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OVER-CORE RECOVERY OF A DRILL STRING BOGGED IN A LONGHOLE

Frank Hungerford[1] and Mitch Fagan[2]

ABSTRACT: Underground in-seam directional drilling regularly encounters zones of unstable strata. In some cases, borehole collapse leads to the bogging of the drill string. With the high cost of in-hole equipment at risk and the likely loss if not recovered at the time, over-coring has become an established form of recovery. Due to in-hole friction of the over-core rods with the borehole and the bogged rods exacerbated by the deviations within a directionally drilled borehole, the depths from which over-core recovery has been successful has been limited. This paper explains the prior installations, precautions, considerations and procedures employed for a successful over-core recovery of a 717 m long drill string bogged in an in-seam borehole.

INTRODUCTION

All longhole drilling in underground coal mines is now undertaken using directional drilling to provide directional control and progressively define the borehole location relative to mine workings. Underground directional drilling regularly encounters zones of instability which must be negotiated for drilling to continue while maintaining a stable borehole. Occasionally, conditions in the borehole deteriorate rapidly and the drill string becomes bogged. With the high cost of in-hole equipment at risk in the borehole, there is an urgency to recover the equipment. Various methods of pulling, pushing and flushing with low pressure additives have been successful at releasing drill strings in the past, but when all such attempts are unsuccessful, an attempt at over-core recovery is required.

This paper presents the results of the successful over-core recovery of a drill string.

DRILLING ENVIRONMENT

The drilling environment in and around a coal seam is usually strong enough to maintain a stable borehole. However, there are numerous geological features and conditions which present strata which will either collapse immediately or deteriorate after contact with water. Features such as mylonite zones, fractured coal associated with faulting, high stress areas and complications around and through dykes have been identified as presenting instability problems with in-seam drilling (Hungerford, 1995). A bogging event is usually preceded by high fluctuations in water pressure not too dissimilar to a low angled intersection with stone at high penetration rates before the water pump stalls. Prior knowledge of what to expect in the area of drilling and driller experience are key aspects in the security of the equipment exposed to risk in the borehole.

With the high number of in-seam boreholes in place for gas drainage, an added problem has been the intersection of previously drilled boreholes and loss of water circulation into those boreholes. Water and cuttings return does not continue out the length of the borehole with the chance of cuttings accumulating at the borehole intersection. In some cases, the intersected borehole can be identified by the diverted water flow and shut to allow continued drilling. But with possible multiple connections between boreholes, this is not always successful. Preceding this event, loss of water return followed by fluctuating water pressure and surging feed are

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indicators of a potential bogging event. The bogging can occur when pulling back after identifying loss of water return.

OVER-CORING DRILLING PRACTICE

Before any over-core operation is undertaken, a risk assessment is conducted to identify the risks and define the operational requirements of the project.

Longhole drilling had become an established practice with the conventional flip-flopping of Down Hole Motor (DHM) bend orientation for directional control. But with the practice of a change in orientation every 6 m, borehole friction is the main factor limiting borehole depth initially with directional drilling and if over-core recovery is required. In the case of over-coring, in-hole friction occurs inside the HQ over-core rods against the bogged CHD rods and externally with the sides of the reamed borehole. This combination of friction is increased with numerous deviations in the borehole and influences the depths from which over-core recovery can be considered.

An assessment can be made on the number and severity of the deviations in the borehole which will adversely affect the in-hole friction on the over-core rods. With the common surveying practice of surveying directly behind the DHM (3 m behind the bit) and changing orientation every 6 m as illustrated in Figure 6, a true indication of the severity of the deviations in the borehole is not available (Hungerford, *et al,* 2012). When severe changes in azimuth and/or pitch are identified, notations can be made to warn the drillers of potential changes in drilling conditions. The VLI drillers in NSW have a common practice of taking a check-shot at the 3 m point between 6m survey intervals when drilling longholes. This provides more accurate control and allows analysis of the response curves to assess directional control of various bent housing and bit diameter combinations. It also allows simple analysis of borehole deviations in the case of over-coring operations.

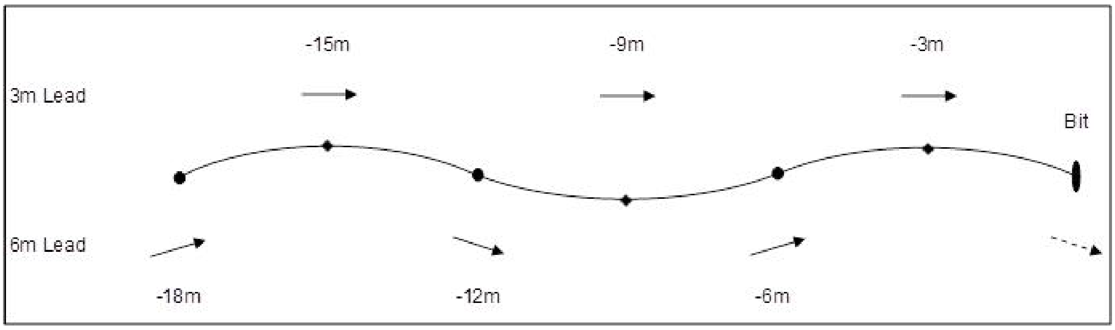

Figure 1: Survey positions with 6 m orientation changes

Another influence of the deviations in the borehole is the effect of rotating the over-core rods while they are being flexed. HQ rods are essentially rods for wire-line coring usually used with close tolerances in boreholes with only slight deviations. When put under “knuckle joint” loading rotating through sharp deviations, failure of the male thread joint is a common occurrence.

The standpipe must be identified and altered if required to suit the proposed over-coring diameter. Most directional drilling is undertaken through a 6 m long 100 mm standpipe grouted into the rib to manage all water, cuttings and gas returns from the borehole while drilling. If a 100 mm standpipe has been installed, this standpipe has to be removed by over-coring and a 150 mm standpipe installed. This can be complicated if high gas flows are being produced from the borehole. Recent practice when drilling into new areas has been to install a 150 mm standpipe (Figure 2) which will allow over-coring if required.

HQ drill rods (88.9 mm OD x 77.7 mm ID) are a standard rod used for over-coring CHD 69.9 mm OD directional drill strings. Most drill rigs designed for directional drilling with CHD rods now have the ability to feed HQ rods through the rotation unit suitable for rotary reaming.

Over-core (shoe) bits were initially produced with Tungsten Carbide (T/C)cutters (Figure 3A). However these bits were only suited for coal drilling and usually suffered loss of cutters which reduced the diameter being reamed. This lead to an increase in in-hole friction and failed recovery attempts. The design and supply of shoe bits with Poly Crystalline Diamond (PCD) cutters provided bits which can penetrate both coal and stone and not require checking or replacement over the length of an over-core operation. These are now provided in 98 m diameter for cleaning out a short borehole through a 100 mm standpipe and 105 mm (Figure 3B), 115 mm and 125 mm (Figure 3C) for reaming to larger diameters in longer boreholes. The inside cutting edge of all shoe bits is stepped out from the inside diameter to ensure the cutters do not contact and potentially cut through the bogged rods.

The larger diameter reamed borehole provides reduced contact between borehole sides and outer surface of the HQ over-core rods and thus reduced in-hole friction

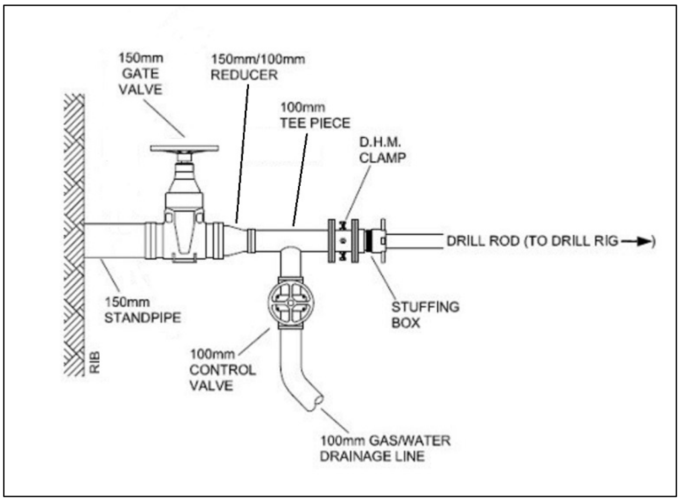

Figure 2: Standpipe configuration with 150 mm to 100 mm reduction

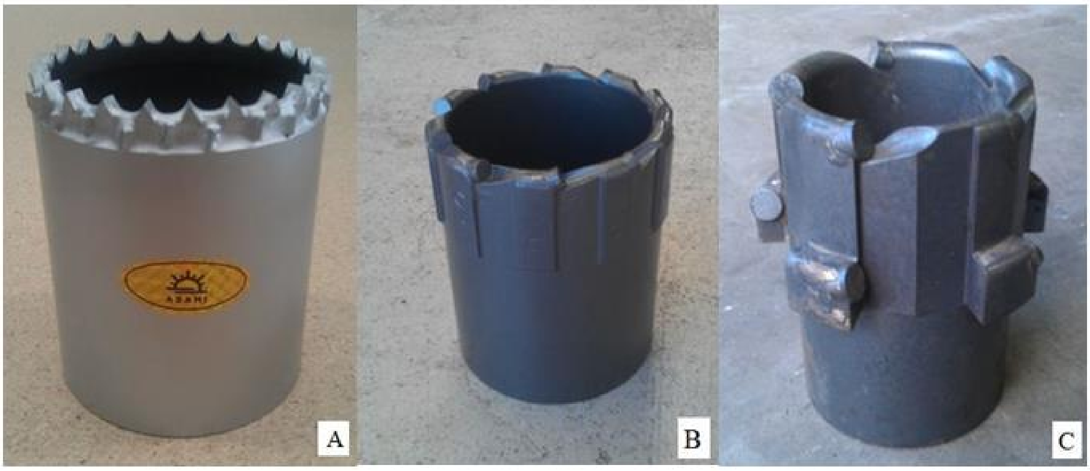

Figure 3: (A) 98 mm T/C shoe bit, (B) 105 mm PCD shoe bit, (C) 125 mm PCD shoe bit

Additives mixed with the flushing water are recommended to reduce the two sources of in-hole friction. A “bit lube” should be considered for the metal to metal contact between the two sets of drill rods, which a normal borehole flushing polymer is considered for flushing of cuttings. The practice of adding unsuitable grease to the inside of the over-core rods increased the “drag” on the over-core rods and made handling difficult when pulling the recovered drill string.

The standard non-magnetic 4/5 Accu-Dril DHM fitted with a 1.25^{O} bent housing presents a problem when completing the final stage of an over-core recovery when it is suspected that the bogging has occurred at the drill bit. The 73 mm OD of the DHM will fit within the 77.7 mm ID of the HQ rods until the over-core bit passes the bent housing 750 mm back from the front of the bit box. At a point 463 mm back from the bit box, the inside of the over-core rod makes contact with the deflected DHM (Figure 4) (REI/DPI, 2012). From there, the over-core rod is forced over the DHM with both DHM and over-core rod flexing to fit. An additional 50 mm of travel is usually required to take the over-core bit up to the back shoulder of the drill bit to eventually release the bogged drill string.

This forced fit provides a secure grip on the recovered directional drill string when pulling out of the borehole. It does present a challenge in removing the DHM from the over-core bit when removed from the borehole.

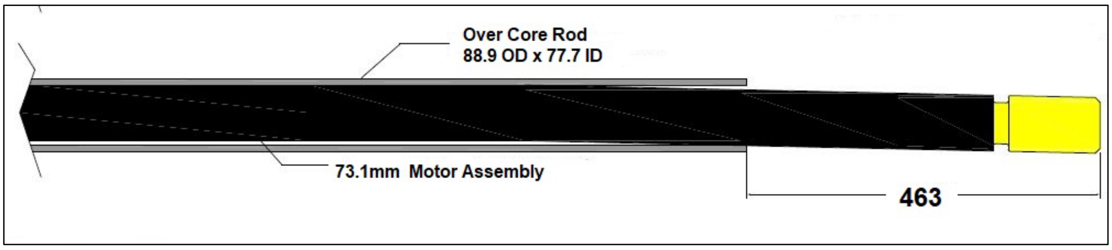

Figure 4: Wash over comparison of HQ drill rods with 93 mm diameter DHM (REI/DPI, 2012)

RIG CAPACITY

A track mounted VLI Series 1000 was being used for the directional drilling at Tahmoor Colliery. With a thrust capacity of 140 kN and a rotational torque capacity of 2430 Nm, the rig is one of the highest capacity being used in the coal industry and thus as adequate as any available to undertake longhole over-coring operations.

THE BOGGING INCIDENT IN THE DIRECTIONAL DRILLED BOREHOLE

Management at Tahmoor instructed VLI to drill a 500 m long borehole (TGW1-5CT-D12) from which to core for gas drainage compliance assessment adjacent to the proposed development of Tailgate TGW1 (Figure 5). A standard Asahi 96.1 mm diameter PCD bit was used. The B Heading of the tailgate in the new western domain had previously been flanked by two 1600m long gas drainage boreholes which had been drilled from 2CT, B Heading. When the compliance cores at 271.5 m, 385.5 m and 500 m (Figure 6) indicated drainage had been insufficient in the area, the mine requested the 500 m long borehole be extended to a depth of 1000 m. The design of the extension was to turn left and cross one of the previously drilled 1200 m long boreholes (at approximately 726 m) before continuing parallel to the proposed rib-line (Figure 7).

Two zones of soft coal at 630 m and 653 m (Figure 6) were identified with the drilling. Otherwise, the coal drilling was stable.

When at a borehole depth of 819 m, the driller noticed the return water flow had reduced by 50%. Extended flushing re-established full return flow and allowed drilling to continue to 837 m before water return reduced again. After a change of shift, water return had been lost

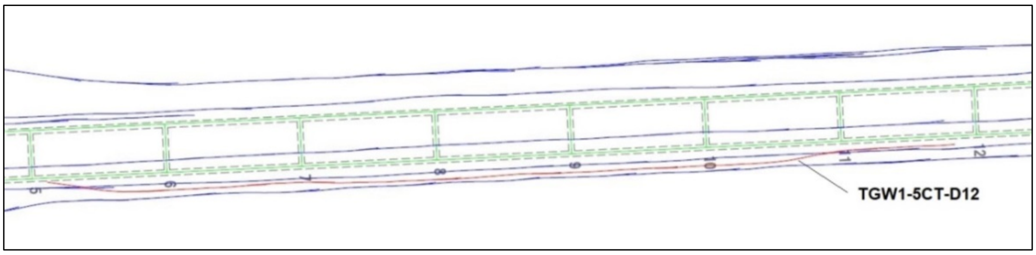

Figure 5: – Borehole TGW1-5CT-D12 location

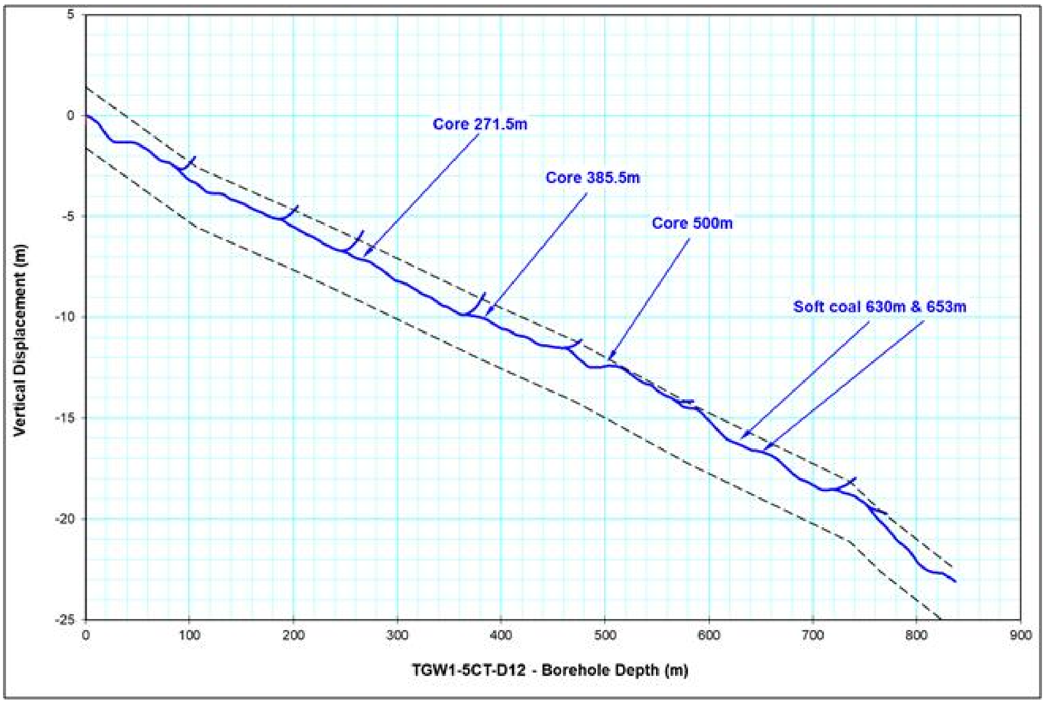

Figure 6: Borehole profile

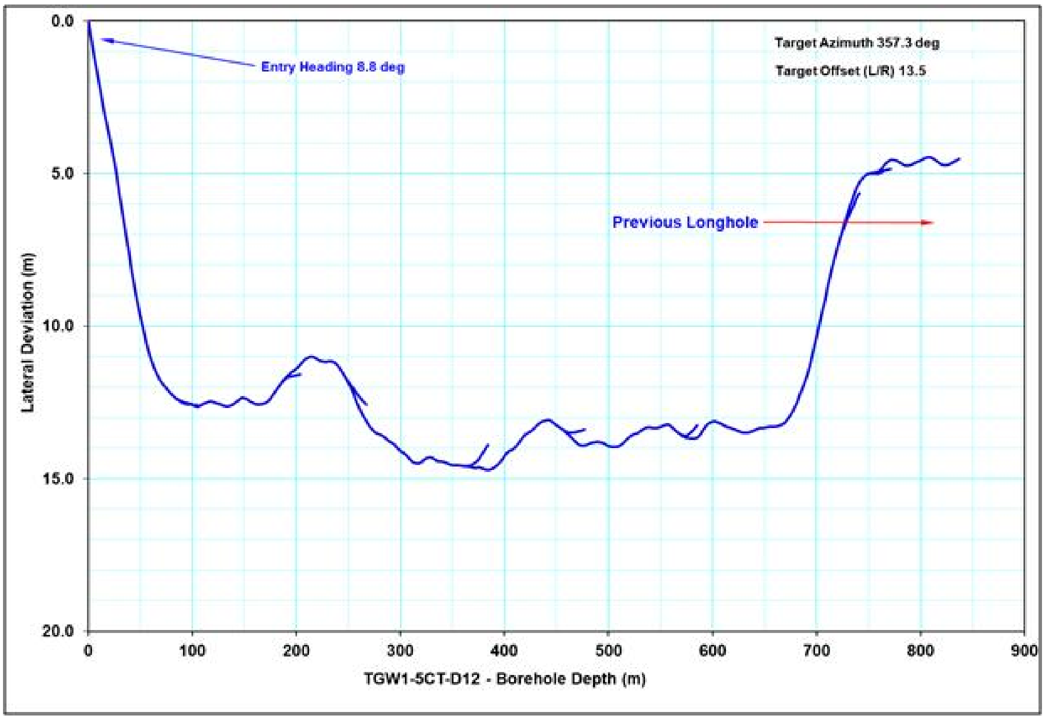

Figure 7: Lateral deviation

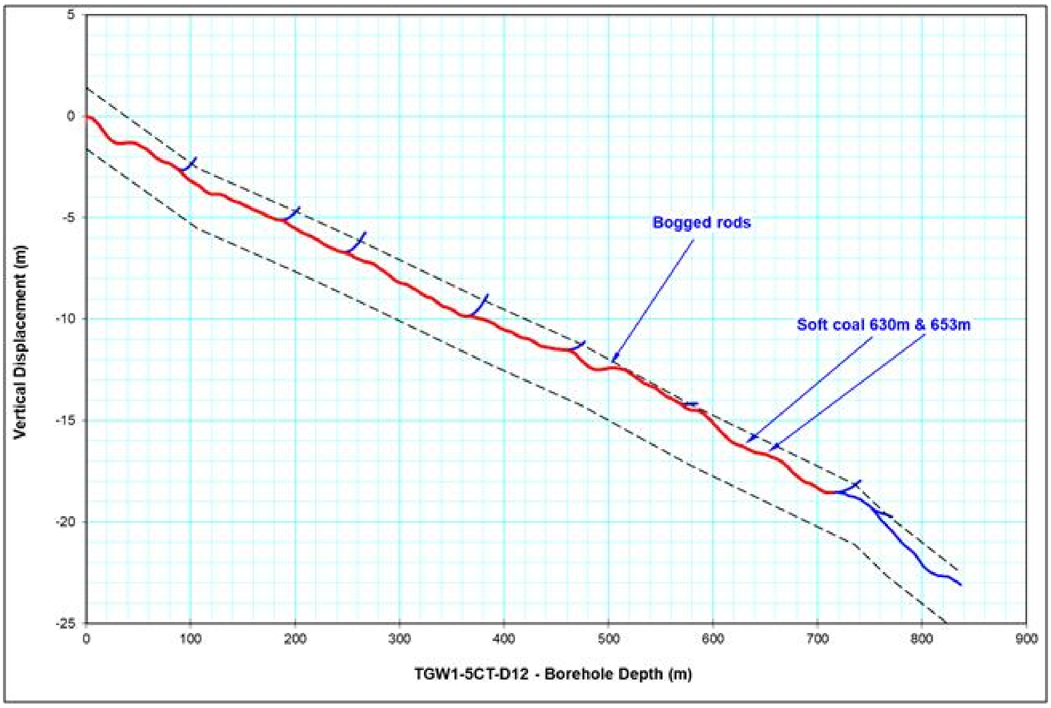

Figure 8: Profile of bogged rods

completely. The rods were pulled back to a depth of 717 m before the drill string become bogged (Figure 8). With a branch point at 720 m, it was thought that dumping of cuttings in the enlarged annulus of the branch point had likely bogged the rods at the bit. The crossing of the previous longhole at approximately 726 m was possible source of instability or water loss dumping cuttings in the borehole. Soft coal had been recorded at 630 m and 653 m during the directional drilling but was not thought to be responsible for the bogging.

The mine’s pressure water was connected to the drill string and all boreholes in the area were checked for water flow then shut off. With no identified connection and no subsequent water return, the decision was made to over-core the bogged drill string.

OVER-CORING DRILLING PRACTICE

Before drilling commenced, the drillers were instructed on the practices required for the recovery operation. The initial drilling practices included:

- Rotational speed of 120 to 150 rpm.
- 240 to 250 l/min water flow rate.
- Record usual drilling parameters of thrust and hold-back hydraulic pressures and water pressure and flow rate.
- Record main hydraulic pump pressure as an indication of the rotary drilling pressure.
- Measure and record the rotational speed.

With a 100mm standpipe installed for the initial drilling, the standpipe was removed by over-coring with HWT casing rods and a 3 m long 150 mm standpipe installed.

With the length of the bogged string of 717 m near the likely maximum over-core recovery depth, it was decided to use the maximum available shoe bit diameter of 145 mm for the initial reaming pass.

With the drillers recording check-shot surveys at 3m intervals, the changes in both azimuth and pitch can be accurately assessed. An analysis of these changes in azimuth (Figure 9) and changes in pitch (Figure 10) did not identify any significant changes in either which would have adversely affected the over-coring operation. The ranges of changes were within normal response curves for directional drilling.

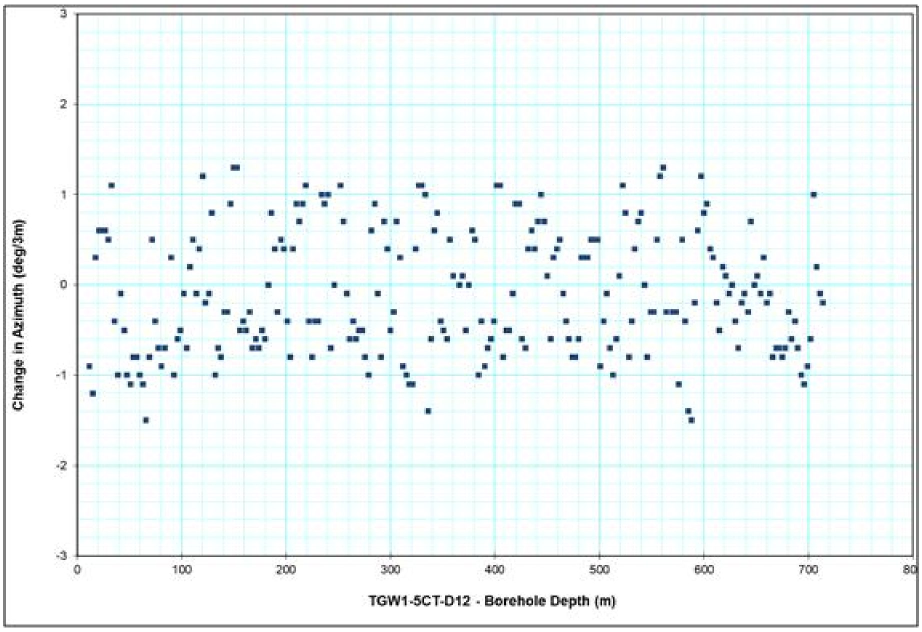

Figure 9: Changes in azimuth

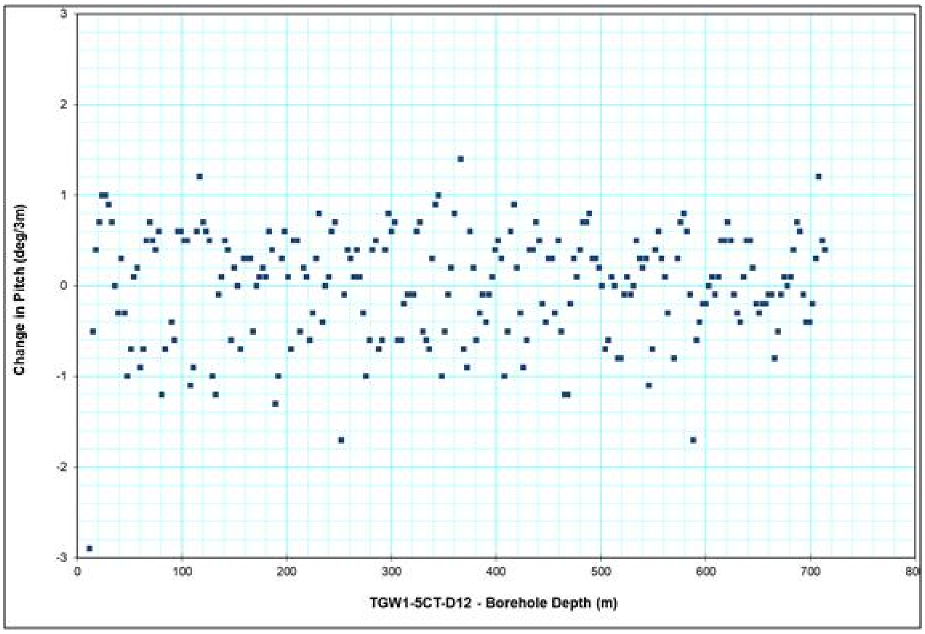

Figure 10: Changes in pitch

The on-site team was also directed to use an “anti-chatter” grease between the rods meant to reduce the metal to metal friction.

The borehole was reamed with progressively increasing torque resistance (Figure 9) until rotation and penetration could not be continued beyond a depth of 633 m. The hydraulic system (rotation) pressure was just below that listed as the maximum available but had plateaued out at 23.6 MPa. The borehole was cleaned out with numerous rotary flushing passes without improving the frictional characteristics of the borehole. The grease between the rods was deemed as adding friction to the system due the binding of the over-core rods when being removed from over the bogged CHD rods. The use of the grease was discontinued.

In an attempt to reduce in-hole friction, the shoe bit manufacturer (Hard Metal Industries) was asked to modify a standard 125 mm diameter bit to increase the reaming diameter to 145 mm. With this modified shoe bit, the borehole was reamed to a depth of 444 m before there was a noticeable reduction in the flow of flushing water returning from the borehole. It was thought that some water was passing through the bogged rods and disappearing into an adjacent borehole. A blanked CHD box to pin-sub was attached to the back of the bogged drill string which re-established full return water flow. The threaded blank was used so access was possible if the drill string was pumped down the rods on release.

Reaming continued to 600 m before further rotation was not possible significantly below the hydraulic pressures achieved with the initial 125 mm reaming. Up to that depth, the frictional load of inter-rod friction and reaming from 125 mm to 145 mm was equivalent to that of reaming from 96 mm to 125 mm (Figure 9).

Several problems had started to develop with the operation of the drill rig during both the reaming and cleaning out operations. The hydraulic systems on the drill rig where checked and reset to ensure the rig was operating at its optimum for the next stage of reaming.

The 125 mm shoe bit was flushed back into the original face at 633 m. From there, reaming continued with water flow reduced to 100 l/min and back-flushed each rod with a water flow of 200 l/min. After reaming to 687 m, the internal CHD rods were no longer visible inside the HQ over-core rods. CHD rods were fed down inside the HQ rods to contact and connect to the blank sub. The bogged rods had been pumped back to the 837 m depth of the directional drilling. The hydraulic pressures were only slightly lower or equal tothose recorded at the limit of the initial 125 mm reaming pass (Figure 9) but rotation was being comfortably maintained.

No instability, structure or borehole crossing was located in the vicinity of the bogging zone. Both sets of drill rods were successfully removed from the borehole.

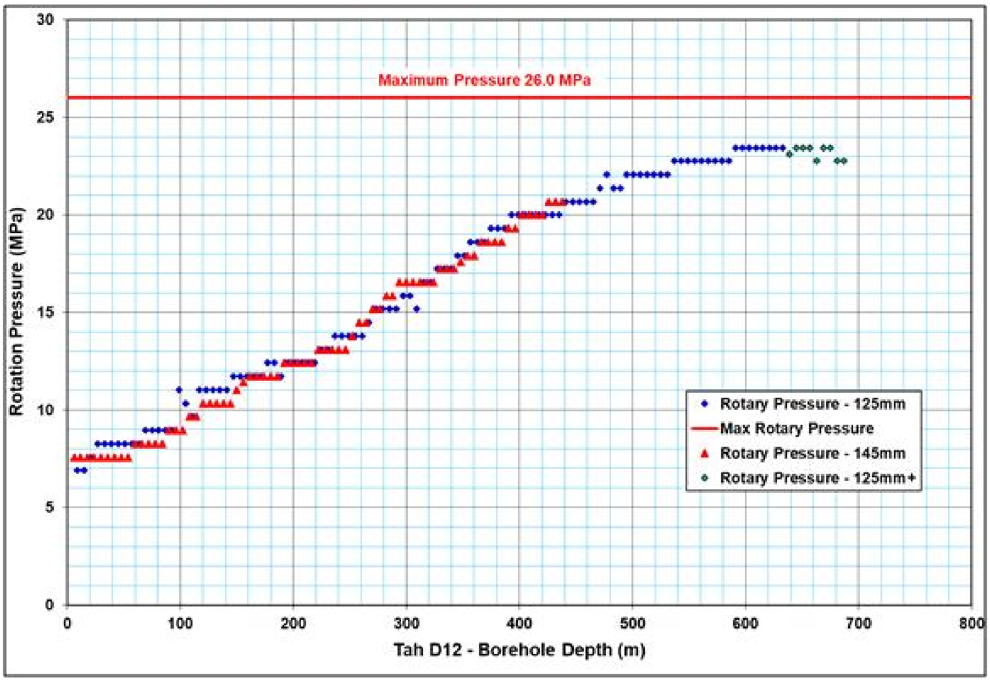

Figure 11: Rotational pressure of over-core drilling

CONCLUSIONS

Directional drilling relies on a combination of prior knowledge of the conditions expected in an area of proposed drilling and the experience and awareness of the driller to respond to a potential bogging incident. Quick response prevents numerous bogging of drill rods during the normal course of directional drilling projects. But some bogging events occur in spite of the precautions and experience. Good directional control while drilling the initial borehole provides characteristics which more easily facilitate the over-coring reaming. These include:

- Good record keeping of in-hole strata intersected and conditions.
- Regular surveying which includes surveys at each change of DHM orientation.
- Drilling with the minimum DHM deflection which provides adequate directional control to minimise deflections in the borehole

A successful over-core recovery then relies on a risk assessment to assess the conditions and determine the most likely course of action required to recover the bogged drill string. Experience from previous recovery operations plays a big part of this assessment.

Due to the expensive equipment at risk when directional drilling in variable conditions, it is advisable to have a dedicated kit of recovery equipment so the operations can commence without long delays and with confidence the equipment is fit for purpose and in good condition.

Then the drillers involved need to be supplied with support information defining the recovery project and any drilling parameters and flushing additives to use. Good record keeping from this point allows a progressive assessment of the progress of the reaming and the likelihood of the initial procedures being successful. Timely adjustments and changes can be made to improve the chances of success.

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