# Successful Placement of Up-dip Horizontal well by analyzing Formation Cuttings and Drilling Parameters: New insights for Cost-effective drilling in Lanwa field of Cambay Basin.

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Horizontal Wells, Cutting Samples, Inclination, Structural Anisotropy, Cost effectiveness, Techno-economics, Production Enhancement

**Abstract**

Horizontal wells are prolific producers for achieving higher recovery, particularly in heavy oil fields due to larger drainage radius, higher liquid withdrawal capacity as well as having fewer water coning and sand production problems. We have in this paper explained the planning & execution of one of recently drilled up-dip horizontal well in Lanwa field of ONGC Mehsana Asset, which leads to the multi-fold increase in the oil production and also reduced the significant well cost. Lanwa oil field of ONGC Mehsana Asset is having one of the heaviest crude oil in the Cambay basin, with viscosity ranges upto 1500 Cp (12°-13° API) at reservoir temperature (60-70 degree Celsius). Main reservoir rock of Lanwa field is unconsolidated Kalol sands deposited in the form of braided bars. Average inclined or vertical well productivity in the Lanwa field is around 2 tpd, therefore large amount of oil inplace (~35 MMt, PD category) still inaccessible due to suboptimal well production. Thus horizontal and high angle wells have been introduced in year 2015 in the southern part of the field along with updip line drive air injection mechanism. Horizontal well **"*Lanwa-A*"** was drilled in September, 2021 in the Block-8 of Lanwa field and it was **Landed at 1073.5m TVD** against the plan of 1072.2m TVD and **inclination at Landing point was 89.7 degree**. Subsequently 188.5m drain hole was drilled **in the 8-9 degree dipping sand body** with **maximum inclination of 97.8 degree.** This is the **highest angle attained** by any horizontal well in heavy oil fields of Mehsana Asset. Landing & drain hole placement was completed with cutting sample analysis, real time demarcation of sand geometry, observing deviations in drilling parameters & gamma ray log correlation. The overall process was extensively monitored and numerous modifications were done at the time of landing and placement for achieving desired trajectory. Aforesaid drilling approach has reduced well CAPEX by around **INR ~1.14 Crores**, which is the average cost of LWD tool in previously drilled updip horizontal wells. Currently well **Lanwa-A** is producing at the rate of **12 tpd oil,** which is **6 fold** increase from average per well production and it has cumulatively produced **4042 tons** as on 01.06.2023. Encouraging results of the aforesaid well gave insights for drilling of future high angle/horizontal wells with identical approach in the reservoirs having similar geometry.

## 1. Introduction

The Mehsana Asset is the well-explored & developed northern part, which lies in Ahmedabad-Mehsana tectonic Block of Cambay Basin. This asset delivers the highest production of oil and oil equivalent of gas amongst the all onshore assets of ONGC. Mehsana Asset also puts an example of reservoir management by on-going recent trends of EOR processes (ISC, Polymer Flooding) in heavy oil fields and exploitation of tight & lensoidal sands in all light oil fields.

Horizontal drilling has become a valuable technique in recent years due to certain advantages over traditional vertical drilling. The horizontal well configuration provides a unique gravity and pressure drawdown geometry. Horizontal oil producers in the heavy or viscous oil fields are often combined with thermal EOR processes, which can highly increase the efficiency of the EOR process resulting in higher incremental oil production **(Table 1)**. In well Lanwa-A, horizontal well placement was designed against the dip direction, keeping the total drain hole in the lower middle part of the sand body and parallel to the pay bottom. Our present effort exemplified the drilling of horizontal well with highest inclination with spending the existing in-house capitals, which further leads to into the minimal drilling expenditure. In this paper, we highlighted the temporal & spatial relationship between lithological characteristics and their resonance with drilling parameters.

Mehsana Asset is the most vibrant and radiant onshore asset of ONGC with over 3200 development & exploratory wells drilled as on date. Currently, 1712 wells are flowing hydrocarbon in various fields and every year almost 90-100 development wells are drilled in the asset. Being a highest onshore oil producing asset, with such a huge number of development drilling, it has become challenging to deploy all kind of contemporaneous hardwares and capitals in all wells. Besides that,

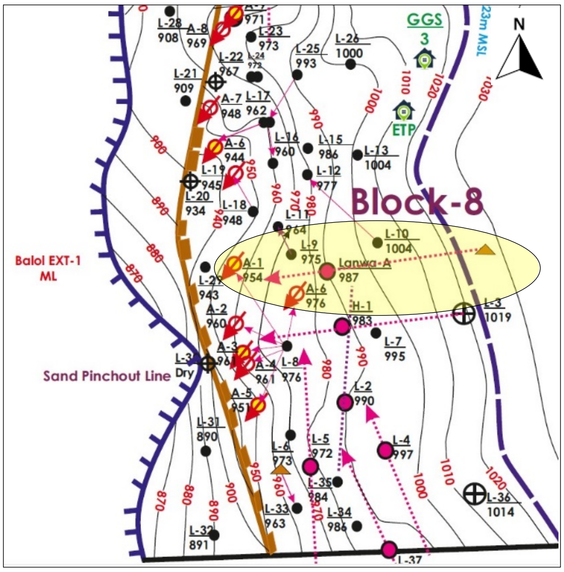


**Figure 1:** Structure Contour Map showing location of Well **Lanwa-A** (Map not to scale)

mobilization of tools is also difficult from one place to another because of the instant and simultaneous requirement in many wells. To subsidise the issues, we have planned well placement by using minimum resources & our subsurface understanding with the support of available dataset. Consequently well **Lanwa-A** was successfully drilled **(Fig. 1)** and completed in the objective sand and it is sustainably producing hydrocarbon since 20 months. Cumulative oil production from the well is 4042 tons as on 01.06.2023. Moreover it has saved the significant cost of the drilling which is the focal supporting reason for expending equivalent methodology in the future wells.

## 2. Geological Setup of Lanwa Field:

Cambay basin was formed during early cretaceous due to rifting along dharwarian orogenic trends in the course of northward migration of the Indian plate after its break up from gondwana land. Rift & drift lead to creation of undulating basin floors with highs and lows providing depocentres for huge thickness of sediments. The basin architecture in rift stage consists of grabens and horsts aligned in general N-S direction which was later separated into small blocks due to the transform faults. Cambay shale is the main source rock for Cambay basin. The deposition of Cambay shale was marked by a hiatus, after which a regressive phase began marked by the deposition of the Kalol Formation sediments from Middle Eocene to Upper Eocene. The Kalol sands of heavy oil fields are clean, extensive and deposited in fluvial environment. These sands are overlain by transgressive marine Tarapur Shale of Upper Eocene to Oligocene age which is the regional cap rock of Cambay Basin.

Lanwa field of ONGC Mehsana Asset falls on the north-east plunge of Mehsana Horst of Cambay Basin and located at about 15 kms. North-west of Mehsana city. The field was discovered in 1971 and put on production in October, 1986. Geologically,

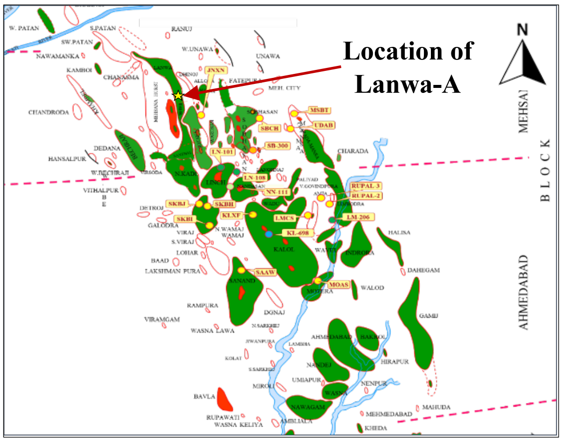


**Figure 2:** Map showing fields of Ahmedabad-Mehsana Block & location of well Lanwa-A (Map not to scale)

Lanwa, Balol, Santhal and North Kadi fields are parts of a contiguous structure with no geological boundaries in between **(Fig. 2)**. Kalol is the main hydrocarbon bearing pay sand of Lanwa field and having permeability ranges in 3-5 Darcy. The average Pay thickness of Kalol sand (KS-I) is about 12-15m at 950m-1030m MSL. Kalol pays in Lanwa field generally show strati-structural entrapment as the formation represents braided bar depositional system. The western limit of the structure abates against eastern margin of Mehsana Horst. There are two major longitudinal faults (NNW-SSE) almost parallel to Mehsana Horst with maximum throw of 35m and few transverse faults are also found on the basis of variation in occurrence of oil-water contact (OWC). All the fault blocks of Lanwa field are hydro-dynamically connected, which is also confirmed by the flue gas (by product of the in-situ combustion process) migration from northern part of Balol to southern part of Lanwa field. The Oil Water Contact (OWC) varies from 994m to 1043m (MSL) in eastern side (down-dip part) of the structure.

## 3. Planning of Well Lanwa-A

Kalol sands are the deposited in the form of braided bars, which are characterized by their fast flow and steep gradients, forming when the bedload sediment is high compared to the suspended load. They form a network of many branches within a channel. These branches are separated by the formation of bars, therefore we have planned the well course in such a way that, it will route in the lower middle part of sand body. Lanwa field of Mehsana Asset is in rapid urbanisation stage, hence it has become more difficult to drill the vertical well in these areas. To avoid any surface contentment, detailed ground survey was done along with land acquisition team prior to the finalizing of surface point. Furthermore, to prevent collision, subsurface modelling was done with the help of directional drilling team before finalization of well path. Surface Point of well **Lanwa-A** was planned in 81.6 degree azimuth and at the horizontal distance of 741.2m from the end point of drain hole in such a way that the horizontal trajectory can be achieved at the time of Landing **(Fig. 3)**. Based on the petrophysical interpretation & production performance of previously drilled nearby wells, it was planned to land the well Lanwa-A at 8m below from the pay sand top **(Table-2)**. Target depth of the well was 1581.6m MD and it was expected to land at 1072.2m TVD.

| SI. No. | Field | Well | Pay Thickness (m) | Drilled Year | Target Depth (m) | Max. Horizontal Drift (m) | Max. Angle (deg.) | Drain Hole (m) | Cumulative Production (tons) (as on 01.06.2023) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Lanwa | H-1 | 18m | 2017 | 1588 | 505 | **96.5** | 221 | 11,584 (Flowing) |
| 2 | Balol | H-2 | 16m | 2015 | 1665 | 650 | **94.0** | 238 | 5,970 (Sick) |
| 3 | | H-3 | 10m | 2017 | 1684 | 659 | **92.4** | 221 | 12,507 (Flowing) |
| 4 | | H-4 | 19m | 2017 | 1697 | 640 | **91.5** | 234 | 9,285 (Flowing) |
| 5 | | H-5 | 18m | 2017 | 1683 | 613 | **94.5** | 230 | 16,870 (Flowing) |
| 6 | | H-6 | 22m | 2017 | 1581 | 482 | **90.0** | 230 | 18,261 (Flowing) |
| 7 | | H-7 | 20m | 2018 | 1595 | 661 | **91.0** | 130 | 4,223 (Flowing) |

**Table 1:** Details of Updip Horizontal Wells in Lanwa & Balol Field drilled prior to the Drilling of **Lanwa-A**.
**(All of above wells have been drilled with LWD & RSS - Rotary Steerable System)**

| LWLV | MSL (m) | | TVD (m) | | MD (m) | | True Thickness | Planned Drift | Angle |
|---|---|---|---|---|---|---|---|---|---|
| **Formation** | **From** | **To** | **From** | **To** | **From** | **To** | **(m)** | **(m)** | **Degree** |
| Alluvium | 0.0 | 335.0 | 78.2 | 413.2 | 78.2 | 413.2 | 335.0 | 0.0 | 0.0 |
| Jhagadia | 335.0 | 562.4 | 413.2 | 640.6 | 413.2 | 641.7 | 227.4 | 0.0 | 0.0 |
| Kand | 562.4 | 844.5 | 640.6 | 922.7 | 641.7 | 969.5 | 282.1 | 12.4 | 11.8 |
| Babaguru | 844.5 | 943.5 | 922.7 | 1021.7 | 969.5 | 1148.8 | 99.0 | 168.8 | 46.4 |
| Tarapur | 943.5 | 982.9 | 1021.7 | 1061.1 | 1148.8 | 1271.5 | 39.4 | 313.7 | 65.1 |
| Kalol | 982.9 | 978.0 | 1061.1 | 1056.2 | 1271.5 | 1581.6 | -4.9 | 432.7 | 78.4 |
| Siltstone | 982.9 | 983.4 | 1061.1 | 1061.6 | 1271.5 | 1274.3 | 0.5 | 432.7 | 78.4 |
| Siltstone | 983.4 | 986.0 | 1061.6 | 1064.2 | 1274.3 | 1288.5 | 2.6 | 435.5 | 78.7 |
| KS-I Top | 986.0 | 994.0 | 1064.2 | 1072.2 | 1288.5 | 1381.6 | 8.0 (upto Landing) | 449.4 | 80.15 |
| **Landing** | **994.0** | | **1072.2** | | **1381.6** | | | **542.1** | **90.0** |
| **End Point** | **978.0** | | **1056.2** | | **1581.6** | | | **741.2** | **99.2** |

**Table 2:** Planned Stratigraphy of well **Lanwa-A**.

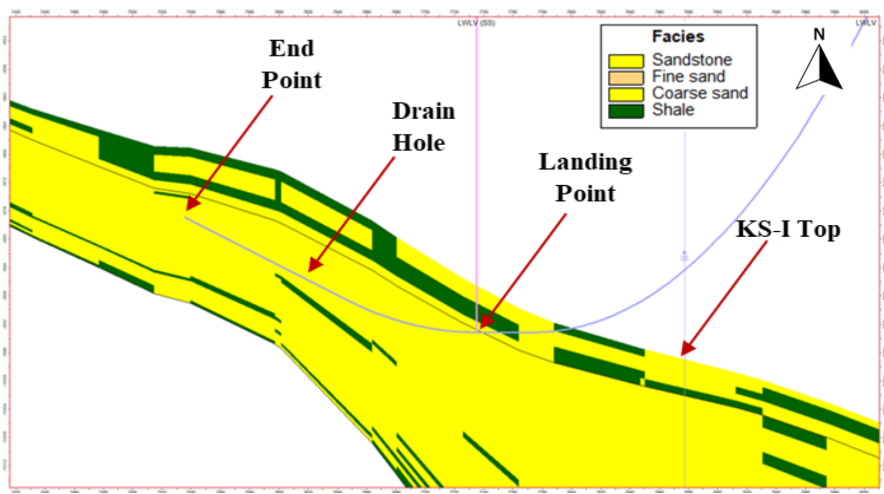


**Figure 3:** Cross Section of KS-I Pay along the plane of existing wells and planned trajectory of well **Lanwa-A**.

## 4. Execution of Various Phases of Drilling

**Phase-1:** Well Lanwa-A was spudded in the July, 2021 with drilling rig D-1. After drilling upto the 301m (MD), 13 3/8" conductor casing was lowered. Subsequently it was drilled upto 983m and 9 5/8" intermediate casing was lowered followed by cementation.

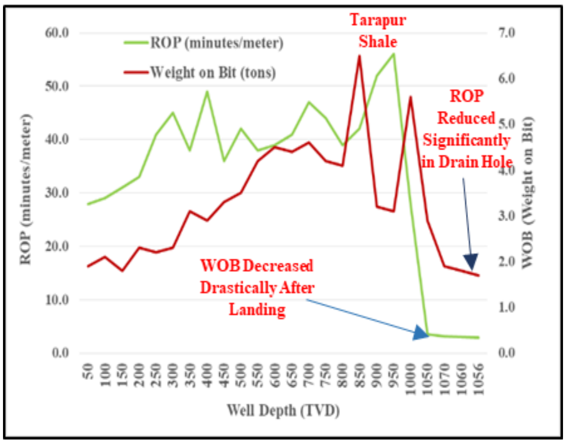


**Figure 4:** ROP & WOB variation with True Vertical Depth.

**Phase-2:** Well site monitoring was started from 1130m (MD) onwards. After the drilling up to 1327m, conventional open hole logs i.e. HDIL-SP-GR & CDL-CNL-CALI-GR were recorded. Consequently log data was integrated with cutting samples & drilling parameters. Based on the correlation, KS-I sand top was expected at 1065.5m (1.3m down) against the plan of 1064.2m at the entry point in the KS-I pay sand.

**Phase-3:** Cutting Samples were collected in every 5m interval from the 1327m depth upto the landing point and analysed unremittingly in geology lab at well site. Based on the grain size, cut & fluorescence, lag time, on bit gamma ray logs, drilling parameters & mud composition, results were integrated with available data and planned trajectory was modified accordingly. Well was found 1.3m down from the expected pay top, therefore well was landed at 1073.5m TVD (plan 1072.2m) which is 8m below the sand top. TVD variation during the well course indicated that sand structure is becoming 10m high in every 95 meters lateral distance when we are drilling against the dip direction and same has been confirmed with the variation in the grain size of sand. Average dip of sand is 8 degree throughout the sand unit. There was incessant gain in the TVD values upto the landing point since the well was drilled in the regional NNE-SSW strike direction upto the landing point.

Drilling parameters indicated the subsurface lithology such as, weight on bit increased with formation tightness, ROP (rate of penetration) increased with sandy nature of formation **(Fig. 4)** and mud weight reduced whenever there is indication of gas influx from the formation. Torque applied by the rotary table to the drill string and the rpm of the drill string is also indicative of formation hardness. After landing at 1381m (MD), 7" producing casing was lowered by clearing held up sections. Successively sand geometry was fabricated for drain hole drilling.

**Phase-4:** After the cementation job of production casing, drain hole drilling was started. During drain hole drilling, cutting samples were collected in every 2m interval and corresponding adjustments were done in the planned trajectory. On treatment in geology lab, these samples have shown strong Cut & GYF **(Fig. 5)**. Since the KS-I pay of Lanwa field is having initial oil saturation of 60-70%, there was huge volume of crude was coming from the formation at the time of drain hole drilling and it started floating on shale shaker **(Fig. 6).** Drain hole route was planned in such a manner that its direction will always remain WNW-ESE, which is parallel to the KS-I sand bottom and against the dip **(Fig. 7).** In the drain hole, maximum angle 97.8 degree was attained at 1062.2m TVD (1516m MD).

TVD values were continuously loosened from the landing point upto the end point, since structure has become high in WNW direction. Based on weight on bit & rate of penetration, a clear-cut sequential and spatial relationship was established between the drilling parameters and sand extension in the drain hole. There was significant surge in rate of penetration & weight on bit, when we drilled Kand & Tarapur shale formations, whereas in Kalol formation, ROP was very diminutive (2-3 minutes/meter) and very low weight on bit was required for drilling in drain hole **(Fig. 4)**. Total length of drain hole was 188.5m against the plan of 200m and inclination angle was 97 degree at 1582m MD **(Table 3)**. Well was completed with 3 ½" GP screen in drain hole and bridge plug was kept at 1582m MD.

## 5. Production Performance of the Well Lanwa-A

Horizontal drilling is preferred over vertical drilling due to its more effectiveness in terms of drainage of the reservoir, which consequently enhances the well productivity. It is pertinent to mention that the performance of horizontal wells is dependent on two major factors: well placement and air-injection to capture mobilized oil. Air injection is ongoing in the close proximity to the toe section of the drain hole of well Lanwa-A and due to some operational issues in air injectors, oil production was suboptimal for initial few months.

Aforesaid well as put on production in October, 2021 and initial rate was 3-4 tpd (January, 2022) when liquid rate and water cut was stabilized.

Subsequently oil production was sustained at 10-12 tpd and liquid rate was also increased gradually in this period due to the effect of in-situ combustion.

Currently well is producing at the rate of 12 tpd with 70% water cut **(Fig. 8)**.

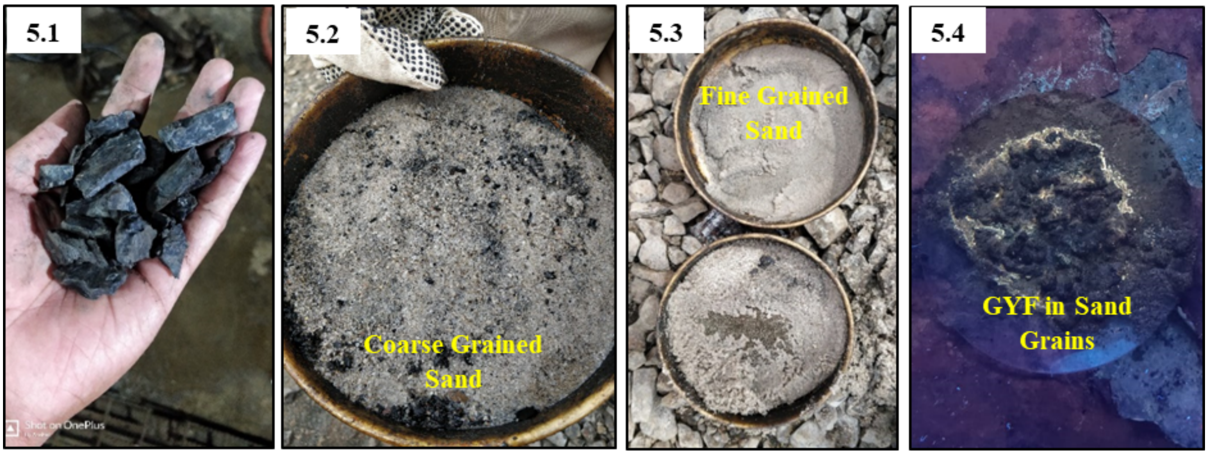


**Figure 5:** Cutting Samples & their analysis,
5.1 Coal samples collected above the KS-I pay (Demarcation of boundary between Upper Suraj Pay & KS-I Pay),
5.2 Coarse size sand grains collected at the time of entry in the KS-I Pay (High Energy Condition),
5.3 Fine Grained Sand collected in the Mid-Course of Drain Hole,
5.4 Sand grains showing GYF in UV Light

| MD (m) | Inc. (Deg.) | Azi. (Deg.) | TVD (m) | VS (m) | Closure Distance (m) | Closure Direction (deg.) | DLS (Deg./30m) | Remarks |
|---|---|---|---|---|---|---|---|---|
| 300.0 | 0.0 | 0.0 | 300.0 | 0.0 | 0.0 | 0.0 | 0.0 | |
| 529.4 | 2.2 | 237.8 | 529.4 | 2.0 | 3.6 | 206.3 | 0.5 | |
| 586.8 | 7.0 | 262.5 | 586.6 | 6.5 | 7.3 | 234.3 | 2.7 | |
| 615.6 | 9.5 | 264.1 | 615.1 | 10.6 | 11.1 | 244.7 | 2.7 | |
| 673.1 | 14.7 | 264.5 | 671.2 | 22.8 | 23.0 | 255.0 | 2.4 | |
| 730.4 | 20.3 | 264.2 | 725.9 | 40.1 | 40.2 | 258.8 | 2.7 | |
| 788.1 | 26.7 | 263.1 | 778.8 | 63.0 | 63.0 | 260.7 | 3.6 | |
| 845.6 | 33.3 | 262.3 | 828.6 | 91.7 | 91.7 | 261.3 | 3.5 | |
| 902.5 | 39.6 | 261.7 | 874.5 | 125.3 | 125.3 | 261.4 | 3.7 | |
| 959.3 | 46.5 | 261.5 | 915.9 | 164.1 | 164.1 | 261.5 | 3.7 | |
| 1013.2 | 51.3 | 261.7 | 951.0 | 205.0 | 205.0 | 261.5 | 1.8 | |
| 1070.8 | 56.8 | 261.8 | 984.6 | 251.7 | 251.7 | 261.6 | 2.5 | |
| 1128.5 | 62.7 | 262.1 | 1013.3 | 301.7 | 301.7 | 261.6 | 2.4 | |
| 1185.8 | 70.6 | 262.2 | 1036.3 | 354.1 | 354.1 | 261.7 | 4.8 | |
| 1243.2 | 75.1 | 261.6 | 1052.9 | 409.1 | 409.1 | 261.8 | 1.7 | |
| 1271.7 | 78.4 | 261.1 | 1059.4 | 436.8 | 436.8 | 261.7 | 3.5 | |
| 1358.0 | 85.0 | 260.7 | 1071.9 | 522.2 | 522.2 | 261.7 | 2.7 | |
| 1378.0 | 87.8 | 263.0 | 1073.1 | 542.1 | 542.1 | 261.7 | 5.5 | 7" Casing Shoe |
| 1393.5 | 89.7 | 263.9 | 1073.5 | 557.6 | 557.6 | 261.7 | 4.1 | **Landing Point** |
| 1422.7 | 93.5 | 264.4 | 1072.6 | 586.8 | 586.8 | 261.8 | 3.9 | |
| 1448.0 | 96.8 | 263.7 | 1070.4 | 611.9 | 611.9 | 261.9 | 4.0 | |
| 1471.9 | 96.4 | 263.0 | 1067.6 | 635.6 | 635.6 | 262.0 | 1.0 | |
| 1491.7 | 96.8 | 262.6 | 1065.3 | 655.3 | 655.3 | 262.0 | 0.9 | |
| 1516.0 | 97.8 | 262.5 | 1062.2 | 679.4 | 679.4 | 262.0 | 1.3 | |
| 1542.2 | 97.2 | 261.0 | 1058.8 | 705.4 | 705.4 | 262.0 | 1.8 | |
| 1565.0 | 97.5 | 260.7 | 1055.9 | 728.0 | 728.0 | 262.0 | 0.6 | |
| 1582.0 | 97.0 | 260.7 | 1053.8 | 744.9 | 744.9 | 262.0 | 0.9 | **End Point** |

**Table 3:** Actual deviation profile of Well Lanwa-A.

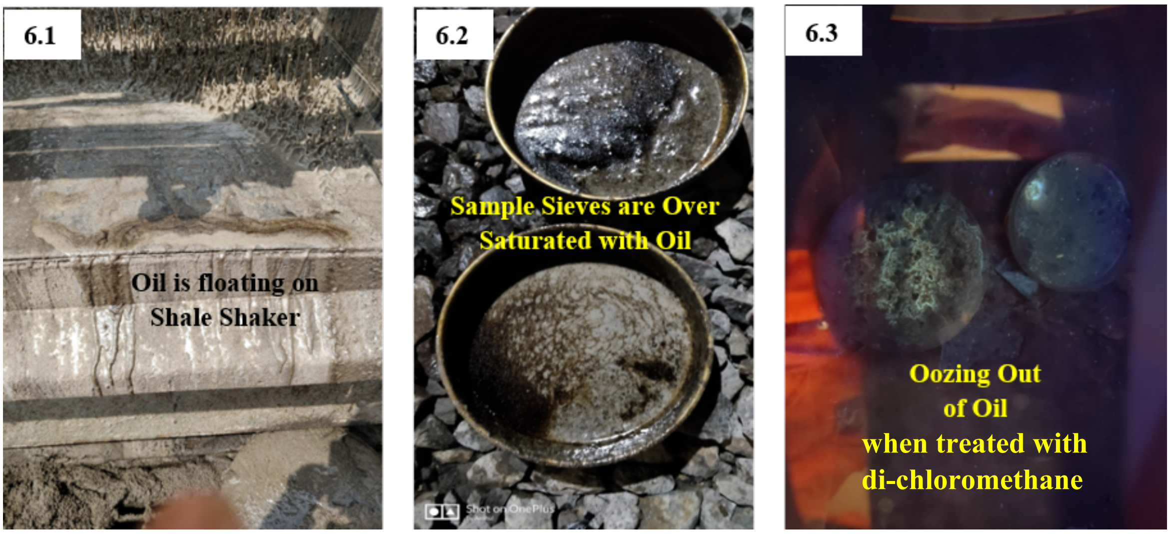


**Figure 6:** Well Site observations during drain hole drilling,
6.1 Oil is floating on Shale-Shaker during drain hole drilling,
6.2 Crude Oil Soaked Sand Samples Collected from the Shale-Shaker,
6.3 Strong cut observed when di-chloromethane poured in the samples

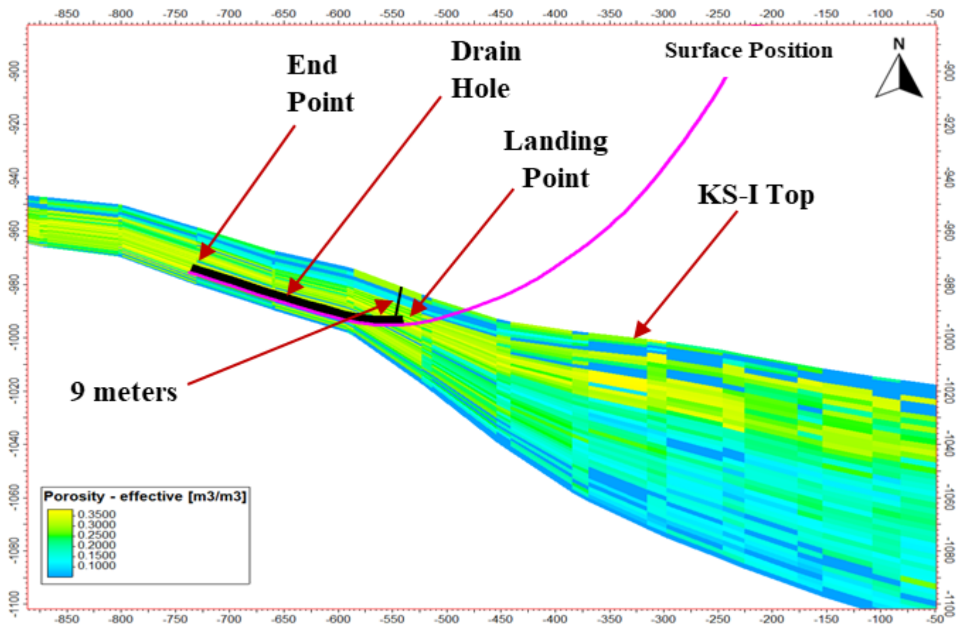


**Figure 7:** Cross Section of KS-I Pay along the plane of existing wells and actual trajectory of well Lanwa-A.

### 6. Techno-economic Analysis

Average inclined/vertical well drilling expenditure in the Lanwa field is around INR 4000 per meter whereas it increased upto INR 7000-8000 per meter in the previously drilled horizontal wells in Lanwa & adjoining fields. In this well, landing and drain hole placement was commenced based on the cutting samples analysis and well site observations followed by sand geometry interpretation in such a structurally anisotropic and highly dipping environment. This has saved the capital expenditure of LWD (Logging While Drilling) tool which is significantly high in the previously drilled wells. Older wells data suggests that LWD outlay is approximately INR 1.14 Crores, which sometime makes onshore development oil wells unviable.

After landing, open hole logging was also skipped and data was correlated based on the real time monitoring, which has also saved the logging cost and resources were optimally utilized in the other fields as per the requirement.

### 7. Discussions

Oil and gas are key economic inputs and drivers for the developing countries since they are planning to ensure sufficiency and affordability. The preliminary analysis of the available data helps us to decide, whether the drilling is worth undertaking from an economic and time perspective. The integration of desirability, viability and feasibility forms a synergistic framework for effective planning and execution of any oil/gas wells.

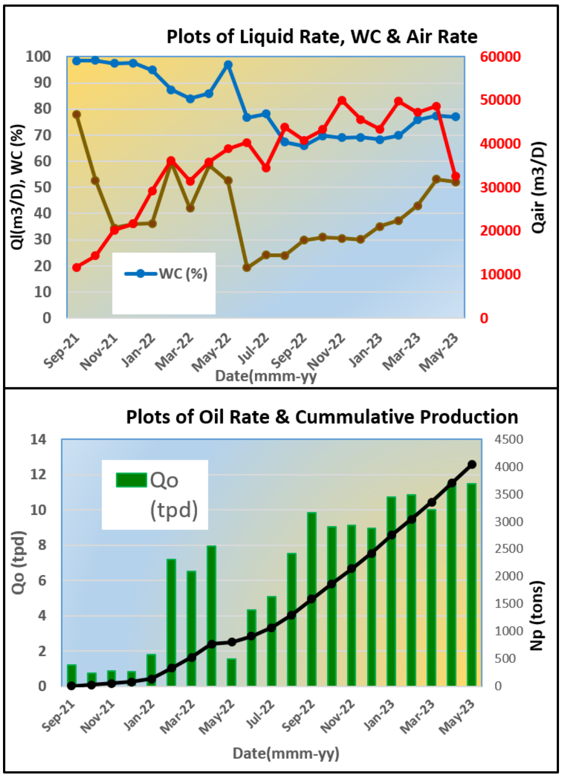


**Figure 8:** Production Performance of Lanwa-A.

Measured depth is the primary, but not the only factor affecting drilling expenditures. CAPEX of wells also strongly depends on the geological formation, technology & methods used in drilling and hydrocarbon potential of the well. Geological setting determines penetration rates, number of casing strings and frequency of drilling string related anticipations. Running a gamma ray log with the bottom hole assembly as drilling progresses helps in differentiating different rock types (like shale, silt and sandstone).

It is clear that, formation heterogeneity prior to landing and in the drain hole is controlled by the sand deposition pattern followed by overbank deposits from floods, which mostly composed of silt and some mud. Likewise petrophysical characteristics of reservoir rock is strongly substantiated with the drilling parameters. Initial development wells in aforesaid fields were drilled with limited prior knowledge about the formation characteristics but when we are in the mature stage of the oil field and so many wells have been drilled, we can make a call for utilizing our resources in the conservative manner. A prior technical feasibility analysis for the oil & gas wells may results into profitable working system. Therefore, in those area where pay sand thickness is 5-15m and well density is very high, cutting samples and well site monitoring can help in the drilling and placement of high angle or horizontal wells.

## 8. Conclusions

In the well **Lanwa-A**, we have harvested the maximum hydrocarbon with our fundamental learnings and de-lineation of sand extension limits within the reservoir by real time monitoring. Currently production rate of the well is 12 tpd which is around 600% of the average per well production in Lanwa field. Mehsana Oil fields are maturing very fast along with sharp annual decline rate, which necessitates the exploitation of reserves on the quicker rate. Since the advance drilling resources are expensive and not have a viable implication always, existing data can be utilised for placement of high angle wells as done in aforesaid well. Our study illustrates the significant role of subsurface understanding and real time well site monitoring in the drilling and placement of horizontal well.

Successful placement of well **Lanwa-A** without LWD saved ₹ 1.14 crores on organization and gave insights to drill more wells with these learnings. There are very thin shale lenses deposited within the sand body, which need to be avoided in drain hole drilling and sharp build-up is required when shaly or silty layer comes in path of drain hole. Therefore viability analytics & sand geometry modelling may be done with the help of available data, prior to the drilling of horizontal and high angle wells in equivalent reservoirs.

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