01 | 4.87 | 29.78 | 0.61 | 30.08 |
| 25 | 534.10 | 9.20 | 75.88 | 19.23 | 532.00 | 5.59 | 32.70 | 0.66 | 33.09 |

**Table B.23** The Results of Minimum Curvature Method for the Well J-1 (2/7)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 26 | 553.20 | 9.14 | 74.90 | 19.10 | 550.86 | 6.36 | 35.64 | 0.26 | 36.13 |
| 27 | 572.75 | 9.31 | 75.08 | 19.55 | 570.15 | 7.17 | 38.67 | 0.26 | 39.26 |
| 28 | 591.62 | 9.25 | 74.92 | 18.87 | 588.78 | 7.95 | 41.61 | 0.10 | 42.30 |
| 29 | 611.11 | 9.27 | 73.36 | 19.49 | 608.01 | 8.81 | 44.63 | 0.39 | 45.44 |
| 30 | 630.30 | 9.19 | 74.52 | 19.19 | 626.96 | 9.66 | 47.58 | 0.32 | 48.51 |
| 31 | 649.70 | 8.92 | 74.46 | 19.40 | 646.11 | 10.48 | 50.53 | 0.42 | 51.57 |
| 32 | 669.10 | 9.02 | 75.12 | 19.40 | 665.28 | 11.27 | 53.44 | 0.22 | 54.59 |
| 33 | 688.13 | 9.46 | 74.25 | 19.03 | 684.06 | 12.08 | 56.39 | 0.73 | 57.64 |
| 34 | 707.55 | 9.44 | 73.54 | 19.42 | 703.22 | 12.96 | 59.45 | 0.18 | 60.83 |
| 35 | 729.90 | 9.28 | 72.79 | 22.35 | 725.27 | 14.02 | 62.93 | 0.27 | 64.46 |
| 36 | 746.27 | 9.08 | 72.42 | 16.37 | 741.43 | 14.80 | 65.43 | 0.38 | 67.07 |
| 37 | 765.62 | 9.07 | 73.33 | 19.35 | 760.54 | 15.70 | 68.34 | 0.22 | 70.11 |
| 38 | 784.99 | 9.00 | 73.48 | 19.37 | 779.67 | 16.57 | 71.26 | 0.11 | 73.15 |
| 39 | 804.15 | 8.71 | 73.77 | 19.16 | 798.60 | 17.40 | 74.09 | 0.46 | 76.10 |
| 40 | 822.94 | 8.88 | 73.02 | 18.79 | 817.17 | 18.22 | 76.84 | 0.33 | 78.97 |
| 41 | 842.26 | 8.90 | 75.28 | 19.32 | 836.26 | 19.03 | 79.71 | 0.54 | 81.95 |
| 42 | 861.70 | 8.96 | 77.90 | 19.44 | 855.46 | 19.73 | 82.65 | 0.63 | 84.97 |
| 43 | 881.05 | 8.85 | 78.39 | 19.35 | 874.58 | 20.35 | 85.58 | 0.21 | 87.96 |
| 44 | 900.05 | 8.71 | 77.42 | 19.00 | 893.35 | 20.96 | 88.41 | 0.32 | 90.86 |
| 45 | 919.92 | 8.49 | 77.20 | 19.87 | 913.00 | 21.61 | 91.31 | 0.34 | 93.83 |
| 46 | 939.20 | 8.36 | 77.11 | 19.28 | 932.07 | 22.24 | 94.07 | 0.20 | 96.65 |
| 47 | 958.60 | 8.23 | 76.43 | 19.40 | 951.27 | 22.88 | 96.79 | 0.25 | 99.45 |
| 48 | 998.40 | 7.49 | 76.80 | 39.80 | 990.70 | 24.14 | 102.09 | 0.56 | 104.90 |
| 49 | 1018.15 | 8.20 | 77.42 | 19.75 | 1010.26 | 24.74 | 104.71 | 1.09 | 107.59 |
| 50 | 1038.20 | 8.67 | 77.83 | 20.05 | 1030.09 | 25.37 | 107.59 | 0.71 | 110.53 |
| 51 | 1057.50 | 8.65 | 78.11 | 19.30 | 1049.17 | 25.97 | 110.43 | 0.07 | 113.44 |
| 52 | 1075.90 | 8.56 | 75.70 | 18.40 | 1067.37 | 26.60 | 113.11 | 0.61 | 116.19 |

**Table B.24** The Results of Minimum Curvature Method for the Well J-1 (3/7)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 53 | 1095.39 | 8.52 | 74.49 | 19.49 | 1086.64 | 27.34 | 115.91 | 0.28 | 119.08 |
| 54 | 1113.84 | 8.62 | 73.72 | 18.45 | 1104.88 | 28.09 | 118.55 | 0.25 | 121.83 |
| 55 | 1133.14 | 8.80 | 72.09 | 19.30 | 1123.96 | 28.95 | 121.34 | 0.47 | 124.75 |
| 56 | 1152.40 | 8.31 | 70.51 | 19.26 | 1143.01 | 29.87 | 124.06 | 0.85 | 127.60 |
| 57 | 1172.01 | 8.00 | 71.15 | 19.61 | 1162.42 | 30.79 | 126.68 | 0.49 | 130.37 |
| 58 | 1191.40 | 7.96 | 71.49 | 19.39 | 1181.62 | 31.65 | 129.23 | 0.10 | 133.05 |
| 59 | 1210.58 | 7.73 | 70.09 | 19.18 | 1200.62 | 32.51 | 131.71 | 0.47 | 135.66 |
| 60 | 1230.01 | 7.29 | 69.93 | 19.43 | 1219.89 | 33.38 | 134.09 | 0.68 | 138.18 |
| 61 | 1248.35 | 7.40 | 69.21 | 18.34 | 1238.08 | 34.20 | 136.29 | 0.23 | 140.51 |
| 62 | 1267.80 | 7.09 | 69.92 | 19.45 | 1257.37 | 35.05 | 138.59 | 0.50 | 142.95 |
| 63 | 1287.50 | 7.06 | 68.50 | 19.70 | 1276.92 | 35.91 | 140.86 | 0.27 | 145.36 |
| 64 | 1306.55 | 6.85 | 69.27 | 19.05 | 1295.83 | 36.74 | 143.01 | 0.36 | 147.65 |
| 65 | 1325.60 | 7.14 | 70.72 | 19.05 | 1314.74 | 37.54 | 145.19 | 0.53 | 149.95 |
| 66 | 1344.50 | 7.17 | 73.48 | 18.90 | 1333.49 | 38.26 | 147.43 | 0.55 | 152.30 |
| 67 | 1364.47 | 7.01 | 73.16 | 19.97 | 1353.31 | 38.97 | 149.79 | 0.25 | 154.76 |
| 68 | 1382.60 | 7.03 | 72.06 | 18.13 | 1371.30 | 39.63 | 151.90 | 0.22 | 156.97 |
| 69 | 1402.15 | 6.84 | 72.02 | 19.55 | 1390.71 | 40.36 | 154.15 | 0.29 | 159.33 |
| 70 | 1422.25 | 6.85 | 71.53 | 20.10 | 1410.67 | 41.11 | 156.43 | 0.09 | 161.72 |
| 71 | 1441.53 | 6.74 | 71.55 | 19.28 | 1429.81 | 41.83 | 158.59 | 0.17 | 163.99 |
| 72 | 1460.96 | 6.82 | 71.70 | 19.43 | 1449.11 | 42.55 | 160.77 | 0.13 | 166.28 |
| 73 | 1480.19 | 7.74 | 72.49 | 19.23 | 1468.18 | 43.30 | 163.08 | 1.44 | 168.71 |
| 74 | 1499.03 | 8.46 | 73.53 | 18.84 | 1486.83 | 44.08 | 165.62 | 1.17 | 171.36 |
| 75 | 1517.80 | 9.36 | 71.61 | 18.77 | 1505.38 | 44.95 | 168.40 | 1.51 | 174.26 |
| 76 | 1536.70 | 10.15 | 70.96 | 18.90 | 1524.00 | 45.98 | 171.43 | 1.27 | 177.45 |
| 77 | 1556.10 | 10.82 | 72.51 | 19.40 | 1543.08 | 47.08 | 174.78 | 1.12 | 180.97 |
| 78 | 1576.32 | 11.63 | 75.94 | 20.22 | 1562.91 | 48.15 | 178.57 | 1.56 | 184.90 |
| 79 | 1595.69 | 12.32 | 78.04 | 19.37 | 1581.86 | 49.05 | 182.49 | 1.26 | 188.92 |

**Table B.25** The Results of Minimum Curvature Method for the Well J-1 (4/7)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 80 | 1614.77 | 12.73 | 79.35 | 19.08 | 1600.49 | 49.86 | 186.54 | 0.78 | 193.05 |
| 81 | 1633.50 | 12.70 | 79.57 | 18.73 | 1618.76 | 50.61 | 190.60 | 0.09 | 197.17 |
| 82 | 1653.40 | 12.85 | 78.68 | 19.90 | 1638.17 | 51.44 | 194.92 | 0.37 | 201.56 |
| 83 | 1672.09 | 12.61 | 77.10 | 18.69 | 1656.40 | 52.31 | 198.94 | 0.68 | 205.68 |
| 84 | 1691.85 | 12.20 | 76.30 | 19.76 | 1675.70 | 53.28 | 203.07 | 0.67 | 209.92 |
| 85 | 1711.27 | 11.79 | 76.44 | 19.42 | 1694.69 | 54.24 | 207.00 | 0.63 | 213.96 |
| 86 | 1729.70 | 11.21 | 76.82 | 18.43 | 1712.75 | 55.09 | 210.57 | 0.95 | 217.63 |
| 87 | 1749.10 | 10.54 | 78.69 | 19.40 | 1731.81 | 55.86 | 214.15 | 1.17 | 221.29 |
| 88 | 1769.01 | 10.45 | 79.94 | 19.91 | 1751.38 | 56.54 | 217.71 | 0.37 | 224.91 |
| 89 | 1788.30 | 10.60 | 80.28 | 19.29 | 1770.35 | 57.14 | 221.18 | 0.25 | 228.43 |
| 90 | 1806.80 | 10.74 | 79.80 | 18.50 | 1788.53 | 57.73 | 224.56 | 0.27 | 231.85 |
| 91 | 1826.98 | 10.33 | 78.93 | 20.18 | 1808.37 | 58.41 | 228.18 | 0.65 | 235.53 |
| 92 | 1845.13 | 10.69 | 78.73 | 18.15 | 1826.21 | 59.06 | 231.43 | 0.60 | 238.84 |
| 93 | 1864.30 | 11.07 | 78.99 | 19.17 | 1845.04 | 59.75 | 234.98 | 0.60 | 242.45 |
| 94 | 1884.02 | 11.08 | 79.44 | 19.72 | 1864.39 | 60.46 | 238.70 | 0.13 | 246.23 |
| 95 | 1903.77 | 11.01 | 79.44 | 19.75 | 1883.78 | 61.16 | 242.42 | 0.11 | 250.01 |
| 96 | 1922.75 | 10.43 | 79.65 | 18.98 | 1902.42 | 61.80 | 245.89 | 0.92 | 253.54 |
| 97 | 1941.45 | 10.16 | 80.00 | 18.70 | 1920.82 | 62.39 | 249.18 | 0.44 | 256.87 |
| 98 | 1961.75 | 9.62 | 81.66 | 20.30 | 1940.82 | 62.94 | 252.62 | 0.90 | 260.35 |
| 99 | 1981.15 | 9.10 | 82.85 | 19.40 | 1959.96 | 63.37 | 255.75 | 0.86 | 263.48 |
| 100 | 1999.95 | 8.87 | 80.94 | 18.80 | 1978.53 | 63.78 | 258.66 | 0.60 | 266.40 |
| 101 | 2018.66 | 8.48 | 75.67 | 18.71 | 1997.03 | 64.35 | 261.42 | 1.42 | 269.22 |
| 102 | 2037.87 | 8.41 | 73.78 | 19.21 | 2016.03 | 65.10 | 264.14 | 0.45 | 272.04 |
| 103 | 2057.66 | 7.99 | 73.78 | 19.79 | 2035.62 | 65.88 | 266.85 | 0.64 | 274.86 |
| 104 | 2076.90 | 8.25 | 70.08 | 19.24 | 2054.67 | 66.73 | 269.43 | 0.91 | 277.57 |
| 105 | 2095.98 | 8.89 | 65.80 | 19.08 | 2073.53 | 67.80 | 272.06 | 1.42 | 280.38 |
| 106 | 2115.82 | 9.31 | 64.46 | 19.84 | 2093.13 | 69.12 | 274.91 | 0.71 | 283.46 |

**Table B.26** The Results of Minimum Curvature Method for the Well J-1 (5/7)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 107 | 2134.69 | 9.45 | 63.20 | 18.87 | 2111.74 | 70.48 | 277.67 | 0.40 | 286.47 |
| 108 | 2153.82 | 9.23 | 62.40 | 19.13 | 2130.62 | 71.89 | 280.43 | 0.40 | 289.49 |
| 109 | 2173.95 | 9.88 | 63.26 | 20.13 | 2150.47 | 73.42 | 283.40 | 0.99 | 292.74 |
| 110 | 2193.25 | 9.84 | 68.00 | 19.30 | 2169.49 | 74.78 | 286.41 | 1.26 | 295.98 |
| 111 | 2212.60 | 8.84 | 71.85 | 19.35 | 2188.58 | 75.86 | 289.36 | 1.83 | 299.10 |
| 112 | 2231.73 | 8.47 | 74.84 | 19.13 | 2207.49 | 76.69 | 292.11 | 0.91 | 301.98 |
| 113 | 2250.62 | 8.35 | 75.48 | 18.89 | 2226.18 | 77.40 | 294.78 | 0.24 | 304.74 |
| 114 | 2257.39 | 8.42 | 76.36 | 6.77 | 2232.88 | 77.64 | 295.74 | 0.65 | 305.73 |
| 115 | 2291.55 | 8.70 | 75.68 | 34.16 | 2266.66 | 78.87 | 300.68 | 0.26 | 310.81 |
| 116 | 2309.98 | 8.78 | 73.74 | 18.43 | 2284.87 | 79.61 | 303.38 | 0.50 | 313.61 |
| 117 | 2329.15 | 8.89 | 75.15 | 19.17 | 2303.82 | 80.40 | 306.21 | 0.38 | 316.55 |
| 118 | 2349.15 | 8.60 | 81.03 | 20.00 | 2323.58 | 81.02 | 309.18 | 1.41 | 319.59 |
| 119 | 2368.82 | 8.05 | 81.16 | 19.67 | 2343.05 | 81.47 | 312.00 | 0.84 | 322.43 |
| 120 | 2389.12 | 6.97 | 81.16 | 20.30 | 2363.17 | 81.87 | 314.62 | 1.60 | 325.07 |
| 121 | 2407.15 | 7.13 | 79.82 | 18.03 | 2381.07 | 82.24 | 316.80 | 0.38 | 327.28 |
| 122 | 2426.50 | 7.77 | 77.10 | 19.35 | 2400.25 | 82.74 | 319.26 | 1.13 | 329.78 |
| 123 | 2444.95 | 7.58 | 74.61 | 18.45 | 2418.54 | 83.35 | 321.65 | 0.62 | 332.25 |
| 124 | 2464.60 | 7.46 | 75.03 | 19.65 | 2438.02 | 84.02 | 324.13 | 0.20 | 334.82 |
| 125 | 2484.05 | 7.40 | 75.29 | 19.45 | 2457.31 | 84.66 | 326.56 | 0.11 | 337.33 |
| 126 | 2503.53 | 7.31 | 75.29 | 19.48 | 2476.63 | 85.30 | 328.97 | 0.14 | 339.82 |
| 127 | 2523.41 | 8.42 | 71.28 | 19.88 | 2496.32 | 86.08 | 331.58 | 1.87 | 342.54 |
| 128 | 2542.46 | 9.17 | 70.50 | 19.05 | 2515.15 | 87.04 | 334.33 | 1.20 | 345.44 |
| 129 | 2560.67 | 8.77 | 70.15 | 18.21 | 2533.13 | 87.99 | 337.00 | 0.67 | 348.26 |
| 130 | 2579.25 | 8.30 | 73.75 | 18.58 | 2551.51 | 88.85 | 339.62 | 1.15 | 351.01 |
| 131 | 2599.30 | 7.94 | 71.14 | 20.05 | 2571.36 | 89.70 | 342.32 | 0.77 | 353.84 |
| 132 | 2618.70 | 7.72 | 70.69 | 19.40 | 2590.58 | 90.57 | 344.82 | 0.35 | 356.47 |
| 133 | 2637.90 | 7.06 | 70.56 | 19.20 | 2609.62 | 91.39 | 347.15 | 1.03 | 358.93 |

**Table B.27** The Results of Minimum Curvature Method for the Well J-1 (6/7)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 134 | 2656.80 | 7.10 | 71.12 | 18.90 | 2628.37 | 92.15 | 349.35 | 0.13 | 361.25 |
| 135 | 2677.79 | 7.85 | 81.40 | 20.99 | 2649.19 | 92.79 | 351.99 | 2.19 | 363.97 |
| 136 | 2695.69 | 8.09 | 83.22 | 17.90 | 2666.91 | 93.12 | 354.45 | 0.58 | 366.43 |
| 137 | 2714.60 | 7.51 | 81.10 | 18.91 | 2685.65 | 93.47 | 356.99 | 1.03 | 368.99 |
| 138 | 2734.80 | 6.79 | 78.64 | 20.20 | 2705.69 | 93.90 | 359.47 | 1.16 | 371.49 |
| 139 | 2753.30 | 6.57 | 76.31 | 18.50 | 2724.07 | 94.37 | 361.57 | 0.57 | 373.65 |
| 140 | 2772.70 | 6.32 | 79.06 | 19.40 | 2743.34 | 94.84 | 363.70 | 0.61 | 375.82 |
| 141 | 2792.20 | 6.36 | 80.62 | 19.50 | 2762.73 | 95.22 | 365.82 | 0.27 | 377.97 |
| 142 | 2811.90 | 6.54 | 80.88 | 19.70 | 2782.30 | 95.57 | 368.00 | 0.28 | 380.18 |
| 143 | 2831.00 | 6.90 | 79.85 | 19.10 | 2801.27 | 95.95 | 370.20 | 0.60 | 382.41 |
| 144 | 2850.10 | 7.00 | 79.32 | 19.10 | 2820.23 | 96.36 | 372.48 | 0.19 | 384.71 |
| 145 | 2869.20 | 7.55 | 75.63 | 19.10 | 2839.18 | 96.89 | 374.84 | 1.13 | 387.13 |
| 146 | 2889.10 | 7.67 | 71.92 | 19.90 | 2858.90 | 97.63 | 377.37 | 0.76 | 389.76 |
| 147 | 2907.10 | 8.29 | 71.99 | 18.00 | 2876.73 | 98.40 | 379.74 | 1.03 | 392.25 |
| 148 | 2927.00 | 7.94 | 76.84 | 19.90 | 2896.43 | 99.16 | 382.44 | 1.16 | 395.06 |
| 149 | 2946.20 | 8.15 | 84.40 | 19.20 | 2915.44 | 99.59 | 385.09 | 1.68 | 397.73 |
| 150 | 2965.50 | 8.26 | 86.78 | 19.30 | 2934.54 | 99.80 | 387.84 | 0.55 | 400.45 |
| 151 | 2985.20 | 8.06 | 88.76 | 19.70 | 2954.04 | 99.91 | 390.63 | 0.53 | 403.19 |
| 152 | 3004.60 | 8.12 | 87.84 | 19.40 | 2973.25 | 99.99 | 393.36 | 0.22 | 405.86 |
| 153 | 3023.20 | 8.17 | 83.25 | 18.60 | 2991.66 | 100.20 | 395.98 | 1.05 | 408.45 |
| 154 | 3041.00 | 8.33 | 81.29 | 17.80 | 3009.28 | 100.54 | 398.51 | 0.55 | 410.99 |
| 155 | 3062.20 | 8.03 | 80.24 | 21.20 | 3030.26 | 101.03 | 401.49 | 0.47 | 414.00 |
| 156 | 3081.00 | 7.55 | 77.11 | 18.80 | 3048.89 | 101.52 | 403.99 | 1.02 | 416.55 |
| 157 | 3100.60 | 8.34 | 70.04 | 19.60 | 3068.30 | 102.30 | 406.58 | 1.92 | 419.25 |
| 158 | 3119.80 | 8.69 | 71.09 | 19.20 | 3087.29 | 103.24 | 409.26 | 0.60 | 422.08 |
| 159 | 3139.40 | 8.77 | 69.53 | 19.60 | 3106.67 | 104.25 | 412.06 | 0.38 | 425.03 |
| 160 | 3158.60 | 8.60 | 68.25 | 19.20 | 3125.65 | 105.29 | 414.77 | 0.40 | 427.91 |

**Table B.28** The Results of Minimum Curvature Method for the Well J-1 (7/7)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 161 | 3178.10 | 8.94 | 72.37 | 19.50 | 3144.92 | 106.29 | 417.57 | 1.10 | 430.87 |
| 162 | 3196.90 | 8.55 | 68.96 | 18.80 | 3163.50 | 107.23 | 420.26 | 1.03 | 433.71 |
| 163 | 3216.30 | 8.29 | 64.56 | 19.40 | 3182.69 | 108.35 | 422.87 | 1.07 | 436.51 |
| 164 | 3235.10 | 8.64 | 64.78 | 18.80 | 3201.29 | 109.53 | 425.37 | 0.56 | 439.22 |
| 165 | 3254.70 | 8.66 | 68.29 | 19.60 | 3220.66 | 110.71 | 428.08 | 0.81 | 442.13 |
| 166 | 3274.00 | 8.13 | 68.13 | 19.30 | 3239.76 | 111.75 | 430.69 | 0.82 | 444.92 |
| 167 | 3294.00 | 7.66 | 65.76 | 20.00 | 3259.57 | 112.83 | 433.22 | 0.86 | 447.63 |
| 168 | 3313.20 | 7.41 | 66.80 | 19.20 | 3278.60 | 113.84 | 435.52 | 0.44 | 450.11 |
| 169 | 3332.60 | 7.94 | 63.91 | 19.40 | 3297.83 | 114.92 | 437.88 | 1.01 | 452.65 |
| 170 | 3351.60 | 8.14 | 64.24 | 19.00 | 3316.64 | 116.08 | 440.27 | 0.32 | 455.25 |
| 171 | 3370.10 | 8.24 | 67.37 | 18.50 | 3334.95 | 117.16 | 442.67 | 0.74 | 457.84 |
| 172 | 3390.00 | 8.23 | 62.04 | 19.90 | 3354.65 | 118.38 | 445.25 | 1.15 | 460.63 |
| 173 | 3409.40 | 8.76 | 57.94 | 19.40 | 3373.84 | 119.82 | 447.72 | 1.24 | 463.38 |
| 174 | 3428.70 | 8.89 | 56.93 | 19.30 | 3392.91 | 121.41 | 450.22 | 0.31 | 466.19 |
| 175 | 3447.70 | 8.65 | 54.78 | 19.00 | 3411.69 | 123.04 | 452.62 | 0.64 | 468.90 |
| 176 | 3467.10 | 8.45 | 50.48 | 19.40 | 3430.87 | 124.78 | 454.91 | 1.04 | 471.55 |
| 177 | 3486.40 | 8.48 | 46.49 | 19.30 | 3449.96 | 126.67 | 457.03 | 0.91 | 474.06 |
| 178 | 3505.60 | 8.40 | 41.88 | 19.20 | 3468.95 | 128.68 | 459.00 | 1.06 | 476.45 |
| 179 | 3525.00 | 8.10 | 37.73 | 19.40 | 3488.15 | 130.82 | 460.78 | 1.03 | 478.69 |
| 180 | 3544.30 | 8.20 | 33.87 | 19.30 | 3507.26 | 133.04 | 462.38 | 0.86 | 480.77 |
| 181 | 3563.70 | 8.07 | 28.07 | 19.40 | 3526.46 | 135.39 | 463.79 | 1.28 | 482.70 |
| 182 | 3582.90 | 8.26 | 22.85 | 19.20 | 3545.47 | 137.85 | 464.96 | 1.20 | 484.43 |
| 183 | 3605.00 | 8.32 | 17.17 | 22.10 | 3567.34 | 140.84 | 466.05 | 1.11 | 486.20 |

### C. The Script of Written Python Programming Code

```
from math import *
import numpy as np
from mpl_toolkits.mplot3d import Axes3D
import matplotlib.pyplot as plt

print("*************************************Directional_Su
rvey_Calculator************************************")
print("""Operations:
1. Calculation: c
2. Quit: q
""")

#*******************************************General_Formu
las*******************************************
def CL(MD1, MD2):
    CL = MD2 - MD1
    return CL

def TVD(TVD1, TVD_Delta):
    TVD = TVD1 + TVD_Delta
    return TVD

def North(N1, North_Delta):
    N = N1 + North_Delta
    return N

def East(E1, East_Delta):
    E = E1 + East_Delta
    return E

def DLS(CL, I1, I2, AZ1, AZ2):
    DL =
degrees(acos(sin(radians(I1))*sin(radians(I2))*cos(radians(
AZ2-AZ1))+cos(radians(I1))*cos(radians(I2))))
    DLS = (DL/CL)*30
    return DLS

def Closure_Distance(N, E, VSON=0, VSOE=0):
    CD = ((N-VSON)**2 + (E-VSOE)**2)**0.5
    return CD

def Closure_Angle(N, E, VSON=0, VSOE=0):
    CA = atan2(E-VSOE, N-VSON)
    return CA
```

```python
def Directional_Difference(VSA, CA):
    DD = VSA - CA
    return DD

def Vertical_Section(CD, DD):
    VS = CD * cos(DD)
    return VS

#*******************************************Tangential_Form
ulas*******************************************
def T_TVD_Delta(CL, I2):
    TVD_Delta = CL*cos(radians(I2))
    return TVD_Delta

def T_North_Delta(CL, I2, AZ2):
    North_Delta = CL * sin(radians(I2))*cos(radians(AZ2))
    return North_Delta

def T_East_Delta(CL, I2, AZ2):
    East_Delta = CL * sin(radians(I2))*sin(radians(AZ2))
    return East_Delta

#**************************************Balanced_Tangential_
Formulas**************************************
def BT_TVD_Delta(CL, I1 ,I2):
    TVD_Delta = (CL / 2) *
(cos(radians(I1))+cos(radians(I2)))
    return TVD_Delta

def BT_North_Delta(CL, I1, I2, AZ1, AZ2):
    North_Delta = (CL / 2) *
(sin(radians(I1))*cos(radians(AZ1)) +
sin(radians(I2))*cos(radians(AZ2)))
    return North_Delta

def BT_East_Delta(CL, I1, I2, AZ1, AZ2):
    East_Delta = (CL / 2) *
(sin(radians(I1))*sin(radians(AZ1)) +
sin(radians(I2))*sin(radians(AZ2)))
    return East_Delta

#*****************************************Average_Angle_For
mulas*****************************************
def AvI(I1, I2):
    AvI = (I1 + I2)/2
```

```
    return AvI

def AvAZ(AZ1, AZ2):
    angles = [AZ1, AZ2]
    weights = np.ones(len(angles))
    sumsin = 0
    sumcos = 0
    angles=np.array(angles)*pi/180
    for i in range(len(angles)):
        sumsin+=weights[i]/sum(weights)*sin(angles[i])
        sumcos+=weights[i]/sum(weights)*cos(angles[i])
    AvAZ=atan2(sumsin,sumcos)
    AvAZ=AvAZ*180/pi
    return AvAZ

def AA_TVD_Delta(CL, AvI):
    TVD_Delta = CL*cos(radians(AvI))
    return TVD_Delta

def AA_Horizontal_Displacement(CL, AvI):
    HD = CL * sin(radians(AvI))
    return HD

def AA_North_Delta(HD, AvAZ):
    North_Delta = HD * cos(radians(AvAZ))
    return North_Delta

def AA_East_Delta(HD, AvAZ):
    East_Delta = HD * sin(radians(AvAZ))
    return East_Delta

#***********************************Radius_of_Curvature_Met
hod_Formulas**********************************
def Radius_of_Vertical_Projection(CL, I1, I2):
    Rv = (180 * CL) / (pi * (I2 - I1))
    return Rv

def RCM_TVD_Delta(I1, I2, Rv):
    TVD_Delta = Rv * (sin(radians(I2)) - sin(radians(I1)))
    return TVD_Delta

def RCM_Horizontal_Displacement(I1, I2, Rv):
    HD = Rv * (cos(radians(I1)) - cos(radians(I2)))
    return HD

def Radius_of_Horizontal_Projection(HD, AZ1, AZ2):
```

```
    if (AZ2 - AZ1 > 180):
        Rh = (180 * HD) / (pi * (AZ2 - AZ1 - 360))
    elif (AZ2 - AZ1 < -180):
        Rh = (180 * HD) / (pi * (AZ2 - AZ1 + 360))
    else:
        Rh = (180 * HD) / (pi * (AZ2 - AZ1))
    return Rh

def RCM_North_Delta(Rh, AZ1, AZ2):
    North_Delta = Rh * (sin(radians(AZ2)) -
sin(radians(AZ1)))
    return North_Delta

def RCM_East_Delta(Rh, AZ1, AZ2):
    East_Delta = Rh * (cos(radians(AZ1)) -
cos(radians(AZ2)))
    return East_Delta

#*************************************Minimum_Curvature_Meth
od_Formulas**************************************
def MCM_DLS(CL, I1, I2, AZ1, AZ2):
    DL =
degrees(acos(sin(radians(I1))*sin(radians(I2))*cos(radians(
AZ2-AZ1))+cos(radians(I1))*cos(radians(I2))))
    DLS = (DL/CL)*30
    return DLS

def RatioFactor(DLS):
    try:
        RF = tan(radians(DLS/2))*(180/pi)*(2/DLS)
        return RF
    except ZeroDivisionError:
        RF = 1
        return RF

def MCM_TVD_Delta(I1, I2, RF, CL):
    TVD_Delta = (cos(radians(I1)) +
cos(radians(I2)))*(RF*CL/2)
    return TVD_Delta

def MCM_North_Delta(I1, I2, AZ1, AZ2, RF, CL):
    North_Delta = (sin(radians(I1))*cos(radians(AZ1)) +
sin(radians(I2))*cos(radians(AZ2))) * (RF*CL/2)
    return North_Delta

def MCM_East_Delta(I1, I2, AZ1, AZ2, RF, CL):
```

```
    East_Delta = (sin(radians(I1))*sin(radians(AZ1)) +
sin(radians(I2))*sin(radians(AZ2))) * (RF*CL/2)
    return East_Delta

#************************************************************
************************************************

L_MD = []
L_Inc = []
L_Az = []
L_CL = [0]

LT_TVD = []
LBT_TVD = []
LAA_TVD = []
LRCM_TVD = []
LMCM_TVD = []

LT_LocalN = [0]
LBT_LocalN = [0]
LAA_LocalN = [0]
LRCM_LocalN = [0]
LMCM_LocalN = [0]

LT_LocalE = [0]
LBT_LocalE = [0]
LAA_LocalE = [0]
LRCM_LocalE = [0]
LMCM_LocalE = [0]

L_DLS = [0]
LMCM_DLS = [0]

LT_VS = [0]
LBT_VS = [0]
LAA_VS = [0]
LRCM_VS = [0]
LMCM_VS = [0]

count = -1
VSA = radians(float(input("Enter desired VSA (Vertical
Section Azimuth): ")))

while True:
    Operation = input("Enter desired operation: ")

    if (Operation == "c"):
```

```
        with open("/Users/01/Desktop/Selected_Wells/J-
1.txt", "r", encoding="utf-8") as file:
            for i in file:
                i = i[:-1]
                row = i.split("\t")
                MD = float(row[0])
                Inc = float(row[1])
                Az = float(row[2])


                if len(L_MD) > 0:
                    L_CL.append(CL(L_MD[count], MD))

                if len(LT_TVD) == 0:
                    LT_TVD.append(MD)
                    LBT_TVD.append(MD)
                    LAA_TVD.append(MD)
                    LRCM_TVD.append(MD)
                    LMCM_TVD.append(MD)
                else:
                    LT_TVD.append(TVD(LT_TVD[count],
T_TVD_Delta(L_CL[count + 1], Inc)))
                    LBT_TVD.append(TVD(LBT_TVD[count],
BT_TVD_Delta(L_CL[count + 1], L_Inc[count], Inc)))
                    LAA_TVD.append(TVD(LAA_TVD[count],
AA_TVD_Delta(L_CL[count + 1], AvI(L_Inc[count], Inc))))
                    if (L_Inc[count] != Inc):

LRCM_TVD.append(TVD(LRCM_TVD[count],
RCM_TVD_Delta(L_Inc[count], Inc,

Radius_of_Vertical_Projection(L_CL[count + 1],
L_Inc[count], Inc))))
                    else:

LRCM_TVD.append(TVD(LRCM_TVD[count],
BT_TVD_Delta(L_CL[count + 1], L_Inc[count], Inc)))
                    LMCM_TVD.append(TVD(LMCM_TVD[count],
MCM_TVD_Delta(L_Inc[count], Inc,
                        RatioFactor(MCM_DLS(L_CL[count +
1], L_Inc[count], Inc, L_Az[count], Az)), L_CL[count +
1]))))


LT_LocalN.append(North(LT_LocalN[count],
```

```
T_North_Delta(L_CL[count + 1], Inc, Az)))

LBT_LocalN.append(North(LBT_LocalN[count],
BT_North_Delta(L_CL[count + 1], L_Inc[count],
                        Inc, L_Az[count], Az)))

LAA_LocalN.append(North(LAA_LocalN[count], AA_North_Delta(

AA_Horizontal_Displacement(L_CL[count + 1],
AvI(L_Inc[count], Inc)),AvAZ(L_Az[count], Az))))
                    if (L_Inc[count] == Inc or L_Az[count]
== Az):

LRCM_LocalN.append(North(LRCM_LocalN[count],
BT_North_Delta(L_CL[count + 1],
                            L_Inc[count], Inc, L_Az[count],
Az)))
                    else:

LRCM_LocalN.append(North(LRCM_LocalN[count],
RCM_North_Delta(

Radius_of_Horizontal_Projection(RCM_Horizontal_Displacement
(L_Inc[count], Inc,

Radius_of_Vertical_Projection(L_CL[count + 1],
L_Inc[count], Inc)),
                            L_Az[count], Az), L_Az[count],
Az)))

LMCM_LocalN.append(North(LMCM_LocalN[count],
MCM_North_Delta(L_Inc[count], Inc,
                            L_Az[count], Az,
RatioFactor(MCM_DLS(L_CL[count + 1], L_Inc[count], Inc,
                            L_Az[count], Az)), L_CL[count +
1])))

                    LT_LocalE.append(East(LT_LocalE[count],
T_East_Delta(L_CL[count + 1], Inc, Az)))

LBT_LocalE.append(East(LBT_LocalE[count],
BT_East_Delta(L_CL[count + 1], L_Inc[count],
                        Inc, L_Az[count], Az)))

LAA_LocalE.append(East(LAA_LocalE[count],
AA_East_Delta(AA_Horizontal_Displacement(
```

```
                        L_CL[count + 1], AvI(L_Inc[count],
Inc)),AvAZ(L_Az[count], Az))))
                    if (L_Inc[count] == Inc or L_Az[count]
== Az):

LRCM_LocalE.append(East(LRCM_LocalE[count],
BT_East_Delta(L_CL[count + 1], L_Inc[count],
                            Inc, L_Az[count], Az)))
                    else:

LRCM_LocalE.append(East(LRCM_LocalE[count], RCM_East_Delta(

Radius_of_Horizontal_Projection(RCM_Horizontal_Displacement
(L_Inc[count], Inc,

Radius_of_Vertical_Projection(L_CL[count + 1],
L_Inc[count], Inc)), L_Az[count],
                            Az), L_Az[count], Az)))

LMCM_LocalE.append(East(LMCM_LocalE[count],
MCM_East_Delta(L_Inc[count], Inc, L_Az[count],
                        Az, RatioFactor(MCM_DLS(L_CL[count
+ 1], L_Inc[count], Inc, L_Az[count], Az)),
                        L_CL[count + 1]))))

                    L_DLS.append(DLS(L_CL[count + 1],
L_Inc[count], Inc, L_Az[count], Az))
                    LMCM_DLS.append(MCM_DLS(L_CL[count +
1], L_Inc[count], Inc, L_Az[count], Az))

                    T_CD =
Closure_Distance(LT_LocalN[count+1], LT_LocalE[count+1],
VSON=0, VSOE=0)
                    T_CA =
Closure_Angle(LT_LocalN[count+1], LT_LocalE[count+1],
VSON=0, VSOE=0)
                    T_DD = Directional_Difference(VSA,
T_CA)
                    LT_VS.append(Vertical_Section(T_CD,
T_DD))

                    BT_CD =
Closure_Distance(LBT_LocalN[count+1], LBT_LocalE[count+1],
VSON=0, VSOE=0)
                    BT_CA =
Closure_Angle(LBT_LocalN[count+1], LBT_LocalE[count+1],
```

```
VSON=0, VSOE=0)
                    BT_DD = Directional_Difference(VSA,
BT_CA)
                    LBT_VS.append(Vertical_Section(BT_CD,
BT_DD))

                    AA_CD =
Closure_Distance(LAA_LocalN[count+1], LAA_LocalE[count+1],
VSON=0, VSOE=0)
                    AA_CA =
Closure_Angle(LAA_LocalN[count+1], LAA_LocalE[count+1],
VSON=0, VSOE=0)
                    AA_DD = Directional_Difference(VSA,
AA_CA)
                    LAA_VS.append(Vertical_Section(AA_CD,
AA_DD))

                    RCM_CD =
Closure_Distance(LRCM_LocalN[count+1],
LRCM_LocalE[count+1], VSON=0, VSOE=0)
                    RCM_CA =
Closure_Angle(LRCM_LocalN[count+1], LRCM_LocalE[count+1],
VSON=0, VSOE=0)
                    RCM_DD = Directional_Difference(VSA,
RCM_CA)
                    LRCM_VS.append(Vertical_Section(RCM_CD,
RCM_DD))

                    MCM_CD =
Closure_Distance(LMCM_LocalN[count+1],
LMCM_LocalE[count+1], VSON=0, VSOE=0)
                    MCM_CA =
Closure_Angle(LMCM_LocalN[count+1], LMCM_LocalE[count+1],
VSON=0, VSOE=0)
                    MCM_DD = Directional_Difference(VSA,
MCM_CA)
                    LMCM_VS.append(Vertical_Section(MCM_CD,
MCM_DD))

                L_MD.append(MD)
                L_Inc.append(Inc)
                L_Az.append(Az)

                count += 1

    elif (Operation == "q"):
```

```
        print("")

print("*******************************************Tangenti
al********************************************")
        print("{:16}".format("Survey No"),
"{:9}".format("MD"), "{:10}".format("Inc"),
"{:9}".format("Az"),
              "{:9}".format("CL"), "{:10}".format("TVD"),
"{:14}".format("Local N"), "{:14}".format("Local E"),
              "{:10}".format("DLS"), "{:9}".format("VS"))
        for i in range(len(L_MD)):
            print("{:5}".format(i+1),
"{:14.2f}".format(L_MD[i]), "{:9.2f}".format(L_Inc[i]),
                  "{:10.2f}".format(L_Az[i]),
"{:9.2f}".format(L_CL[i]), "{:9.2f}".format(LT_TVD[i])
                  , "{:13.2f}".format(LT_LocalN[i]),
"{:14.2f}".format(LT_LocalE[i]),
                  "{:11.2f}".format(L_DLS[i]),
"{:10.2f}".format(LT_VS[i]))
        print("")



print("***************************************Balanced_Tan
gential***************************************")
        print("{:16}".format("Survey No"),
"{:9}".format("MD"), "{:10}".format("Inc"),
"{:9}".format("Az"),
              "{:9}".format("CL"), "{:10}".format("TVD"),
"{:14}".format("Local N"), "{:14}".format("Local E"),
              "{:10}".format("DLS"), "{:9}".format("VS"))
        for i in range(len(L_MD)):
            print("{:5}".format(i+1),
"{:14.2f}".format(L_MD[i]), "{:9.2f}".format(L_Inc[i]),
                  "{:10.2f}".format(L_Az[i]),
"{:9.2f}".format(L_CL[i]), "{:9.2f}".format(LBT_TVD[i])
                  , "{:13.2f}".format(LBT_LocalN[i]),
"{:14.2f}".format(LBT_LocalE[i]),
                  "{:11.2f}".format(L_DLS[i]),
"{:10.2f}".format(LBT_VS[i]))
        print("")



print("******************************************Average_A
ngle******************************************")
```

```
        print("{:16}".format("Survey No"),
"{:9}".format("MD"), "{:10}".format("Inc"),
"{:9}".format("Az"),
              "{:9}".format("CL"), "{:10}".format("TVD"),
"{:14}".format("Local N"), "{:14}".format("Local E"),
              "{:10}".format("DLS"), "{:9}".format("VS"))
        for i in range(len(L_MD)):
            print("{:5}".format(i+1),
"{:14.2f}".format(L_MD[i]), "{:9.2f}".format(L_Inc[i]),
                  "{:10.2f}".format(L_Az[i]),
"{:9.2f}".format(L_CL[i]), "{:9.2f}".format(LAA_TVD[i])
                  , "{:13.2f}".format(LAA_LocalN[i]),
"{:14.2f}".format(LAA_LocalE[i]),
                  "{:11.2f}".format(L_DLS[i]),
"{:10.2f}".format(LAA_VS[i]))
        print("")


print("*************************************Radius_of_Curva
ture_Method************************************")
        print("{:16}".format("Survey No"),
"{:9}".format("MD"), "{:10}".format("Inc"),
"{:9}".format("Az"),
              "{:9}".format("CL"), "{:10}".format("TVD"),
"{:14}".format("Local N"), "{:14}".format("Local E"),
              "{:10}".format("DLS"), "{:9}".format("VS"))
        for i in range(len(L_MD)):
            print("{:5}".format(i+1),
"{:14.2f}".format(L_MD[i]), "{:9.2f}".format(L_Inc[i]),
                  "{:10.2f}".format(L_Az[i]),
"{:9.2f}".format(L_CL[i]), "{:9.2f}".format(LRCM_TVD[i])
                  , "{:13.2f}".format(LRCM_LocalN[i]),
"{:14.2f}".format(LRCM_LocalE[i]),
                  "{:11.2f}".format(L_DLS[i]),
"{:10.2f}".format(LRCM_VS[i]))
        print("")


print("**************************************Minimum_Curvat
ure_Method************************************")
        print("{:16}".format("Survey No"),
"{:9}".format("MD"), "{:10}".format("Inc"),
"{:9}".format("Az"),
              "{:9}".format("CL"), "{:10}".format("TVD"),
```

```
"{:14}".format("Local N"), "{:14}".format("Local E"),
              "{:10}".format("DLS"), "{:9}".format("VS"))
        for i in range(len(L_MD)):
            print("{:5}".format(i+1),
"{:14.2f}".format(L_MD[i]), "{:9.2f}".format(L_Inc[i]),
                  "{:10.2f}".format(L_Az[i]),
"{:9.2f}".format(L_CL[i]), "{:9.2f}".format(LMCM_TVD[i])
                  , "{:13.2f}".format(LMCM_LocalN[i]),
"{:14.2f}".format(LMCM_LocalE[i]),
                  "{:11.2f}".format(LMCM_DLS[i]),
"{:10.2f}".format(LMCM_VS[i]))


print("****************RMS_for_Tangential****************")
print("{:11}".format("RMS_TVD"), "{:14}".format("RMS_Local
N"), "{:14}".format("RMS_Local E"),
"{:14}".format("RMS_VS"))
T_RMS_TVD = 0
T_RMS_LocalN = 0
T_RMS_LocalE = 0
T_RMS_VS = 0
for i in range(len(L_MD)):
    T_RMS_TVD += (LT_TVD[i]-LMCM_TVD[i])**2
    T_RMS_LocalN += (LT_LocalN[i] - LMCM_LocalN[i]) ** 2
    T_RMS_LocalE += (LT_LocalE[i] - LMCM_LocalE[i]) ** 2
    T_RMS_VS += (LT_VS[i] - LMCM_VS[i]) ** 2
T_RMS_TVD = sqrt(T_RMS_TVD/len(L_MD))
T_RMS_LocalN = sqrt(T_RMS_LocalN/len(L_MD))
T_RMS_LocalE = sqrt(T_RMS_LocalE/len(L_MD))
T_RMS_VS = sqrt(T_RMS_VS/len(L_MD))
print("{:5.2f}".format(T_RMS_TVD),
"{:13.2f}".format(T_RMS_LocalN),
"{:14.2f}".format(T_RMS_LocalE),
"{:12.2f}".format(T_RMS_VS))


print("***********RMS_for_Balanced_Tangential************")
print("{:11}".format("RMS_TVD"), "{:14}".format("RMS_Local
N"), "{:14}".format("RMS_Local E"),
"{:14}".format("RMS_VS"))
BT_RMS_TVD = 0
BT_RMS_LocalN = 0
BT_RMS_LocalE = 0
BT_RMS_VS = 0
for i in range(len(L_MD)):
    BT_RMS_TVD += (LBT_TVD[i]-LMCM_TVD[i])**2
```

```
    BT_RMS_LocalN += (LBT_LocalN[i] - LMCM_LocalN[i]) ** 2
    BT_RMS_LocalE += (LBT_LocalE[i] - LMCM_LocalE[i]) ** 2
    BT_RMS_VS += (LBT_VS[i] - LMCM_VS[i]) ** 2
BT_RMS_TVD = sqrt(BT_RMS_TVD/len(L_MD))
BT_RMS_LocalN = sqrt(BT_RMS_LocalN/len(L_MD))
BT_RMS_LocalE = sqrt(BT_RMS_LocalE/len(L_MD))
BT_RMS_VS = sqrt(BT_RMS_VS/len(L_MD))
print("{:5.2f}".format(BT_RMS_TVD),
"{:13.2f}".format(BT_RMS_LocalN),
"{:14.2f}".format(BT_RMS_LocalE),
"{:12.2f}".format(BT_RMS_VS))


print("**************RMS_for_Average_Angle***************")
print("{:11}".format("RMS_TVD"), "{:14}".format("RMS_Local
N"), "{:14}".format("RMS_Local E"),
"{:14}".format("RMS_VS"))
AA_RMS_TVD = 0
AA_RMS_LocalN = 0
AA_RMS_LocalE = 0
AA_RMS_VS = 0
for i in range(len(L_MD)):
    AA_RMS_TVD += (LAA_TVD[i]-LMCM_TVD[i])**2
    AA_RMS_LocalN += (LAA_LocalN[i] - LMCM_LocalN[i]) ** 2
    AA_RMS_LocalE += (LAA_LocalE[i] - LMCM_LocalE[i]) ** 2
    AA_RMS_VS += (LAA_VS[i] - LMCM_VS[i]) ** 2
AA_RMS_TVD = sqrt(AA_RMS_TVD/len(L_MD))
AA_RMS_LocalN = sqrt(AA_RMS_LocalN/len(L_MD))
AA_RMS_LocalE = sqrt(AA_RMS_LocalE/len(L_MD))
AA_RMS_VS = sqrt(AA_RMS_VS/len(L_MD))
print("{:5.2f}".format(AA_RMS_TVD),
"{:13.2f}".format(AA_RMS_LocalN),
"{:14.2f}".format(AA_RMS_LocalE),
"{:12.2f}".format(AA_RMS_VS))


print("********RMS_for_Radius_of_Curvature_Method********")
print("{:11}".format("RMS_TVD"), "{:14}".format("RMS_Local
N"), "{:14}".format("RMS_Local E"),
"{:14}".format("RMS_VS"))
RCM_RMS_TVD = 0
RCM_RMS_LocalN = 0
RCM_RMS_LocalE = 0
RCM_RMS_VS = 0
for i in range(len(L_MD)):
    RCM_RMS_TVD += (LRCM_TVD[i]-LMCM_TVD[i])**2
```

```
    RCM_RMS_LocalN += (LRCM_LocalN[i] - LMCM_LocalN[i]) **
2
    RCM_RMS_LocalE += (LRCM_LocalE[i] - LMCM_LocalE[i]) **
2
    RCM_RMS_VS += (LRCM_VS[i] - LMCM_VS[i]) ** 2
RCM_RMS_TVD = sqrt(RCM_RMS_TVD/len(L_MD))
RCM_RMS_LocalN = sqrt(RCM_RMS_LocalN/len(L_MD))
RCM_RMS_LocalE = sqrt(RCM_RMS_LocalE/len(L_MD))
RCM_RMS_VS = sqrt(RCM_RMS_VS/len(L_MD))
print("{:5.2f}".format(RCM_RMS_TVD),
"{:13.2f}".format(RCM_RMS_LocalN),
"{:14.2f}".format(RCM_RMS_LocalE),
"{:12.2f}".format(RCM_RMS_VS))
break



fig = plt.figure()
ax = fig.add_subplot(111, projection = '3d')

ax.plot(LT_LocalN, LT_LocalE, LT_TVD, color='red')
ax.plot(LBT_LocalN, LBT_LocalE, LBT_TVD, color='blue')
ax.plot(LAA_LocalN, LAA_LocalE, LAA_TVD, color='green')
ax.plot(LRCM_LocalN, LRCM_LocalE, LRCM_TVD, color='yellow')
ax.plot(LMCM_LocalN, LMCM_LocalE, LMCM_TVD, color='black')

ax.set_xlabel('N axis')
ax.set_ylabel('E axis')
ax.set_zlabel('V axis')
plt.show()
```