Modernising an Underground Gas Drainage System in Response to Increased Production and Gas Content

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MODERNISING AN UNDERGROUND GAS DRAINAGE SYSTEM IN RESPONSE TO INCREASED PRODUCTION AND GAS CONTENT

Andrew McInerney¹ and Miles Brown²

ABSTRACT: This paper highlights a successful step change in the management of increasing gas contents and compressed drainage timeframes. The improvements have overcome safety risks concerned with a system not suitable for handling the required gas loading for current and future production targets. The paper discusses how the upgrades manage increasing seam gas content, high rig drilling rates, record development and longwall performance. Improvements to the system included specific design to suit continuity, in-seam hole stability, predicted peak gas flows, drilling and drainage direction, infrastructure type and capacity, formation of empirical gas decay curves and fines and water removal from the system. Using data captured from the commencement of the upgrade, steps toward an efficient and malleable long and short term design and planning tool have been taken. Variable flow rates has led to the investigation of high fluctuation of gas capture, moving away from traditional prediction methods and relying on analysed mine specific data.

INTRODUCTION

Anglo-American’s Grasstree Underground Mine operates the German Creek Seam in the Bowen Basin. Production for 2015 is approaching 10Mt. Underground in-seam gas drainage with only two in-seam drilling rigs is utilised to drain the German Creek seam. With virgin gas contents approaching 16m3/t in the German Creek Seam and with Methane as the predominant gas, the management task is large.

Increased production with increasing gas content is the real challenge for Grasstree’s underground in-seam gas drainage management team. In April 2015, following incidents involving gas emissions at drill stubs and development faces, the complete system needed an overhaul. This paper quantifies all the changes that have been introduced and discusses the intense reconciliation that occurs to ensure all changes are successful. The system will only be deemed successful if safety concerns are mitigated and predicted values are achieved. Hence by managing safety as the primary objective for changes to gas drainage, the technical improvements at the site have followed. Additionally any changes to the Underground In-seam (UIS) drainage system must cater for ever changing geological situations. The drainage designs and drainage infrastructure used require flexibility within their designs to suit all situations that are foreseen. Permeability, dykes, faults, gas content all vary in size and eliminate the ability of one design fits all.

APPROACH FOR UIS GAS DRAINAGE

To achieve change there must be a solid framework, which provides a clear flow path to success. This framework needs to outline all principles that provide the solution. The two over riding key governances for ensuring that gas drainage is effective at Grasstree Mine are;

- Science – where gas drainage rates, gas flows, gas pressures and business continuity values are predictable
- Design – where all potential safety, geological and structural risks are engineered to as low as possible.

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The Grasstree underground gas drainage upgrade was aimed at creating a “Gas Drainage System” that is transparent in all its designs and all its predictions. The system is best shown in Figure 1.

The key principles to be continually used for an effective scientific approach are:

- Prediction
- Continuity
- Monitoring

Prediction

Utilising first principles to form an operational design program requires understanding on how drilled drainage holes actually react. This can be done with or without permeability data. Analysing hole flow data from existing underground in-seam holes, where known virgin gas contents is the primary method. This data along with monitoring the hole right through to the compliance core result can create a base decay curve. Once the decay curve is developed, and for Grasstree there are two distinct curves used for predicting flows, the other principles are applied to estimate hole flows.

Principles for hole flow estimation and subsequent drainage decay include;

1. Drilling rate – metres/day or metres per week
2. Hole spacing – this is the variable when determining continuity requirements
3. Seam thickness
4. Virgin Gas Content and target Gas Content
5. Hole length
6. Decay Curve (Figure 2)
The output from the design program is estimated individual hole gas flows and total site gas flow profile. (Figure 3). This information allows for future tracking of hole performance.

![Figure 3: Predicted gas flow](image)

**Continuity**

Gas Drainage continuity with development is achieved using the Grasstree gas drainage design program in conjunction with the mine production profile. The system is used for both single holes and drill sites and is also used for Life Of Mine (LOM) continuity. Life of Mine planning becomes a simple task of ensuring the correct spacing is applied to achieve continuity. The following two figures represent the planning spreadsheet tool for an individual drill site.

![Figure 4: Planning spreadsheet A](image)

Drainage continuity with development is achieved by modifying the drainage hole design to suit the variable permeability, quantified by specific gas decay curves, to set a hole spacing that achieves a planned gas drainage target content of approximately 3 m$^3$/t.
Figure 5: Planning spreadsheet B

<table>
<thead>
<tr>
<th>Drill Site</th>
<th>Target Zone</th>
<th>Area to Drain m²</th>
<th>Ave Seam Thickness</th>
<th>Tonnes Coal to Drain</th>
<th>Vol of gas to remove m³/t</th>
<th>Start date of gas flow to pipe</th>
<th>Expected Time to drain to target (Days)</th>
<th>Required Time to drain to target</th>
<th>Continuity with Development at commencement of Zone</th>
<th>Initial PEAK total flow from holes at 3m³/t</th>
<th>Total flow from holes at 3m³/t</th>
<th>Probable Gas Content when Mined m³/t</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hole 1</td>
<td>Inbye</td>
<td>13 to 13.5</td>
<td>93366</td>
<td>1027026</td>
<td>28/06/2015</td>
<td>134</td>
<td>16/12/2015</td>
<td>37</td>
<td>411</td>
<td>17</td>
<td>2.8</td>
<td></td>
</tr>
<tr>
<td>Hole 2</td>
<td>12.5 to 13</td>
<td>17700</td>
<td>69906</td>
<td>735966</td>
<td>1/07/2015</td>
<td>104</td>
<td>7/12/2015</td>
<td>54</td>
<td>379</td>
<td>16</td>
<td>2.75</td>
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</tr>
<tr>
<td>Hole 3</td>
<td>12 to 12.5</td>
<td>27000</td>
<td>102693</td>
<td>1122660</td>
<td>4/07/2015</td>
<td>143</td>
<td>28/11/2015</td>
<td>3</td>
<td>423</td>
<td>18</td>
<td>3</td>
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<td>Hole 4</td>
<td>11.5 to 12</td>
<td>25400</td>
<td>96012</td>
<td>1056132</td>
<td>8/07/2015</td>
<td>146</td>
<td>19/11/2015</td>
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<td>389</td>
<td>16</td>
<td>3.25</td>
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<td>58212</td>
<td>698544</td>
<td>12/07/2015</td>
<td>117</td>
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<td>Hole 6</td>
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<td>48364</td>
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<td>110</td>
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</tr>
</tbody>
</table>

Figure 6: UIS Design Drainage time to 5m³/t and 3m³/t

Figure 7: Life of Mine Planning for Drainage hole spacing
Monitoring

The key component to any gas drainage system is acquiring reliable data. Every UIS hole is fitted with a gas flow measuring set outbye of the holes isolation valve. Two styles have been utilised. High flowing holes (>30 l/sec) utilise orifice plate styles. This is so that when the hole is not being measured the inserted orifice plate is removed to stop potential blockages. The Venturi style is employed as required on lower flow holes or lower risk holes. The orifice plate style is the predominant tool. This is because there is less chance of a blockage especially as Grasstree UIS holes release a high volume of material.

Weekly individual hole flow monitoring is in place. This data is placed into operating spreadsheets for determining how the hole is draining against predicted flows. Anomalies identified from these actual vs. predicted flows then allow the site to remedy low flowing holes or analyse high flowing holes. Additionally, holes which are found to have a blockage can then be treated. Furthermore, every surface riser has real time monitoring allowing for accurate calibration of decay curves and reconciliation of results.
DESIGN – UNDERGROUND GAS DRAINAGE

The key principles to be continually used for an effective design approach are;

- UIS Hole Design
- Infrastructure

UIS hole design

The following diagram depicts the principle design being utilised for remaining LOM UIS drilling. The design variable is the hole spacing at the target future development gate road. Spacing will vary with regards to continuity with development (schedule), gas content variations and lower permeability zones (identified from geological interpretation and micro cleat analysis).

The new UIS design has numerous strengths. These include;

1. UIS hole stability improvement. Previously holes would fail during or after the hole was completed. The majority of these issues occurred on cleat direction where the drill bit struggled to maintain the desired drilling direction. The holes also failed where branches were occurring on the same direction as the cleat. The new design requires branching to avoid cleat directions at all times. The design principle is - “all branches are to be directed away from cleat angles”. Branches are planned and sequenced to ensure that this occurs. Since the change there have been minimal issues in hole and after completion.

Figure 10: UIS design principles

2. Hole branching. Hole density has increased at the target locations where development are to mine. This is achieved by reducing standpipes and increasing planned branches. This design has an added control that the last branch drilled from any standpipe is the first hole intersected by development. This is to reduce chances of long hole blockages.

1. Hole direction. The design has identified an improved drainage direction when drilling through planned gate roads or zones of very low permeability and drilling difficulty. The additional benefit is that when development intersect these holes in the gate road the virgin side of the hole is in
the rib line while the suction side is in the face. This naturally improves borehole management when developing. Additionally, direction when drilling through geological structures (dykes/fault zones) allows enhanced stability and drainage when the correct angle is chosen.

2. Directional permeability is evident at Grasstree and has been backed by recent micro cleat analysis at UNSW in these zones. Micro cleat analysis validates this assumption as areas of good drainage show a micro cleat clear of obstructions. The new design has rotated the angle of the holes so as to not be parallel with lower permeability directions.

3. Roof touches. All holes require a roof touch prior to drilling across a planned gate roads. This is to achieve highest possibility of the hole being mid seam in these areas, maximising gas drainage. Mid seam intersections on development are far easier to manage.

4. End of UIS hole sump. All UIS holes and branches now have a sump at the end of the holes to accommodate drill fines and reduce chances of holes being blocked upon intersection in development. These sumps are 12 m in length and are drilled down to the floor. Tails are 45 m past the gate road to suit these tails. Additionally these sumps allow flanking drill holes to avoid the end of the holes, reducing the chance of interaction.

5. Virgin gas content cores. At least one core is taken when drilling a full pattern. In conjunction with initial hole flows, an accurate virgin content allows for immediate recalibration of the prediction model. This data is also fed into the “NEW” planning spreadsheet to better plan for how a section is going to be drained.

6. Infrastructure size. Predicting flows is an output of the planning spreadsheet and determines the pipeline and gas riser size. Infrastructure (pipes) needs to suit predicted flows. A single UIS site has recorded flows peaking up to 2500 l/sec which needs to be managed by infrastructure or planning.

7. Fines management. In-hole fines creation occurs during the drainage of the German creek seam. These fines and stone fragments are predominantly emitted into the drill site gas pipework, lifting and removing it when the gas pressure and flow is at it's peak. It is paramount for the infrastructure design to have the ability to remove this waste underground through a water trap off the range. The remaining fines, so as to not cause a build up or blockage in-hole, are targetted at being deposited in the end of hole sump. The final 12m’s of the hole is drilled downwards to create this sump.

8. Structure identification. The UIS design has the ability to be changed where there is an identified or a predicted outburst prone structure(s). “Close the grid” style drilling is used to attempt to locate these structures. It should be noted that small structures are very difficult to predict with UIS drilling as they can be penetrated without noticing changes. These "close the grid" designs can be conducted at the commencement of drilling by “looping” the tails of the holes across each other or just prior to mining by drilling from behind the development operations. The earlier a structure is identified means a lesser chance of a structure being unexpectedly intersected by development. Once structures are identified then additional compliance cores can be designed and conducted prior to development. Figure 11.
9. Standpipe placement. Holes are drilled left to right in a drill site to maximise room for driller operators. Standpipes are limited by the hole spacing. Basically two branches off the trunk are designed for every hole that targets a future gate road. Figure 12.

![Figure 12: UIS design change](image)

**Infrastructure**

The current drill site arrangements can relate to both stubs or open sites. The drill site design standard has the objectives of both allowing operators a less congested site (ergonomical) and provide a separate water and fines system allowing flow to the gas riser.

The arrangement requires flexibility depending on the location of the riser. Each site will be arranged to suit, however the general layout applies. There must be;

1. A method of isolating water and fines from the riser and pipes in order to remove from the system. (see water trap in Figure 13).
2. Equipment installed for measuring individual hole gas flows, known as Measuring Sets.
3. Infrastructure in line for allowing holes to be unblocked without releasing gas to the atmosphere. This is by a 100 mm (4”) to 50 mm (2”) t-piece between the standpipe and hole isolation valve.
4. Adequate pipe infrastructure to allow gas to flow to the gas riser with minimal restrictions
5. Pressure monitoring in pipe infrastructure to ensure that the pressure TARP is easily managed. Installing the correct size riser assists with reducing the chances of high pressures. The decision tool for the riser diameter is shown in Figure 14
6. Adequate height differential for separating drillers gas and water/fines to their fines bins. This will minimise water and fines inflow into main pipe range from the drillers.

![Figure 13: Drill site pipe infrastructure](image)
RECONCILIATION OF DESIGN

Predicting and monitoring of gas flows and mining gas content

The main output of the prediction and monitoring model is the final gas reconciliation for purposes of guaranteeing precise gas capture from the reservoir, model accuracy and correction and low gas content upon coring and mining. Figure 15.

Case Study- 905MG 9ct A Heading

This is the second new style drill pattern to be intersected by development. All core results were below 3 m³/t and suction was seen at face upon intersection by development for all holes. Figure 16, shows a comparison between actual measured flow rates versus the predicted flow rates for the pattern shown in Figure 19. This actual flow data gathered is used in a process of reconciliation of the individual borehole reservoir to predict residual gas content at desired times to develop robust compliance core schedules to ensure development continuity. This flow data and characteristics is fed back into the decay model by
means of comparing gas captured (volume) to the flow rate of the hole at a particular time from commissioning. This makes the prediction of flow rates at a set gas content more accurate for future patterns in similarly permeable areas.

Figure 16: UIS design predicted vs. actual gas make

Figure 17: 905MG 9ct actual drilling and compliance results
Figure 18: 905MG 9ct actual individual hole flows

Figure 19: 905MG 9ct actual individual hole flows
ADDITIONAL IMPROVEMENTS

Microcleat analysis

Although it has been identified through monitoring that there are definite zones of lower permeability (lower gas flow) the reason has not been proven. Dr Lila Gurba from the University of New South Wales was engaged to analyse coal samples for potential flaws to coal gas flow. These tests also looked at areas where there were poor gas drainage flows and good gas drainage flows encountered. These tests were at a micro level.

The analysis has shown a definite directional issue with micro cleats thwarting gas migration in one direction. The direction is clear and appears to be sheared closed hence the poor gas flow. More analysis is to continue.

Extended Q1 analysis

Grasstree mine utilises both surface and underground coring for both compliance gas content cores and virgin gas content core data. To take a core from underground at a distance which would normally take greater than 40 minutes to place under test, the site required a method to be acceptable to allow this to occur. GeoGAS was engaged to provide a correction factor for this purpose.

The following diagram represents Grasstree Q1 correction factor for when cores take greater than 40 minutes to be put onto test. The advantage of this test increases the use of longer cores or cores where there were issues recovering, providing data well before current time limits allow.

Borehole intersection suction level TARP

Creating a TARP for suction levels prior to development intersection is the final key to the puzzle for improving mine safety for UIS drainage vs development interaction. Improvement and quality standards of roadway hose over standpipes and methods is also vital to successful gas control post intersection.
CONCLUSIONS

The development of a reconcilable underground gas drainage system is the key to sustaining effective gas drainage for the remainder of the mines life. This system must and can cover all changes in coal characteristics in relation to varying gas content and effects from geological structures. The following points highlight the success of this system.

- Underground Inseam hole gas flow is able to be estimated accurately with or without permeability data. Variable decay curves can be created and calibrated with regards to different coal characteristics.
- Understanding microstructure is vitally important to understanding hole flow variations. Also a link with microcleat issues and outburst prone structures or even coalburst characteristics.
- Correct Infrastructure design (size) is required to limit reduce gas pressure increases from hole flows or from gas surging. This includes gas pipe or gas riser diameter.
- Being able to reconcile the complete design of a gas drainage system in regards to its performance versus planned is vital for not just approval to mine but for the workforce confidence, especially for such a gassy operation.
- Designing a system that sets standards for suction levels required to be applied to UIS holes prior to developing thru is a massive step in reducing potential for gas incidents in development faces.

The final hurdle is the opinion of the crews and staff at site. The support for change was always positive, however the results and confidence gained for the current management of gas drainage is justified. Providing a new handbook for all aspects of Underground gas drainage now allows all on site to understand the volume of processes conducted at Grasstree. This handbook will be used for all training aspects of gas Drainage and as a support document to Principle Hazard Management Plans.

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Dr Lila Gurba from the UNSW has provided analysis of coal properties at the microstructure level and Geoff Williams from GeoGAS for completing the extended Q1 Analysis.

REFERENCES