NSW GOVERNMENT | Trade & Investment Mine Safety

Investigation report

Investigation into a serious drill rig incident at Ashton Coal Mine on 12 August 2012

Report prepared by the NSW Mine Safety Investigation Unit

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Executive summary

Incident overview

About 2.00 pm on 12 August 2012, a 26-year-old drill rig operator was seriously injured at the Ashton coal mine in the NSW Hunter Valley.

Silver City Drilling (NSW) Pty Ltd employed the driller. The incident occurred within the surface boundary of Mining Lease 1533.

Silver City Drilling was conducting a drilling operation under contract from Ashton Coal Operations Pty Ltd for the purpose of installing a dewatering pump to dewater the underground longwall operation. The incident site was known as dewatering Borehole 4.

The drilling technique used at the time was air rotary hammer. Air rotary hammer drilling is primarily used in hard formations where penetration rates are superior to other rotary techniques such as rotary mud. The air rotary hammer technique uses a down hole hammer incorporated into the bottom hole assembly that achieves penetration through a rapid succession of impacts causing the rock formation to break. Compressed air and water mist, or compressed air and foam removes the rock chips (cuttings). This is commonly known as a drill fluid. This air was used to expel drill cuttings from the hole to a purpose built sump via an air discharge line known as a “blooie line”.

The air discharge line was a 220 mm diameter steel pipe that was about five metres long with a 90 degree elbow attached. The air discharge line traversed below the driller’s platform and was secured to the ground with two star pickets and wire.

The drilling operation was delayed on the day of the incident because there was significant water flowing into the borehole from an alluvial aquifer. This water was filling the sump at an elevated rate, which led to down time as the sump had to be pumped out using two water cartage trucks contracted for the task.

During the day, discussions took place about the excessive water in the borehole and changing the drilling technique to rotary mud. Rotary mud drilling uses a rotating grinding tool instead of a hammer bit. The drill fluid used to remove the cuttings from the hole is usually a weighted bentonite (water-based) mud as opposed to compressed air. Nevertheless, the air rotary hammer method was continued.

At the time of the incident, the driller was in the process of lowering the drill rods to the bottom of the hole when a large pressure event occurred. The surface casing was pushed out of the ground and made contact with the bottom of the drill rig. The air discharge line broke free of its securing system and travelled in an upwards arc and hit the hinged driller’s platform where the driller was working. The force of the impact lifted the hinged platform upward and the driller was forced up against the control panel until the air discharge line travelled past the drilling platform. The driller and the platform fell with the driller coming to rest with his neck across the driller’s platform guard rail. The air discharge line then fell down striking the driller on the back of the neck.

The driller sustained multiple injuries including complete disruption of the spinal column at C4-C6 vertebra, a severed carotid artery and a severe laceration to the back of his head. He was flown to Royal North Shore Hospital where he underwent emergency surgery. The driller sustained permanent incapacitating injuries.

Contributing factors

The Mine Safety Investigation Unit conducted an investigation into the cause and circumstances of this incident. The following factors contributed to the incident:

- The conductor casing was not installed to a sufficient depth to isolate the Bowman Creek/Hunter River alluvials.
- Excessive water entered the borehole and created hazardous drilling conditions.
- The design and modification of the air discharge line to include a 90 degree elbow created additional risk to the system of work.
- The design of the air discharge line anchoring system was ineffective.
- The design of the drill pad and orientation of the drill rig required the air discharge line to travel under the drilling platform.
- An alternative method of drilling (i.e. mud drilling) was available and was more suitable for the drilling conditions at Borehole 4, but was not used.
- Risk management processes were not undertaken in relation to site specific conditions, specific drilling techniques and the prescribed system of work.
- Identification and management of the risks associated with the change in the system of work did not comply with the documented change management procedure.
- Supervisors did not ensure that workers conformed to the agreed system of work stipulated by the Ashton Coal Operations contract proforma.

Remedial safety measures

Following the incident Ashton Coal Operations undertook a number of reviews, and introduced system changes for drilling, contract management, emergency response, and safety management.

Various controls were put in place at Ashton Coal Operations drill sites as a result of the incident and drilling procedure review. For example, the driller must consider the following in their risk assessment: location of sump / air discharge line & anchoring; set up of drill pad; design of air discharge line (straight); restraining system against air discharge line movement; barricaded access for personnel to the air discharge line; position of operators; assessment of potential stored pressures in the drill hole including if the hole becomes blocked; engineering design of casing system in ground and above ground; verification process to confirm integrity of casing grouting (pull tests); and development of trouble-shooting Trigger Action Response Plans (TARP).

Remedial actions are outlined in Chapter 5.

Recommended practice for industry

This incident highlights the importance of an effective risk management program in relation to drilling operations. The following are recommended practices to industry to improve industry safety and reduce the likelihood of similar incidents reoccurring.

1. Unconsolidated ground should be identified and effectively controlled via the use of adequate casing installed to the required depth.
2. Site specific drilling risks must be identified and controlled using the hierarchy of controls.
3. The design and modification of drilling equipment should be risk assessed.
4. Changes to drilling systems of work should be identified and adequately risk assessed.
5. Air discharge lines must be secured and anchored effectively.
6. Drill pad design should minimise the potential for hazards and take into account the location of sumps, location of operators and location of discharge lines.

7. The appropriate method of drilling should be identified and be suitable for site specific conditions.
8. Clear reporting lines and supervisory arrangements should be in place that clearly defines roles and responsibilities for drilling operations.

Contents

Purpose of this report

This report concerns an incident that resulted in serious injuries to a drill rig operator at 2.00 pm on Sunday, 12 August 2012 at the Ashton coal mine in the NSW Hunter Valley.

Jurisdiction and powers

Investigators from the Investigation Unit have undertaken an investigation into this incident using powers under the *Work Health and Safety Act 2011* (WHSA).

The department administers the *Coal Mine Health and Safety Act 2002* (CMHSA) and the *Mining Act 1992 (*MA*)*.

Under the WHSA a 'coal workplace' is defined as, "a place of work to which the CMHSA applies." The places of work to which the CMHSA applies are listed in section 8 of the CMHSA, and include underground coal mines.

The department's investigators are appointed as investigators under section 145 of the CMHSA. Under section 156A of the WHSA, investigators are taken to have been appointed as inspectors for the purposes of the WHSA and its accompanying regulations. As a result, investigators are authorised to exercise powers under the WHSA with respect to a coal workplace, and other premises, for the purpose of investigating any matter under the WHSA in relation to a coal workplace incident.

The department's records identify the incident site as surface operations of the Ashton coal mine, which is within the Ashton Colliery Holding, mining lease 1533 (ML1533) of the MA.

ML 1533 was held by White Mining (NSW) Pty Ltd and ICRA Ashton Pty Ltd as part of an unincorporated joint venture (Ashton Coal Joint Venture). The lease was renewed on 26 February 2003 and has a period of renewal until 25 February 2024. ML 1533 has a five metre surface exception and a depth restriction for the first 20 metres.

Dewatering Borehole 4 is part of an underground coal operation within ML1533 and is therefore a coal workplace to which the WHSA applies and a place where the department's investigators are authorised to exercise powers under the WHSA.

The investigation unit

The department's Investigation Unit was established to investigate serious mine incidents and prepare reports to the Secretary. It is autonomous and independent of the department's Mine Safety Inspectorate.

The incident that is referred to in this report was assessed in accordance with the department's incident decision procedure and was considered to be an appropriate incident to be referred to the Investigation Unit for a major investigation.

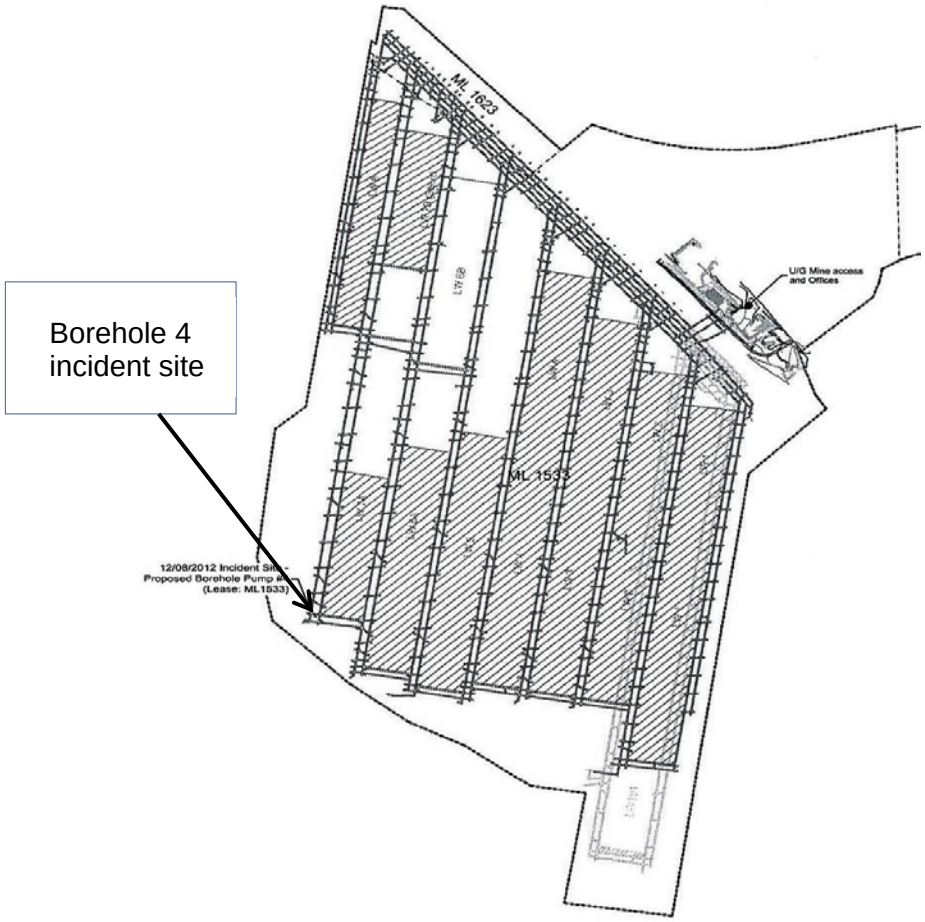
Investigators from the Investigation Unit first attended the scene on Monday, 13 August 2012.

Chapter 1. Ashton coal mine and Silver City Drilling (NSW) Pty Limited

The mine

Ashton coal mine is 14km north-west of Singleton in the NSW Hunter Valley. The coal mine includes an open cut coal mine, an underground coal mine, a coal preparation plant and a rail siding.

Figure 1. Plan of Ashton coal mine Indicating location of Borehole 4.



Ashton coal mine produces and exports approximately 3.0 million tonnes per annum of predominately semi-soft coking coal; with some thermal coal capacity. Coal is shipped predominately to Asian steelmakers through the rail link and port of Newcastle.

The mine operator - Ashton Coal Operations

Section 3 of the CMHSA defines an operator as the employer with the day-to-day control of the coal operation.

At the time of the incident, the colliery holders for the coal operation (Ashton coal mine) were:

- White Mining (NSW) Pty Ltd
- ICRA Ashton Pty Ltd

The colliery holders nominated Ashton Coal Operations Pty Ltd as the operator of Ashton coal mine.

The contractor - Silver City Drilling

Ashton Coal Operations contracted Silver City Drilling (NSW) Pty Ltd to drill two large diameter surface-to-seam boreholes for the purpose of dewatering their longwall operations.

At the time of the incident, Silver City Drilling employed about 32 drillers and supervisory staff who operated drill rigs at various places in Australia.

Silver City Drilling reported that it had extensive experience in directional controlled drilling and wedging. It had capability for diamond drill core (R/C, air core, RAB, rotary and 'Navi' drilling) and to produce other holes as required.

Included in the Silver City Drilling's Safety Management Plan was the Safety Management Plan manual. The manual outlines the Silver City Drilling commitment to health and safety and outlines the Silver City Drilling workplace health and safety obligations and responsibilities.

The Safety Management Plan references Australian Standard AS4801 (Occupational Health and Safety Systems).

Chapter 2. Incident chronology and overview

The drilling program (scope of work)

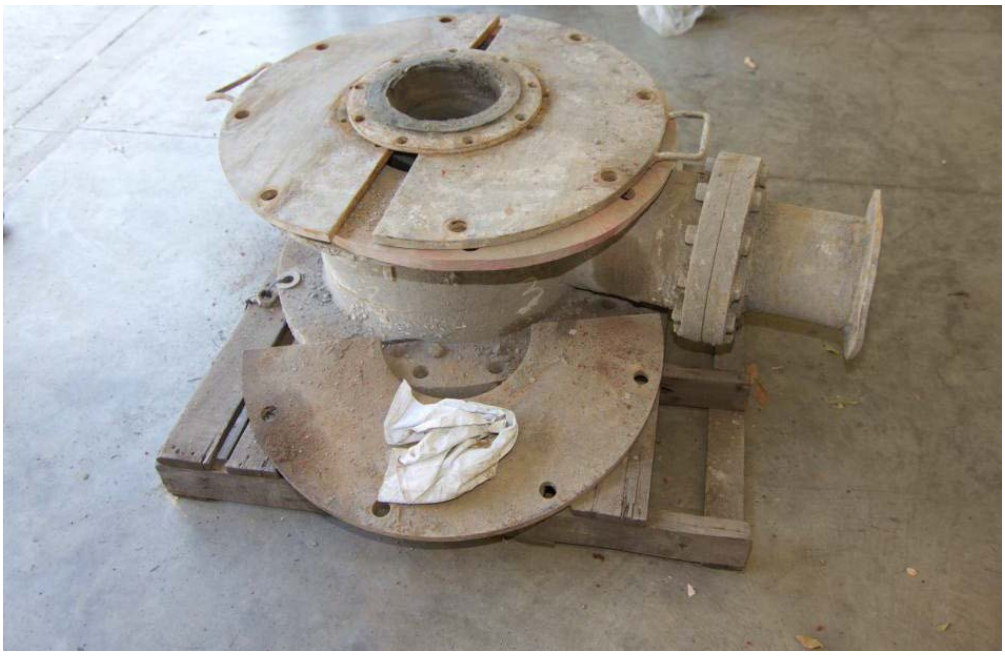
Ashton Coal Operations' mining operations plan for the Ashton coal mine (2007-2012) described the planned dewatering system as including 'future dewatering bores proposed to be installed at the in-bye end of alternate longwall blocks subject to mine dewatering requirements. These will connect into the existing surface dewatering pipeline'.

Ashton Coal Operations contracted Silver City Drilling in early June 2012 to drill two large diameter surface to seam blind boreholes (Boreholes 3 and 4) for the purpose of dewatering their longwall operations. The target depth and diameter of Borehole 4 was to be about 193 metres with a 406 millimetre diameter casing to be installed. Silver City Drilling used air rotary hammer drilling to cut both boreholes. This is a common technique for drilling in hard, competent ground.

The fluid used to expel the cuttings was either compressed air or compressed air and foam or compressed air and water mist (depending on depth and geology). Three compressors were used in the drilling process. Each compressor had the capacity to deliver 2482-2586 KPa and a volume of 543 litres per second when operating at low setting.

Silver City Drilling used a single surface casing (diameter 600mm) at both borehole locations. Above the casing sat a diverter box with a rubber seal (Washington seal), pictured below in figure 2, which allowed the drill pipe to travel through and maintain rotation. The diverter box was designed to divert the cuttings into the air discharge line which would expel the cuttings into a purpose built sump. When drilling was completed a secondary casing (406mm) was to be installed for the purposes of dewatering the mine.

Figure 2. Diverter box that was installed at Borehole 4



The equipment

Silver City Drilling used a Schramm T130XD drill rig for drilling operations at the Ashton Coal Operations. The specifications of the rig are as follows:[1]

- 130,000 pounds pull back pressure
- Capable of 22” hammer hole to 500 metres
- Capable of 8” hammer hole to 1000+ metres
- Head travel 15 metres

An assessment and functional test was carried out on the rig post incident. There were no adverse findings related to the function of the rig.

Figure 3. The Schramm T130XD drill rig[2]

Drilling with the air rotary hammer technique requires air pressure. Air pressure was supplied to the drill rig with three Sullair 900XHH/1150XH air compressors.

These compressors can run in two modes, high and low pressure. The parallel configuration of the three compressors at Borehole 4 meant that the pressure and volume obtained would have been about 2400kPa and 1628l/s when on low setting and 3100kPa and 1274l/s when on high setting.

The original equipment manufacturer (OEM) reported that there were no functional issues with the compressors when they were tested after the incident.

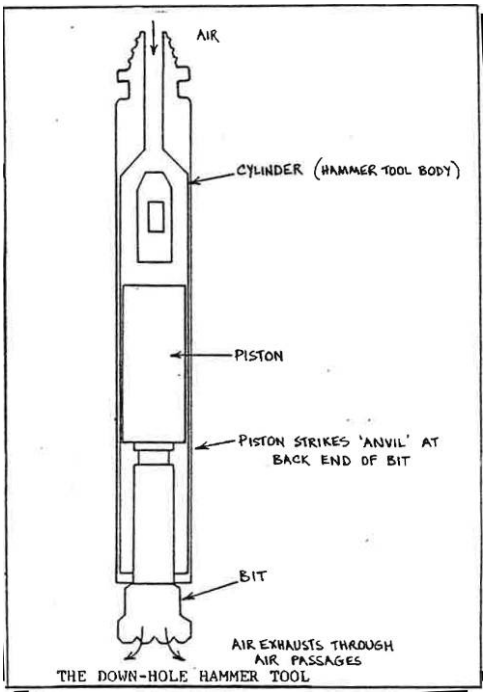
1 Equipment http://www.silvercitydrilling.com.au.
2 The Schramm TX130D drill rig <http://www.silvercitydrilling.com.au> (16/07/2013).

The drilling technique

The drilling technique used at the time of the incident was air rotary hammer drilling. The down hole hammer achieves penetration through a rapid succession of impacts causing the rock formation to break. The cuttings are removed with compressed air (drill fluid).

The capacity of the drill fluid to effectively remove the cuttings is called the bailing capacity. Bailing capacity is affected by the flow rate (velocity and volume), rheology of the drill fluid, geology, water make and depth of the hole.[3] Figure 4 below is a diagram of the bottom hole assembly (BHA) for a typical hammer drilling operation.

Figure 4. Bottom hole assembly for rotary percussion (Rotary Hammer)[4]



Energy is required to drive the hammer assembly. This energy is obtained in the form of compressed air. The performance of a down hole hammer depends on the energy delivered to it. According to the *Australian Drillers Guide*: 'Provide twice the pressure, deliver twice the energy, get twice the penetration rate'.[5]

Using high pressure air as a drilling fluid has some safety considerations. Compressed air is a hazard. The higher the pressure, the greater the hazard.[6]

Air pressure used by Silver City Drilling in their drilling operations was greater than 2400KPa. To put this into perspective, this amount of pressure equates to a potential 69 tonnes of force, applied to a 600 mm diameter blockage.[7]

Sonic Energy Services Ltd is a US company specialising in coal seam gas drilling, Sonic Energy Services, said that it used rotary hammer drilling for its higher penetration rates, less drilling time

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3 Australian Drillers Guide (1983) [8.8] 891.
4 Australian Drillers Guide (1983) [8.8].
5 Australian Drillers Guide (1983).
6 Australian Drillers Guide (1983).
7 This calculation utilises the following formulae, area equal to Πr^2 and Force is equal to mass times acceleration. The calculation does not attempt to determine the actual area of the annulus or the actual force at the time of the incident. It is provided to give perspective of the forces that can be created with 350psi.

and lower costs; minimal damage to producing formations; ability to analyse formation productivity while drilling; minimise loss of circulation and increased meterage per bit.[8]

Drilling with rotary hammer has two lithological limitations. They are well bore stability and water production. The following is quoted from Sonic Energy's information release, Underbalanced Drilling, as it has direct relevance to the conditions experienced at the incident site.

> The hydrostatic pressure of a mud is transferred across a filter cake to aid borehole stability by replacing some of the stresses relieved by drilling. The gradients noted above indicate how trivial a factor this would be in an air filled hole. Some formations will slough when drilled with air because they are too soft and not competent enough. Other formations may slough because they are stressed. In formations prone to sloughing due to stress, a four arm calliper will reveal an elliptical wellbore termed "wellbore breakout". One method of reducing sloughing due to wellbore breakout is to increase the mud weight. In an air drilled hole, increasing the mud weight is not a possibility. Of all the potential problems, wellbore breakout is considered to be the most problematic for the air drilled wells.
>
> Air has a limited capacity to carry out produced water, beyond which it must be supplemented by mist or foam, and ultimately the hole must be mudded up**.** Air drilling is therefore limited to lithologies with either little water or low permeability. Even a little water can cause hole stability problems with some shales, while some formations are relatively unaffected by water. If water sensitive shales are encountered then shale inhibitors can be added to the water to minimize the effect of water.[9]

It is evident that air drilling in loose unconsolidated ground, where there is water inflow from aquifers is problematic. Drilling in these conditions should ultimately be performed using a technique that ensures greater well bore stability and well control, such as rotary mud drilling.

The Ashton Coal Operations contractor management plan

As part of its obligations to manage risk arising from the undertakings of the contractor on its operation, Ashton Coal Operations created a contractor management plan. Its purpose was to ensure the safety of coal mine workers employed by Ashton Coal Operations (and those working for and on behalf of contractors engaged by Ashton Coal Operations) and the protection of the environment.

The plan, which applied to contract holders, contract support personnel and/or contractors, detailed the process for managing contracts and contractors on site during pre-tender, mobilisation, work execution and close-out of contract work.

Under the plan, an Ashton Coal Operations representative was assigned the role of contract holder. The plan identified that a contract holder was a 'person who manages all aspects of the contract on behalf of Ashton Coal Operations.'

The plan required a contract holder to hold certain qualifications:

- Have a working knowledge and understanding of the Ashton Coal Operations safety, health, environment, community management system standard.
- Have an understanding of, or experience in, the overall job/tasks that is the subject of the contract.
- Possess risk management qualifications and/or experience commensurate with the level of risk associated with the contract.

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[8] Sonic Energy Services Limited Underbalanced Air Drilling, Drilling Optimisation and Production Enhancement for CBM Projects [1] 4-6.

[9] Sonic Energy Services Limited Underbalanced Air Drilling, Drilling Optimisation and Production Enhancement for CBM Projects[1.2] 7.

Contract holder responsibilities

The responsibilities of the contract holder were defined in the Ashton Coal Operations contractor management plan. They included being the person responsible for effective management of the contract.

The contract holder was required to liaise with Safety Health Environment Community personnel on management of the contract and associated issues, and to establish a program of monitoring contractor performance to ensure adherence to the Safety Health Environment Community risk management strategy.

Ashton Coal Operations appointed a contract holder for the drilling of dewatering Boreholes 3 and 4. The contract holder was responsible for monitoring Silver City Drilling in relation to compliance with the agreed systems of work.

The risk assessment process

The *Coal Mine Health and Safety Act 2002* sets out duties of a mine operator regarding contractors. These include the provision of, and compliance with, a safe work method statement.

It is a duty of the mine operator to ensure that the activities of a contractor are monitored, to determine compliance with the safe work method statement and relevant legislation.

Investigators have identified that as part of the Ashton Coal Operations contractor management plan, a consultative approach to creating a health and safety management system for the proposed contract work was undertaken with Ashton Coal Operations and Silver City Drilling employees. A specific contractor management proforma was negotiated between these two parties. This proforma outlined the Safe Work Method Statements that were to be adhered to while work was undertaken at the Ashton coal mine.

Risk assessments created by Silver City Drilling that were included in the Ashton Coal Operations contract proforma were generic in nature and not specific to the work that was to be carried out at Ashton coal mine. For example, risk assessments created by Silver City Drilling did not appear to identify specific hazards relating to:

- the proposed drilling technique
- the proposed geology
- the likelihood of excessive water
- modification to the design of the air discharge line.

Under the Ashton Coal Operations contractor management plan, one part of the role of the contract holder is to ensure that the contractor works in conformance with the agreed system of work set out in the contract proforma. This was expected to be achieved through audits, including an examination of documents and direct observation of activities.

Development of drilling pads for Boreholes 3 and 4

The drill rig and load safe rod handler required a drilling pad to be constructed before the rig and ancillary equipment could be set up. Consultation between the contract holder and the Silver City Drilling operations manager was undertaken at both borehole locations before work began.

Ashton Coal Operations were unsure of the area the Silver City Drilling rig would require. The Silver City Drilling operations manager informed Ashton Coal Operations about the size and nature of the drill pad design for both borehole locations.

Drilling at Borehole 3

Silver City Drilling representatives were first contacted by Ashton Coal Operations in June 2012. The nature of the work described to the company was to drill a dewatering borehole at the Borehole 3 location. This hole was to be a blind borehole, targeting the Upper Liddell seam approximately 180 metres below the ground, which underground mining operations would intersect at a later date.

The planning phase for Borehole 3 began before Silver City Drilling was contracted to undertake drilling the borehole. Initially, Ashton Coal Operations approached a local drilling company to undertake the drilling operation however, they were not confident that their equipment was powerful enough to undertake such a large diameter blind borehole to the depths required.

At that time, a formal risk assessment involving contract geologists, the local drilling company staff, and Ashton Coal Operations employees had been undertaken. This risk assessment did not take into account the actual drilling operations. Instead it focused on the ancillary tasks that would be performed on the site, such as mobilisation, running casing and vehicle interactions.

After Silver City Drilling was awarded the contract to undertake the drilling operations at Borehole 3 the contractor proforma review was undertaken. Part of the early interactions between Silver City Drilling and Ashton Coal Operations involved the review of the local drilling company's risk assessment. There is no evidence that Silver City Drilling communicated the contents of the risk assessment to the Silver City Drilling employees that were to undertake the work.

Borehole 3 was located on the side of a ridge that runs across the south eastern quadrant of ML1533. Ashton Coal Operations designated this to be an area of voluntary conservation.

Due to the voluntary conservation constraints placed on the operation, the drill pad design was critical. Silver City Drilling specified the drill pad requirements to the contract holder. The drill pad was a terraced design, whereby the drill rig sat on an upper level of the terrace, and the sump sat on a lower terrace approximately two metres below. A photo of the drill is provided in Figure 5.

Figure 5. Borehole 3 operations, showing terraced drill pad design.

Drilling at Borehole 3 required the installation of conductor casing into bedrock. This is standard procedure for this type of drilling.

Drilling began on 27 June 2012, about 4.30pm. The conductor casing was set to a depth of five metres as this was as far as the drill rig could penetrate with the large diameter spade bit required for opening the hole to the required diameter. A bore log of a borehole near to Borehole 3 suggests that bedrock (consolidated ground) started at a depth greater than 7.5 m.

The lack of capability of the spade bit to penetrate to a greater depth appears to have been associated with the condition of the spade bit. It was reported that the spade bit was well worn with many of the tungsten carbide cutting edges worn out.

On 4 July 2012, an environmental incident was reported to the contract holder involving drill fluid and cuttings being ejected over the sump wall.

Following the environmental incident, drilling operations continued until Silver City Drilling broke a 22 inch reaming head in the process of opening up the pilot hole at a depth of 48 metres. Efforts to retrieve the tool bit were unsuccessful and a decision to abandon the hole was taken by Silver City Drilling and Ashton Coal Operations.

Silver City Drilling and Ashton Coal Operations proposed that the rig be moved five metres to the west (still on the same drill pad), where drilling operations restarted. Silver City Drilling experienced the same issues with the conductor casing installation and again installed the conductor to a depth of five metres.

Drilling operations at the new Borehole 3 site proceeded, with only a few minor issues, until, a second environmental incident was reported to the contract holder, who directed Silver City Drilling to ensure that drill cuttings from the air discharge line be diverted to the sump, and not the surrounding environment. Figure 6 shows makeshift efforts to direct discharge from the drilling operation into the sump on the lower terrace. The photo shows a shovel taped to the end of the air discharge line with tape to divert the cuttings.

Figure 6. The second environmental incident location borehole 3.

Following these incidents, Silver City Drilling added a 90 degree elbow to the end of the air discharge line.

The change in air discharge line design at Borehole 3 to incorporate a 90 degree elbow represented a significant change to the design of the rotary air hammer drilling system, which meant a significant change in the directional forces created by the air discharge line. This change led to jet forces from the air/water discharge shifting from horizontal to vertical. There was no documented risk assessment process undertaken by Silver City Drilling in relation to the change to the air discharge line to incorporate a 90 degree elbow.

Drilling at Borehole 4

Drilling at Borehole 3 was completed on 7 August 2012 at which time Silver City Drilling moved the drill rig to the Borehole 4 location. As with the earlier drill pad, this drill pad was constructed by Ashton Coal Operations in consultation with Silver City Drilling.

As part of the risk management consultation between Silver City Drilling and Ashton Coal Operations a documented risk assessment process was undertaken for the Borehole 4 site. This risk assessment process was similar to the one completed between the local drilling company and Ashton Coal Operations on Borehole 3 and did not cover site-specific drilling operations.

The location of the Borehole 4 site was somewhat different to the Borehole 3 site. Instead of being on a ridge, the site was in the south west corner of ML1533 in an area colloquially known as the Bowmans Creek/Hunter River alluvial plains.

The intended procedure for this borehole was to intersect mining operations in the Pikes Gully Seam (193 metres deep) for the purpose of dewatering the longwall operation.

Information provided to Silver City Drilling by Ashton Coal Operations suggested that the alluvial layer (unconsolidated layer) at the Borehole 4 site was approximately 20 metres deep. As a result of this, two 12 metre lengths (total 24 metres) of conductor casing were ordered by Ashton Coal Operations for the drilling operations at Borehole 4. It was intended that the alluvial section would be cased off to this depth.

Drilling started on Borehole 4 on 9 August 2012. Difficulties were experienced by another Silver City Drilling driller who, while drilling the pilot hole for the conductor casing, reported that the hole was ‘collaring badly’ and the top 20 metres consisted of gravel.

The work roster for Silver City Drilling typically involved two drilling crews working alternate fortnights.

On 10 August 2012 the drilling supervisor and the driller involved in the incident replaced the back shift crew. The driller did not review the previous crew’s drilling activities log sheet at the start of his first shift.[10]

The driller started reaming out the pilot hole with the large diameter spade bit used on Borehole 3. At about 12 metres he reported that he was unable to achieve further penetration and a drilling supervisor decided to stop drilling and run casing to this depth.

The investigation confirmed that the exact depth of conductor casing was 11.4 metres, while the unconsolidated layer was between 20 and 30 metres. It is important to note that while the alluvial layer was approximately 12-14 metres deep the weathered unconsolidated layer went far deeper.

After the installation of the casing and grouting had been completed the drilling of the pilot hole began on 11 August 2012.

As this site was considered an archaeologically significant site by Ashton Coal Operations, Silver City Drilling was told that there could be no environmental incidents. As a result, Silver City Drilling chose to leave the 90 degree elbow on the end of the air discharge line.

[10] A PLOD sheet is a record of the jobs completed on a given day. It also serves as a drilling log for the operation.

Drilling proceeded on 12 August 2012 until the pilot hole reached approximately 85 metres. At this stage, water production was becoming a significant issue for the drilling operations. Water production became so significant that the hole was producing approximately 15,000 to 20,000 litres of water every hour.

This water production resulted in elevated sump levels. Penetration had significantly slowed as the drill rig had to wait for the sump to be pumped out regularly.

On the same day, the driller discussed the site conditions and excessive water with the drilling supervisor and suggested that the conditions required a change in drilling technique from air rotary hammer to rotary mud drilling. The driller reported that at one stage he turned the drill rig off and proceeded to have a 45-minute discussion with his supervisor about the merits of continuing with the existing air drilling technique.

The driller reported that he shut the rig down because he had never seen so much water in a hole before and was concerned about the drill becoming stuck. He considered the water make was unusual, and that it was something he had never seen before. Nevertheless, the air rotary hammer drilling technique was continued. A review of the technique was planned to be undertaken that evening by Silver City Drilling.

The incident on 12 August 2012

About 2.00 pm that day, the Silver City Drilling supervisor and driller prepared to recommence air rotary hammer drilling at Borehole 4. While refuelling an air compressor, the supervisor confirmed the compressors and the drill rig were running. The driller was positioned on the drilling platform to operate the drill rig from its control panel. The supervisor confirmed that the driller had rotation on the drill string via a hand signal and the driller activated the air to the drill string and lowered the drill string to the bottom of the hole.

At that time, the supervisor reported that he heard an explosion and he saw the well unload. He saw the air discharge line shoot up in the air and hit the hinged drilling platform that the driller was standing on. The force of the impact lifted the hinged platform in an upward direction and the driller was forced upwards against the control panel until the air discharge line travelled past the driller's platform. The driller and the platform fell back down with the driller coming to rest with his neck across the drilling platform hand rail. The air discharge line then fell, striking him on the back of the neck.

The supervisor ran to the drill rig control panel and turned the rig off. He then attended to the injured driller, contacted Silver City Drilling and requested emergency services. Silver City Drilling personnel contacted Ashton Coal Operations which initiated the mine's emergency response procedures.

Emergency response personnel attended the scene. Due to the driller's injuries and the equipment that he was trapped under, NSW Ambulance rescue had to cut him free from the equipment using the Jaws of Life. The time from when the incident occurred until the time the driller was airlifted from the scene was about two hours.

The driller sustained multiple injuries including complete disruption of the spinal column at C4-C6 vertebra, a severed carotid artery and a severe laceration to the back of the head. He was flown to Royal North Shore Hospital where he underwent emergency surgery. The driller sustained permanent incapacitating injuries.

Figures 7 and 8 depict the Silver City Drilling drill rig at Borehole 4, post incident. The air discharge line was secured in an elevated position by emergency response personnel.

Figure 7. Silver City Drilling drill rig at Borehole 4 post incident.

Figure 8. Drilling platform and elevated air discharge line.

Figures 9 and 10 demonstrate the direction of travel the driller's platform was able to take and the likely trajectory that the air discharge line could have taken.

Figure 9. The driller's platform in a simulation designed to show the trajectory that was possible during the incident.

Figure 10. The likely final resting point of the driller's platform. The air discharge line is represented by a white polyethylene pipe.

The injured driller

The driller had been working with Silver City Drilling for the past three years. Before the driller worked for Silver City Drilling he worked as a driller and offsider for other drilling companies in Queensland. He held a number of formal qualifications, including a Certificate II in drilling and numerous other mining and drilling-related competencies.

Chapter 3. Contributing factors

Investigators have determined that the following factors contributed to the incident:

- The conductor casing was not installed to a sufficient depth to isolate the Bowman Creek/Hunter River alluvials.
- Excessive water entered the borehole and created hazardous drilling conditions.
- The design and modification of the air discharge line to include a 90 degree elbow created additional risk to the system of work.
- The design of the air discharge line anchoring system was ineffective.
- The design of the drill pad and orientation of the drill rig required the air discharge line to traverse under the driller's platform.
- An alternative method of drilling (i.e. mud drilling) was available and was more suitable for the drilling conditions at Borehole 4, but not used.
- Risk management processes were not undertaken in relation to site specific conditions, specific drilling techniques and the prescribed system of work.
- Identification and management of the risks associated with the change in the system of work did not comply with the documented change management procedure.
- Supervisors did not ensure that workers conformed to the agreed system of work stipulated by the Ashton Coal Operations contract proforma.

These factors are discussed in more detail below.

The depth of conductor casing

Drilling on the Ashton alluvial plains was difficult and required a degree of experience and expertise. Drilling in alluvial ground necessitates casing off the alluvial layer to prevent well bore instability and inflow of excessive water. Best practice requires a geologist to help identify the depth of alluvial cover. In this case, a bore log from a neighbouring hole identified that the alluvial layer was between 20 and 30 metres deep. Silver City Drilling's drilling notes identified gravel to a depth of 19 metres and the hole was collaring badly.

It is evident that the alluvial layer was not cased off at the Borehole 4 site. The contract holder ordered 24 metres of conductor casing but only 14 metres was used. The shorter length was based on a belief that the drilling had struck a sandstone band but this was not the case.

The casing is required to be bonded to consolidated ground, but grouting will generally not be effective in alluvial layers. It is generally considered necessary to bond the casing to solid strata, such as bedrock. Inadequate installation of the conductor casing in an alluvial area enabled water to enter the borehole from an alluvial aquifer. Just before the incident, Silver City Drilling estimated that the borehole was producing 15,000 to 20,000 litres of water every hour.

Figure 11 identifies the conductor casing and diverter box at the Borehole 4 incident site.

Figure 11. The conductor casing being supported by a steel bracket and the drill string.

The design and installation of a 90 degree elbow on the air discharge line

The addition of a 90 degree elbow to the end of the air discharge line is a key contributing factor in the incident that occurred at the Borehole 4 site. The air discharge line with the 90 degree elbow can be seen in figure 12.

Figure 12. 90 degree elbow on the end of the air discharge line.

This change to the air discharge line resulted in a shift of forces from horizontal to vertical.

The 90 degree elbow was installed by Silver City Drilling in response to concerns about the environmental problem that occurred on Borehole 3. A 90 degree elbow was available on site as a result of a previous job where it had been attached at the collar end of the blow out preventer (BOP). A BOP was not required on the Ashton Coal Operations job but remained on site until it could be transported back to the Silver City Drilling depot.

The introduction of the 90 degree elbow was an adaptation to the existing air discharge line. A task analysis was completed for the actual work of fitting the elbow, but there was no risk assessment undertaken by Silver City Drilling in relation to the change in the drilling system or the change to directional forces.

Air discharge line anchoring system

Figure 13 below depicts the air discharge line anchoring system that was in place at the time of the incident. It can be seen in the photograph that two star pickets and a length of fencing wire was used. The air discharge line anchoring system was implemented without any written risk assessment.

This anchoring system was ineffective and failed to prevent the air discharge line from lifting when the direction of force from the end of the air discharge line was changed from horizontal to vertical.

Figure 13. Borehole 4 scene depicting star pickets and fencing wire used as an air discharge line anchor.

The photograph below shows the air discharge line anchoring system that Ashton Coal Operations now requires prior to air drilling.

Figure 14. Air discharge line anchor required post incident.

Alternative drilling techniques

The technique of rotary mud drilling was identified as an alternative drilling technique available to the drilling operation. Rotary mud drilling does not use compressed air to remove cuttings from the hole.

The use of bentonite muds remove cuttings from the hole and creates a stable layer on the borehole wall, preventing well bore instability.

The likelihood of drilling Borehole 4 with the rotary mud technique was identified in the planning stages. However, air rotary hammer drilling was used instead.

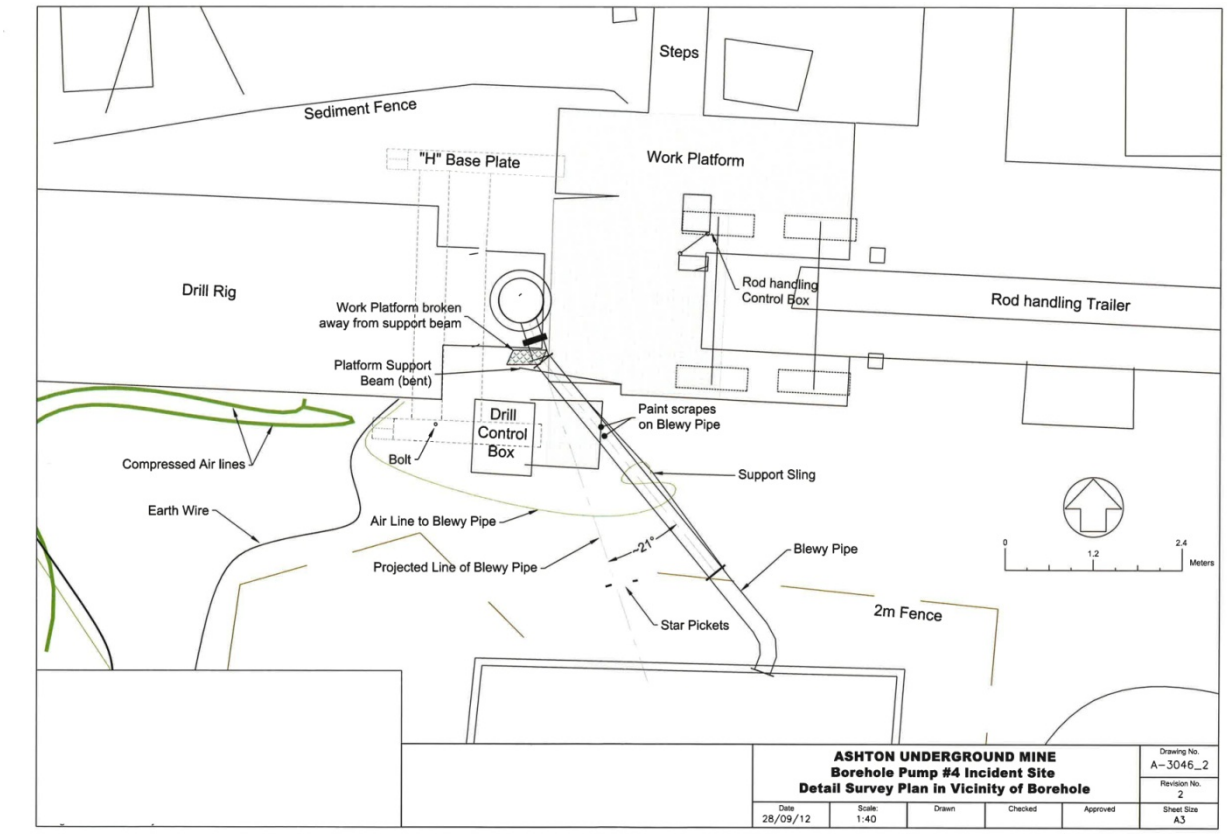
It would have been possible to convert to this form of drilling when the issue of excessive water was first raised. Silver City Drilling had the required equipment to undertake rotary mud drilling on site. The following picture identifies a Triplex mud pump that was on site at the time of the incident.

Figure 15. A Silver City Drilling Triplex mud pump on site at Ashton Coal Operations premises.

The design of the Borehole 4 drill pad

The following picture shows the Borehole 4 site layout.

Figure 16. The Borehole 4 drill pad post incident.



The design of the drill pad, location of the sump and orientation of the drill rig required the air discharge line to travel under the driller's platform. An alternative drill pad design could have prevented the air discharge line from traversing under the driller's platform.

Supervision and contractor management

The investigation identified that there was ambiguity in the reporting and supervision structure established for the drilling operation.

The drilling supervisor reported that he believed that the Ashton Coal Operations contract holder was the highest authority on site. The Ashton Coal Operations contract holder reported that he was relying on the expertise of Silver City Drilling and believed that they would instruct themselves on technical drilling matters.

Part of the Ashton Coal Operations health and safety management system focused on ensuring that contactors adopted safe systems of work. The document known as site SHEC standards - contractor management detailed Ashton Coal Operations system for the effective management of risks associated with contractors on Ashton Coal Operations sites.

The specific Ashton Coal Operations contractor proforma was a document created in consultation with Silver City Drilling. It was the contract holder's responsibility to ensure that the system of work negotiated between the two parties was adhered to by the workers of Silver City Drilling. It was also Silver City Drilling's responsibility to undertake the work using the risk management approach stipulated in the contract proforma.

In order to ensure that Silver City Drilling workers did conform to the prescribed system of work, measures were required that included performing planned task observations (PTOs) by the Ashton Coal Operations contract holder.

No formal documented PTOs for the work conducted at Borehole 3 or Borehole 4 were completed by the contract holder. Rather, site visits were conducted by the contract holder who made diary notes in relation to compliance with the agreed system of work.

The change management process

The system of work negotiated between Silver City Drilling and Ashton Coal Operations included the Silver City Drilling change management procedure. It has been identified that on at least two occasions it would have been appropriate for Silver City Drilling to undertake the documented change management procedure. Specifically, the addition of a 90 degree elbow to the air discharge line and the change in location from Borehole 3 to Borehole 4.

Silver City Drilling did create a task analysis after the second environmental incident, as required by the contract holder, before work recommenced. This task analysis focussed on the tasks associated with installing the 90 degree elbow rather than the effect this would have on the drilling system of work and directional forces.

Chapter 4. Alternate views on causation considered by investigators

Examination of other drilling incidents in the Hunter Valley

Investigators considered two other drilling incidents that have occurred in the Hunter Valley.

According to reports on those incidents, both exploration drill rigs appear to have intersected high pressure aquifers after drilling through broken ground later determined to be geologically significant. The resultant circumstances of drilling into an aquifer under pressure were an ejection of the core barrel and the release of fugitive water and gas from the well. These types of incidents are commonly referred to as a ‘blow out’.

No-one was injured in either of these two incidents. A picture of one of the incidents is shown below.

Figure 17. A ‘blow out’ incident on an exploration drill rig in the Hunter Valley.

‘Blow out’ event

Investigators considered whether the presence of other blow out incidents in the Hunter Valley shows evidence of a possible alternative cause and circumstance for the Ashton Coal Operations incident.

It was suggested that there could be a high pressure zone in the region of Borehole 4. This was based on the observation that where there is a major geological structure, such as a thrust fault, there is the possibility of high pressure pockets forming in the vicinity.

Investigators did not identify any significant geological structures within the incident site.

A senior geologist who had drilled more than 300 exploration holes on ML1533, considered the prospect of intersecting a high pressure zone at Borehole 4 to be highly unlikely.

Ashton Coal Operations considered the possibility of gas pockets forming in strata units along the trajectory of Borehole 4, and concluded that ‘given (a) the measured ground movement from survey data is at the limit of measuring accuracy, (b) the minimal effects of any possible ground movement and, (c) the pressure monitoring from the piezometers, it is almost impossible to have a situation where gas pockets could form in the strata. The likelihood is therefore extremely low if not impossible’.

Explosion

Investigators considered whether there may have been an ignition of methane gas, which led to the over-pressure event occurring. Sampling and testing found no evidence of deflagration or combustion explosion in the air discharge line, and the level of methane in the borehole was insufficient to support ignition.

Drill rig failure

Examination and testing of the drill rig by investigators and the OEM found that the drill rig sustained limited damage as a result of the incident and that damage that was present before the incident did not contribute to the event.

Air compressor failure

Investigators and the OEM of the three air compressors onsite performed a detailed analysis of the three compressors. Apart from low compressor oil in one of the compressors, no other functional issues were identified.

Chapter 5. Remedial actions

Immediate actions

Both Ashton Coal Operations and Silver City Drilling took steps to support the injured driller, crew members and rescuers. Both Ashton Coal Operations and Silver City Drilling ceased all drilling operations at the incident site and all other planned drilling works until the circumstances of the incident could be understood by them.

Changes to contractor management plan

A contracts coordinator was appointed as an additional resource to assist Ashton Coal Operations and contractors in preparing scopes of works and formalising commercial contracts.

Ashton Coal Operations conducted a gap analysis of its contractor management plan, leading to its review and modification. Contractor health and safety management plan audit sheets were incorporated into the contractor management plan. Ashton Coal Operations also applied a renewed focus on change management at management and planning meetings.

Development of drilling safety standards

IGA-003 *Surface Minerals Exploration Drilling Safety Management Assessment* issued by NSW Trade & Investment on 13 February 2013 was incorporated into existing drilling job safety assessments and safety systems and provided to drilling contractors for their reference.

Various controls were put in place at Ashton Coal Operations drill sites as a result of the incident and drilling procedure review. For example, the expert driller must consider the following in the risk assessment: location of sump/air discharge line and anchoring; set up of drill pad; design of air discharge line (straight); restraining system against air discharge line movement; barricaded access for personnel to the air discharge line; position of operators; assessment of potential stored pressures in the drill hole including if the hole becomes blocked; engineering design of casing system in ground and above ground; verification process to confirm integrity of casing grouting (pull tests); and development of trouble-shooting Trigger Action Response Plans (TARP).

Safety management plan auditing

Ashton Coal Operations began an overall mine site health and safety management system audit in accordance with the SHEC Auditing Standard that required an audit to be conducted following a dangerous incident. Approximately 30 to 40 employees across the Yancoal businesses (including Ashton Coal Operations) were trained as auditors in order to conduct the audits under the SHEC Management System.

Review of emergency response procedures

A review was conducted of emergency response procedures through a debrief with the emergency response personnel involved in the incident. Ashton Coal Operations' induction for contractors now requires additional emergency contact details to be provided to contractors including an emergency mobile phone number. Helicopter coordinates have been made more accessible and easier to read in the first aid room. Helicopter coordinates have also been added to the emergency response duty cards.

Daily planning

Daily underground plans were revised to focus on ensuring surface activities are also included in the 24-hour plan.

Risk management

Implementation of the Yancoal Risk Matrix requiring risks to be reported to various levels of management depending on their risk ranking (e.g. Risks ranked high or extreme must be reported to the Chief Operating Officer).

Implementation of recommendations

There have been two publications from the NSW Trade & Investment relating to the Ashton incident. They are;

- NSW Mine Safety Safety Alert (SA 13-03)
- NSW Mine Safety Investigation Unit Information Release (IIR 13-03)

Both of these documents are available on the NSW Trade & Investment Mine Safety website.

Ashton Coal Operations reviewed the recommendations outlined in the Safety Alert issued on the incident confirmed that all the recommendations were implemented.

Corporate changes

Since the incident Silver City Drilling has undergone substantial organisational changes and is under new management.

Chapter 6. Conclusions and recommendations

Conclusion

This incident highlights the need for an effective risk management program in relation to drilling operations.

In this case, the conductor casing was not installed to the correct depth into consolidated ground. This led to alluvial material and water entering the borehole and air rotary hammer drilling was used in lieu of mud rotary drilling.

The installation of the 90 degree elbow on the air discharge line changed the directional forces from horizontal to vertical creating a lifting force on the air discharge line. The air discharge line securing system was inadequate to restrain the air discharge line. The risks involved with the system were not identified or adequately controlled.

During the application of air to the hole to unload the well, there was a uncontrollable release of water and cuttings from the borehole. These explosive forces escaped the borehole via the air discharge line causing a lifting force and resulted in the air discharge line shooting up in the air and hitting the driller's platform and then falling onto the driller causing him serious injury.

Recommendations

This incident highlights the need for an effective risk management program in relation to drilling operations. The following are recommended practices to industry to improve industry safety and reduce the likelihood of similar incidents occurring in the future.

1. Unconsolidated ground should be identified and effectively controlled via the use of adequate casing installed to the required depth.
2. Site specific drilling risks must be identified and controlled using the hierarchy of controls.
3. The design and modification of drilling equipment should be risk assessed.
4. Changes to drilling systems of work should be identified and adequately risk assessed.
5. Air discharge lines must be secured and anchored effectively.
6. Drill pad design should minimise the potential for hazards and take into account the location of sumps, location of operators and location of discharge lines.
7. The appropriate method of drilling should be identified and be suitable for site specific conditions.
8. Clear reporting lines and supervisory arrangements should be in place that clearly defines roles and responsibilities for drilling operations.