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LONGWALL "PORE PRESSURE" GAS EMISSION MODEL

David Ashelford [1]

ABSTRACT: Extraction of coal by longwall mining methods has improved greatly over recent years with tonnage rates per week now surpassing yearly tonnes of a few years ago. As mines go deeper and tonnage rates increase then gas emission also increases. For the purposes of understanding gas emission and planning strategies short and long term, modelling of gas emission using the "Pore Pressure" longwall gas emission technique, illustrated is an attempt to model this phenomenon.

The input data to the model includes the gas reservoir properties relevant to underground coal seams and extraction of coal using the longwall technique to evaluate the release of gas into the mine workings. Variations in weekly production, face airflow quantities, the efficiency of gas drainage levels and differing face widths can be tested using the model.

Mine planners can use the interactive spreadsheet developed through this model to assess the limits of production, ventilation capacity and gas drainage requirements.

INTRODUCTION

Gas emission in a coal mining environment is a function of the mining process and its interaction with the gas reservoir. Planners are aware of the problem right from the start - how much emission and how to deal with the problem are where a model can assist.

The development of the "Pore Pressure" model took account of many gas reservoir and geological parameters of coal seams and allowed variation of mining operations in arriving at a gas emission value. This can be directly related to roadway gas concentrations in return and bleeder airways and can be adjusted for gas capture in an interactive spreadsheet. The process is quite complex involving an understanding of the changes in "pore pressure" resulting from rock mechanics processes associated with longwall extraction and the changes in gas desorption from those strata where the pore pressure has been sufficiently reduced. The level of uncertainty can be addressed by using a probability modelling approach.

GAS RESERVOIR PROPERTIES

The longwall "Pore Pressure" model draws on the following gas reservoir properties for the determination of gas release.

- Measured gas content (Qm) at reservoir temperature
- Gas desorption rate
- Gas composition
- Gas sorption capacity at reservoir temperature
- Seam thickness and mineral matter above and below the working section (ash/density)
- Pore pressure
- Coal and sandstone porosity

These parameters and how they are measured are described by Williams, Casey and Yurakov (2000).

Gas desorption occurs in those regions above and below the working seam, where the pore pressure is reduced , as a result of mining, to below the gas desorption pressure of the coaly gas sources. Within the relaxation zone, permeability is deemed to be sufficiently high that gas emission is determined only by desorption rate, which is a function of the pressure differential between gas desorption pressure and pore pressure. An active region of gas emission occurs between the front and rear abutments. When the relaxed zone and goaf passes into the rear

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abutment, the gas desorption rate is reduced to simulate the rise in pore pressure, with a resulting large reduction in gas emission. Once the gas is released it is assumed to be available for gas capture by drainage or ventilation.

THE MODEL

The model is derived from approaches used in Europe (Boxho et al. 1980) where the gas sources within an empirically defined envelope defining the "degree of gas emission" are summed to arrive at a specific emission value. In the pore pressure model, the "degree of gas emission" is variable according to whether the gas desorption pressure exceeds the relaxed zone pore pressure. The gas desorption pressure is determined by the interaction of gas content and gas composition with the gas sorption capacity of the coal at that particular pore pressure. The European models also suffer from the simplistic assumption that gas emission is directly proportional to production rate. In the pore pressure model, re-elevating the pore pressure by reconsolidation of the goaf was found to be essential to obtain a model match with measured data. Definition of the pore pressure resulting from mining is obtained as output from the finite difference simulator FLAC (ITASCA, 1995).

The model consists of a three dimensional array of elements, each being assigned values reflecting the state of the gas reservoir at a particular instant and with respect to location to the mining face and rear abutment. When calculation of gas released is summed from these elements a total gas emission from coal and rock strata from the surface to the working seam, and from the working seam to the extent of the stratigraphy in the floor is achieved. This three dimensional matrix is nominally eight blocks wide with as many as 300 vertical blocks and 250 blocks in length totalling up to 600,000 elements.

The size of the each element horizontally is a function of face width and a length based on production rate. Vertically the elements are related to the thickness of geological strata above and below the working section (Figure 1).

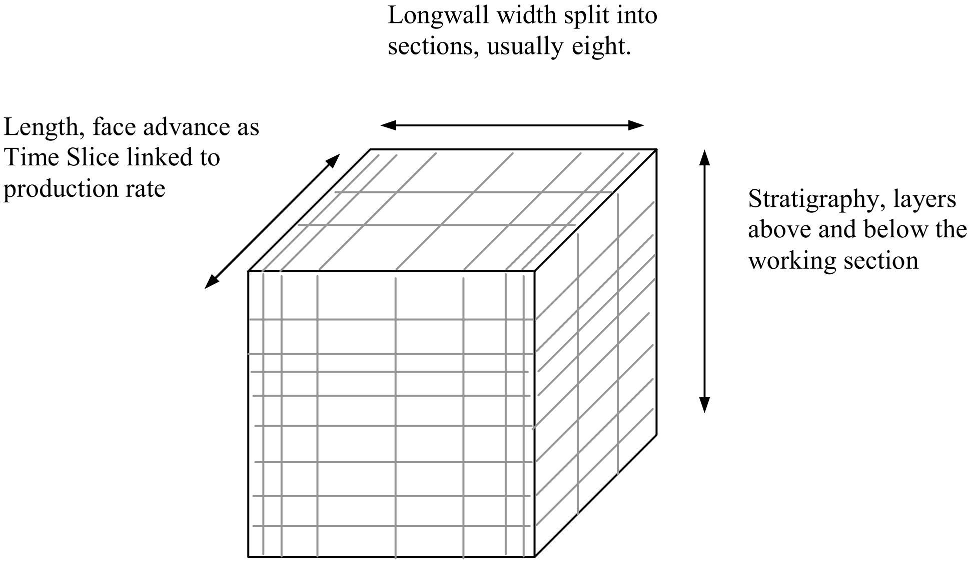
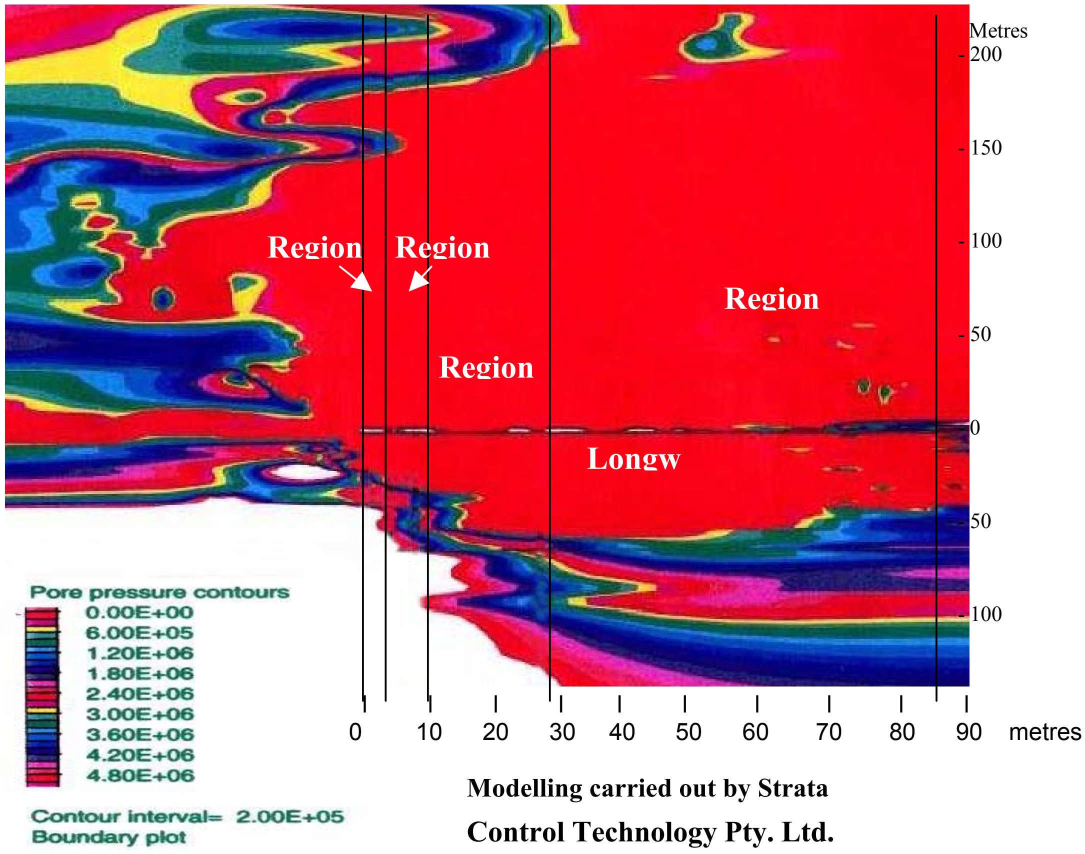


FIG. 1 – Simplified Block Arrangement for Longwall Model

The dimensions of elements are calculated in the following way:

Width	The full-face width is divided in half with four equivalent sections that relate to the boundaries indicated in the FLAC model (Figure 2, NB: Only half the face width is indicated.)
Length	Relates to production rate as a time slice per day: eg 5,000 tpd from a 2.5 m extraction height equals 7.1 m/day. (This value varies with production rate.)
Depth	Represents the thickness of each layer from stratigraphy of the borehole, used for the model. (Examples Figure 3). Layers or sections are normally limited to a maximum thickness of five metres, (to assist with calculation accuracy).



Modelling carried out by Strata Control Technology Pty. Ltd.

FIG. 2 - FLAC Model of Pore Pressure Contours with Half Longwall Width Indicated

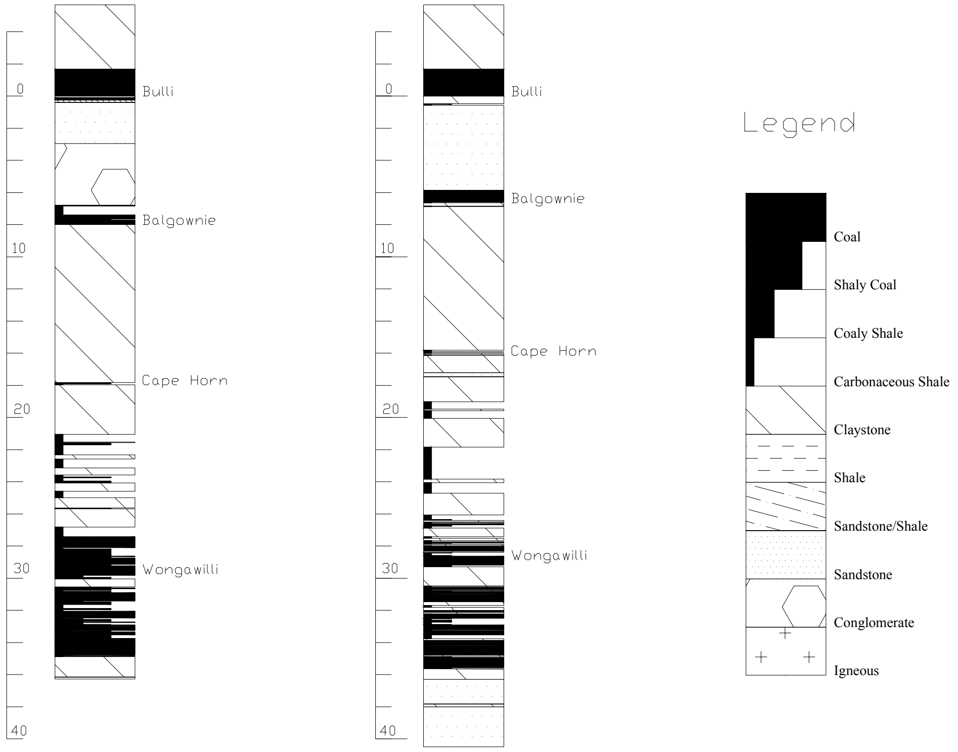


FIG 3 - Borehole Stratigraphy Examples

As an aid to understanding the modelling output and comparisons between boreholes, all the coal and coaly layers from the entire borehole are summed to give a profile of ; this is plotted as Coal Equivalent Thickness, (Figure 4).

For each element, the following is specified:

- Gas content (in m^3/t, m^3/m^3 and m^3/m^2, described by Williams (1996) for each element is initially assigned from defined gas content data or more often as a relationship with depth from borehole gas content analysis.
- The pressure of the fluid in the pore volume induced by mining (normally from FLAC modelling, Figure 2)
- Desorption pressure is calculated from the gas content using gas sorption isotherms, (Figure 4).
- Gas desorption rate, which is a function of the gas content, and the extent to which the gas desorption pressure exceeds the mining induced pore pressure. Gas is not allowed to desorb below the gas sorption capacity at one atmosphere absolute pressure.
- Reductions in gas desorption rate in response to goaf loading, set at a prescribed distance behind the face position.
- Proximity to the face and working seam.
- Non-coal stratigraphy such as sandstone and conglomerates assume pore spaces and these are assigned proportional gas content.

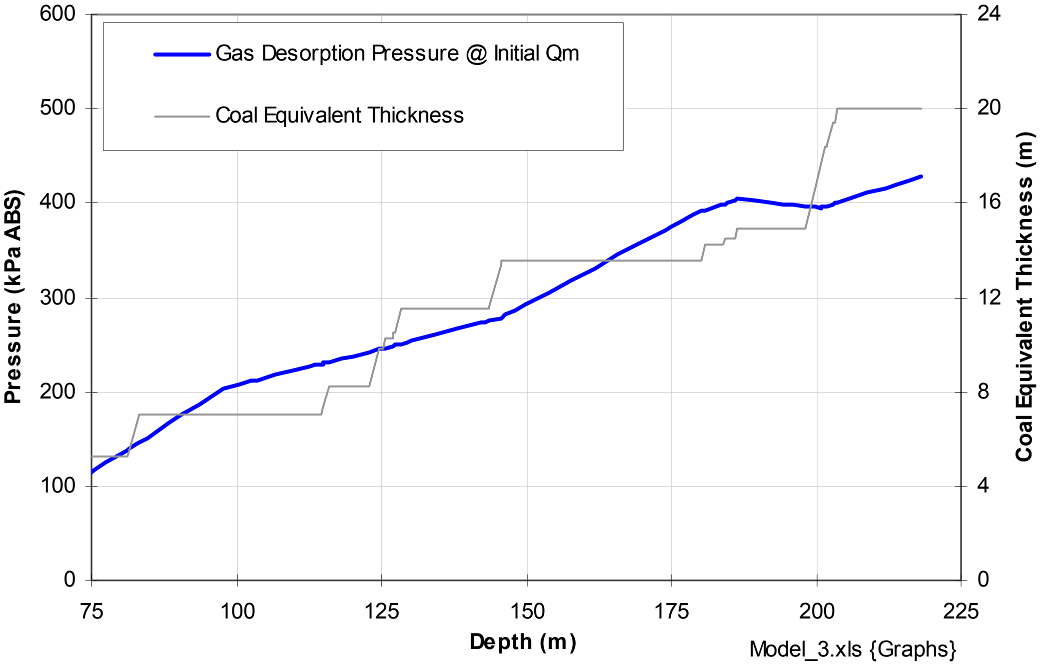


FIG. 4 – Coal Equivalent Thickness and Gas Desorption Pressure at Initial Gas Content

When the model is run, the pressure for each element is recalculated as per the pore pressure induced by mining and if this is below it's desorption pressure then gas is released. In an example, say the initial desorption pressure was 1,200 kPa αv 5.9 m3/t then a pressure reduction to 800 kPa would mean a gas release of 1.4 m^3/t at a rate defined by the gas content and the pressure difference (Figure 5). Gas release does not occur below the one atmosphere pressure.

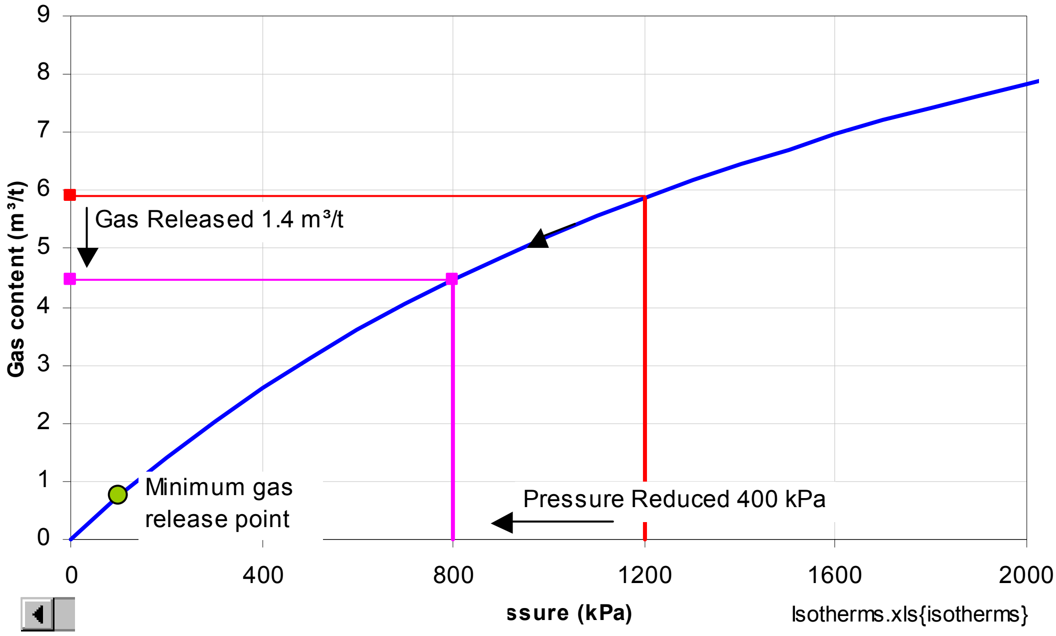


FIG. 5 – Sorption Isotherm Indicating Gas Release with Pressure Reduction

A zone of influence can be plotted where the pore pressure is less than the desorption pressure allowing gas release, (Figure 6).

It is this calculated volume of gas release in each element that is then summed for differing production rates to calculate the total gas make. The initial output is identified points that are fitted with a power trend curve as a gas make curve, (Figure 7).

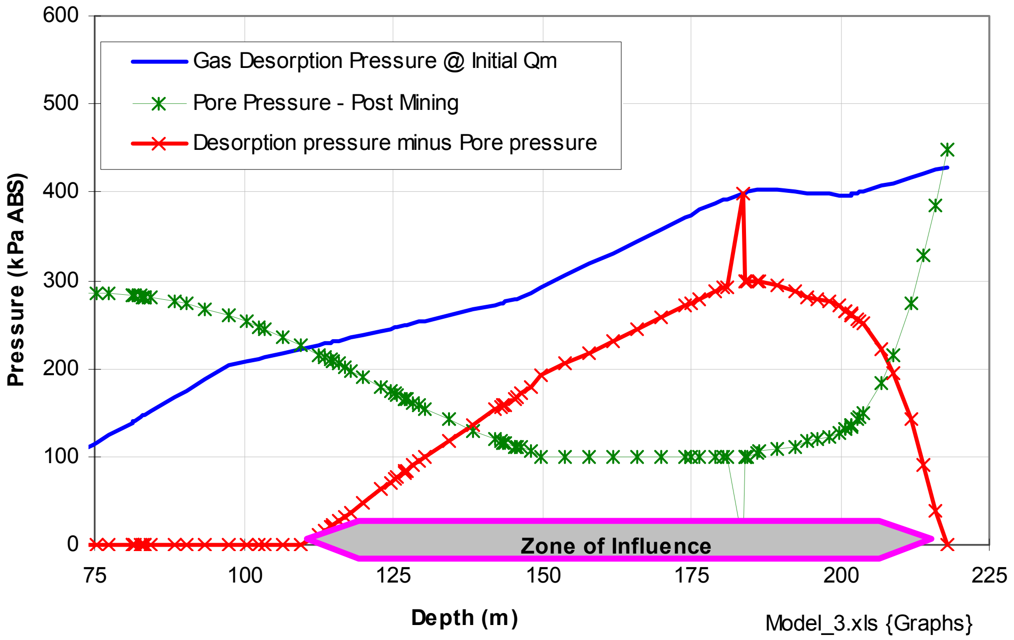


FIG. 6 – Zone of Influence, Where Desorption Pressure Greater Than Pore Pressure

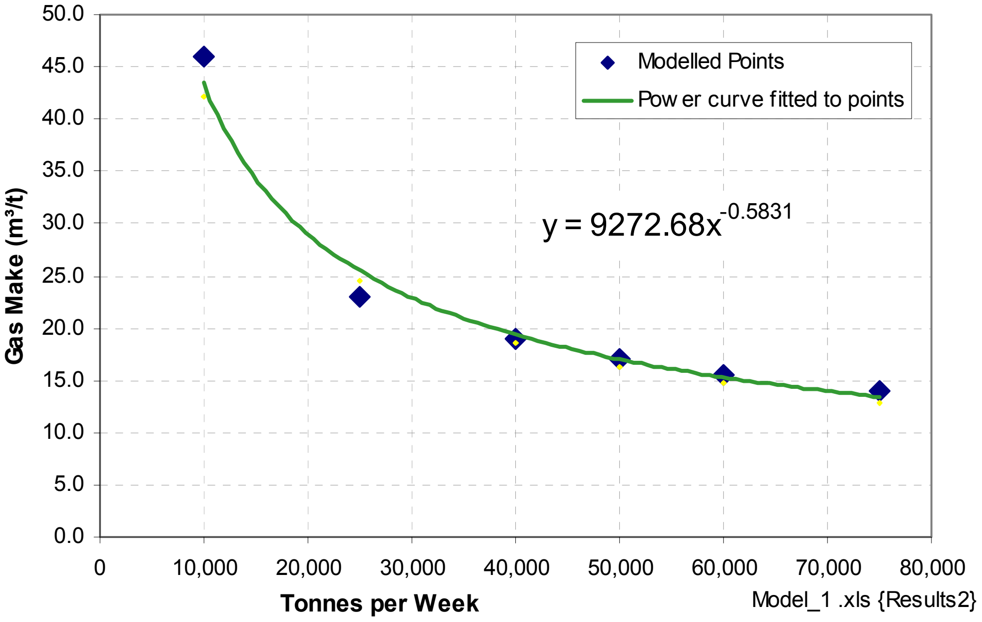


FIG. 7 – Gas Make Curve Plotted from Model Results

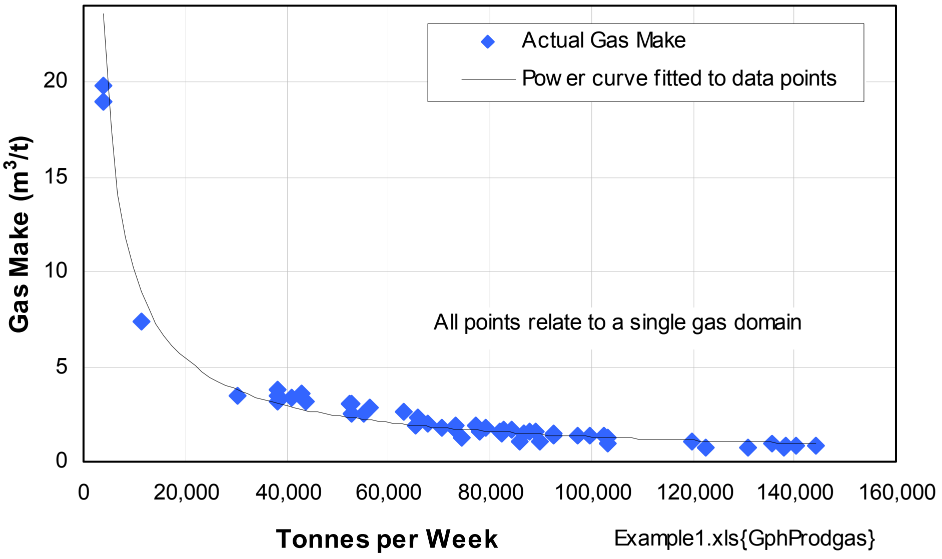
GAS MAKE

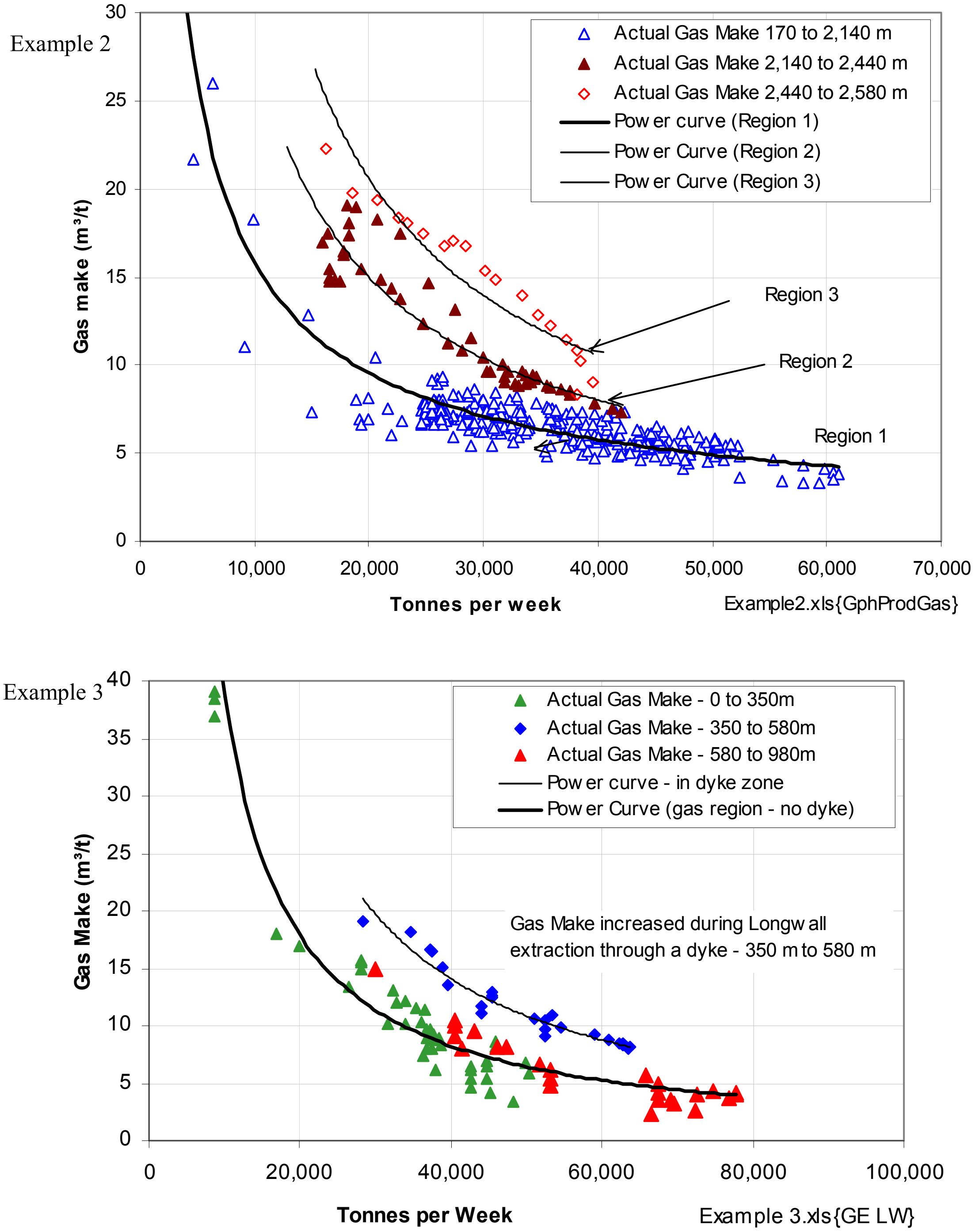
Why model Gas Make? Gas make (m³/t) as a function of production when plotted as a consistent relationship indicates similar gas domains. Complete longwalls or large areas of longwalls have been found with consistent gas domains. A relationship has been established between the gas make coefficients linking gas emission and production rate (Williams, Maddocks and Gale (1992). This relationship will be explored later to explain the use of the modelling result.

As a means of comparison three examples of actual curves have been included to show the gas domains that occur while longwall mining.

- Example 1 (Figure 8) is a typical Gas Make curve from a standard longwall operation.
- In Example 2, the longwall has continued with three separate domains indicated.
- The third chart (Example 3) indicates additional gas emission issuing from a dyke crossing diagonally across the face. Note the return to normal gas make levels after the dyke disappeared from the face area.

Example 1





Example2.xls{GphProdGas}

Example 3.xls{GE LW}

FIG. 8 - Gas Make Curves of Actual Longwall's

GAS EMISSION MODEL CAPABILITIES

The longwall gas emission model is capable of quantifying the gas make depend on changes in:

- Gas content of the coaly material
- Coal sorption properties
- Porosity and water saturation of the non coaly material
- The thickness and proximity of the gas sources to the working seam
- Longwall face width

Using the interactive spreadsheet demonstrated below changes can also be made to the following

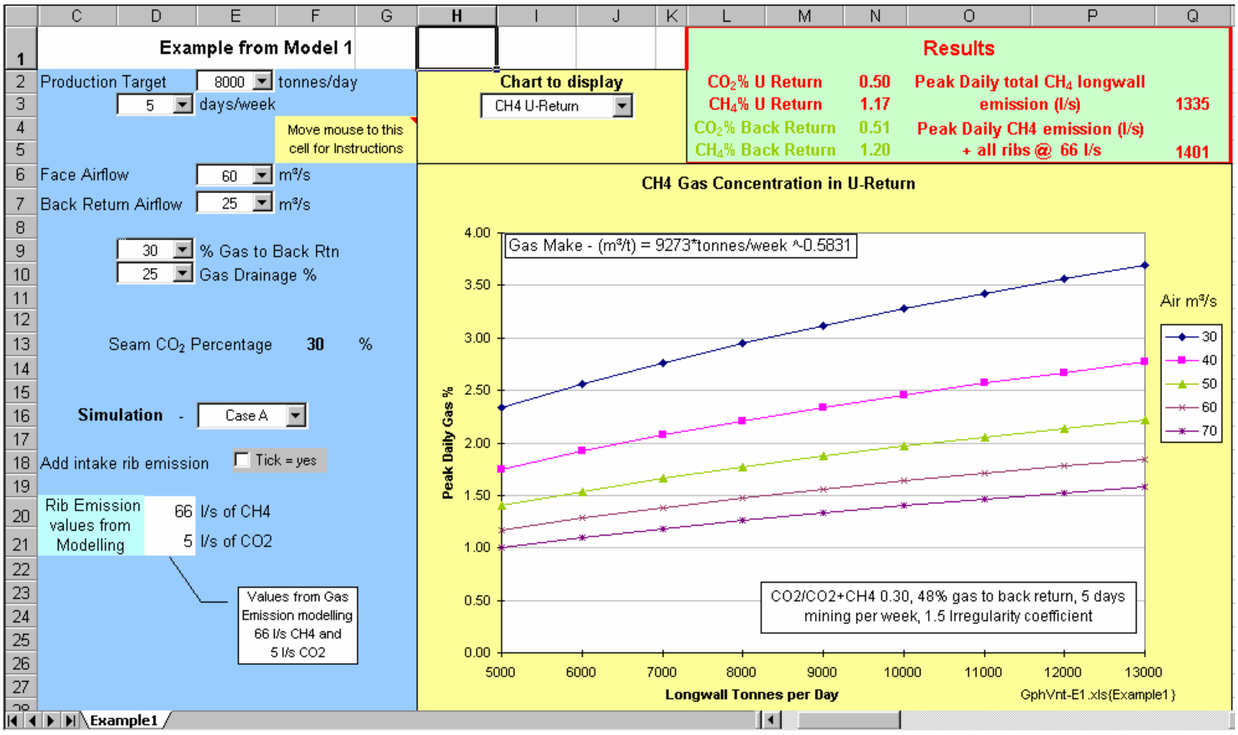
- Mining rate, including production days per week

- Ventilation airflows along the faceline and bleeder airways
- Gas capture and working seam predrainage

The gas make curve from the "Pore Pressure" model alone is only the first stage of modelling. It is the interpretation and information that is obtained from this initial modelling in the form of an interactive spreadsheet that is the real advantage of the model.

An example of an interactive spreadsheet with the gas make curve coefficients entered has variable options in the form of drop down boxes, (Figure 9). In this case the variable options are:

- Daily Production
- Number mining days per week
- Face Airflow
- Bleeder Airflow
- Gas Drainage – percentage and
- Bleeder face separation %



Example from Model 1

Production Target 8000 tonnes/day
5 days/week
Move mouse to this cell for instructions
Face Airflow 60 m³/s
Back Return Airflow 25 m³/s
30 % Gas to Back Rtn
25 Gas Drainage %
Seam CO_2 Percentage 30 %
Simulation - Case A
Add intake rib emission ☐ Tick = yes
Rib Emission values from Modelling 66 l/s of CH4
5 l/s of CO2
Values from Gas Emission modelling 66 l/s CH4 and 5 l/s CO2

Chart to display CH4 U-Return

Results

CO_2% U Return	0.50	Peak Daily total CH_4 longwall emission (l/s)	1335
CH_4% U Return	1.17		
CO_2% Back Return	0.51	Peak Daily CH4 emission (l/s) + all ribs @ 66 l/s	1401
CH_4% Back Return	1.20		

FIG.9 - Example Longwall Emission Model Input/Output

The indicated gas emission results for a daily production of 6,000 tonnes are 1,184 l/s and with 25 % to drainage and 30 % to the bleeder return have the Peak CH_4 percentage in the face return at 1.04%. (NB: Peak Value is the calculated value from modelling times an irregularity coefficient of 1.5)

Altering the daily production to 8,000 tpd changes the Peak Daily CH_4 gas emission to 1,335 l/s and the Peak CH_4 gas percentage in the face return to 1.17%.

GAS EMISSION MODEL LIMITATIONS

Only regular gas emission can be modelled. The emission model cannot simulate the propensity for sudden gas releases from floor breaks. The emission model elements are not capable of interaction with each other.

Apart from the effect of goaf reconsolidation, gas desorption rate is the limiting factor in the supply of gas to the system. Included in the goaf reconsolidation effect is the re-establishment of hydraulic head in the floor behind the face.

Gas emission model strengths are its ability to give:

- A reasonably plausible mechanism (compared to traditional European approaches).
- A high level of geological and gas reservoir detail

CONCLUSIONS

The modelling scenario offers a tool that can assist mining planners to understand and control longwall gas emission. Its most accurate application is where settings are defined in matching actual emission. In Greenfield sites, where input parameters and model setting can be less reliable, the accuracy of any result is limited by this uncertainty. As experience increases over time, the accuracy of modelling will improve.

ACKNOWLEDGEMENTS

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REFERENCES

Boxho J., Stassen P., Mucke G., Noack K., Jeger C., Lescher L., Browning E.J., Dunmore R. and Morris I.H. 1980 Firedamp Drainage Verlag Gluckauf GmbH Essen.

Itasca (1995) Flac: Fast Iagrangian Analysis of Continua 3.0, User Manual, Itasca Consulting Group Inc., Minneapolis, USA

Williams R.J., Maddocks P.I. and Gale W.J. 1992. Longwall gas emission modelling, *Symposium on Coal Bed Methane Research and Development in Australia, Townsville.* Volume 5 pp. 1-5

Williams R.J. 1996. Application of gas content test data to the evaluation of gas emission and hazards during longwall development and extraction. *Symposium on Geology in Longwall Mining* November 1996, pp.35-40

Williams R.J., Casey D. and Yurakov E., 2000. Gas Reservoir Properties For Mine Gas Emission Assessment*, Bowen Basin Symposium 2000, The New Millennium – Geology Proceedings,* Rockhampton, Queensland, 22-24 October 2000, pp. 325-333