XXX School of Underground Mining
Methane in the Context of the Transition of the Coal Sector
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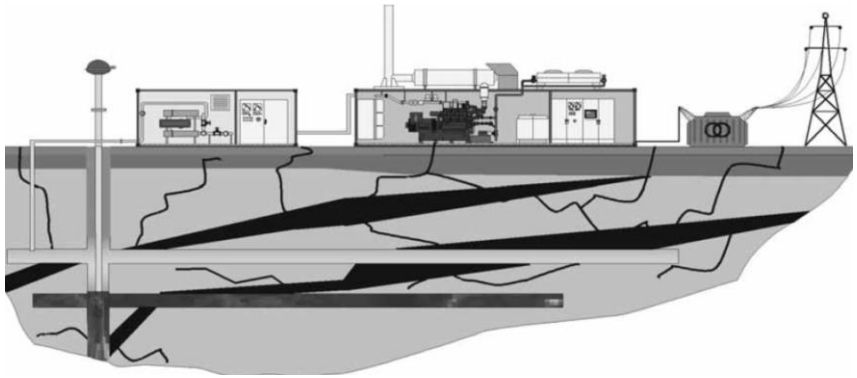
A New Approach to AMM Resources/Reserves Estimation in the Upper Silesian Coal Basin



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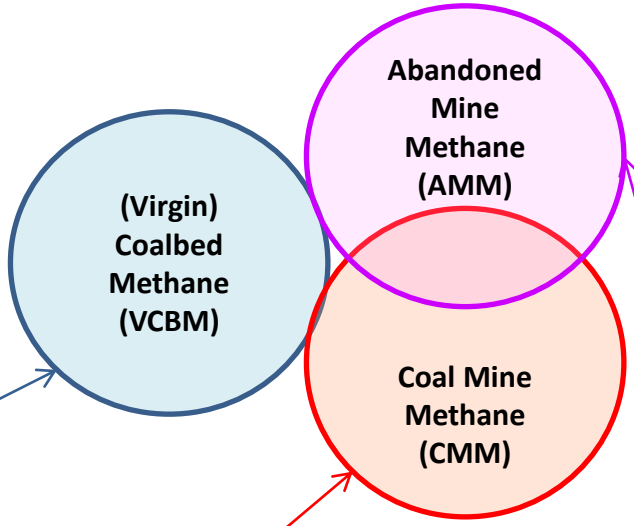
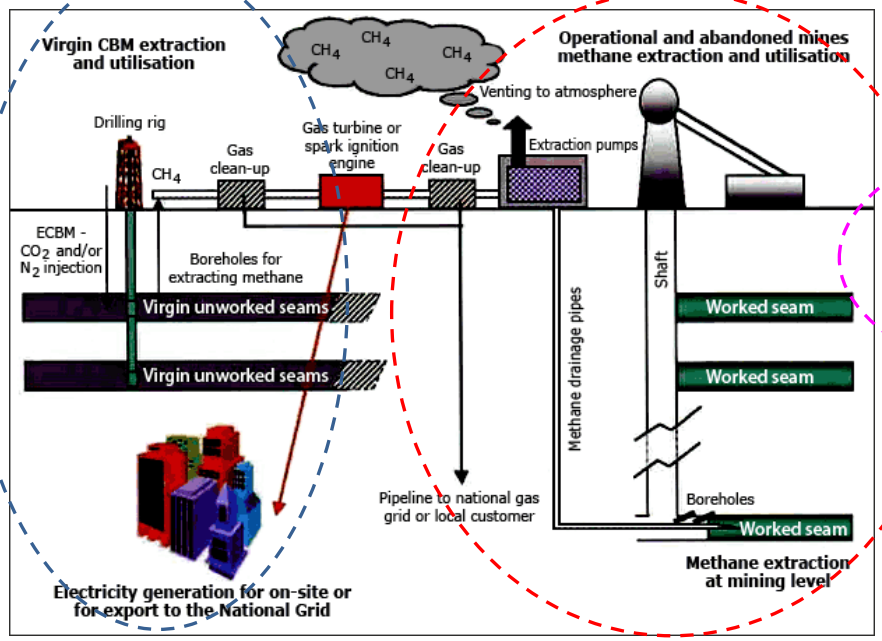
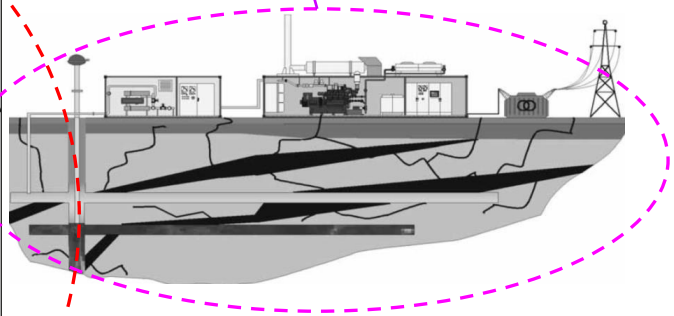
Definitions of Gas Reservoirs Related to Coalbed Methane







Existing Approach to AMM Resources/Reserves Estimation

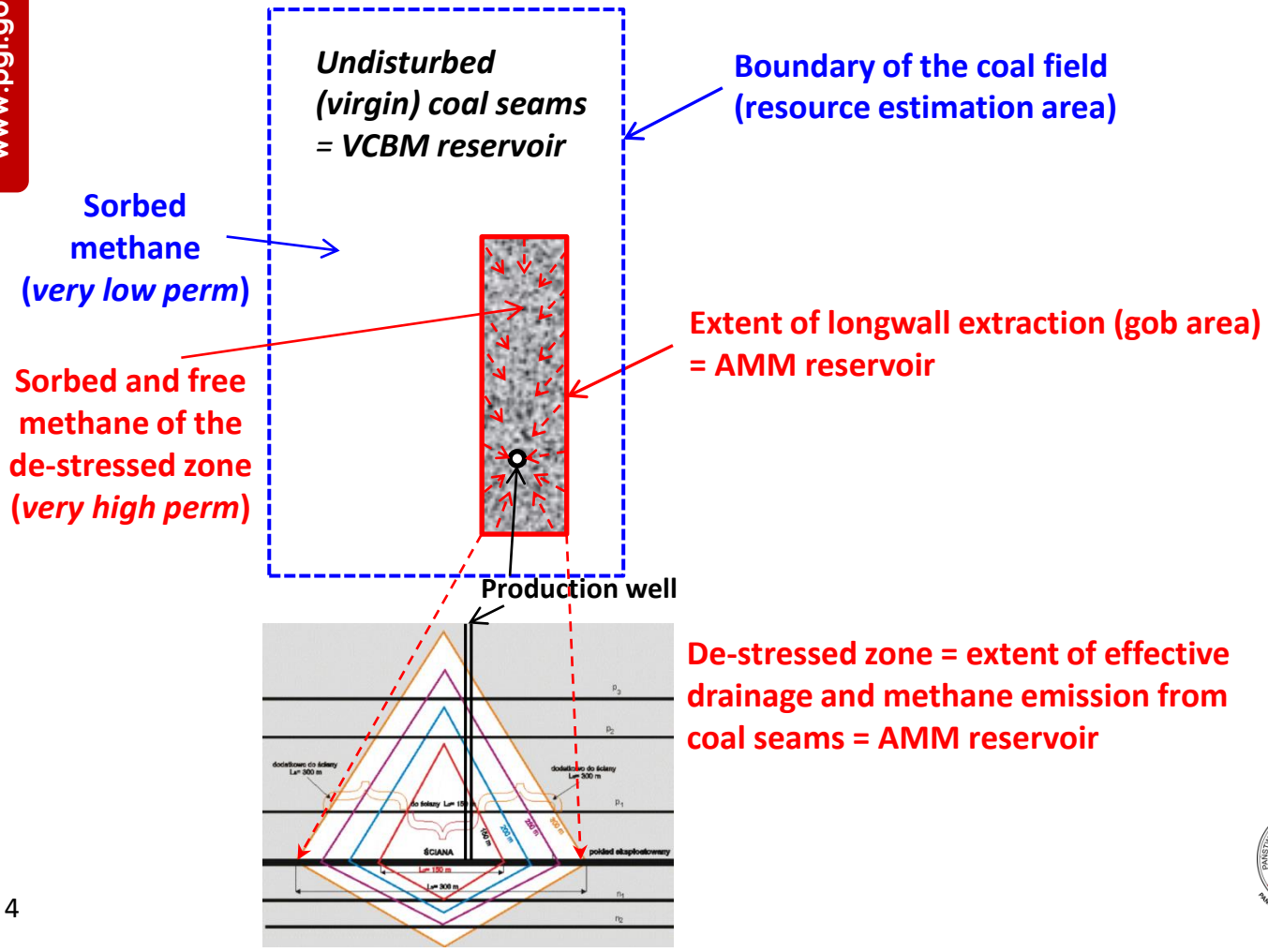
- **The Polish regulations concerning gas from coal deposits have influenced the way AMM resource is evaluated (AMM = VCBM).**
- **Recoverable resources and reserves are estimated.**
- **Technically recoverable resources (*QMt*) of methane from coal within the whole mining area:**

  QMt = QMs + QMd

  - ✓ ***QMs – free methane trapped in the gob zone, abandoned workings and porous rocks***
  - ✓ ***QMd – desorbable methane volume of the remaining unworked gassy coal.***
- **AMM reserves are estimated based on gas production prediction. Gas is planned to be produced using surface wells to gob zones, usually assuming constant flow rates over several years.**
- **Existing approach to AMM resources/reserves evaluation leads to certain problems that may result in reserves estimation errors. The two most important issues will be addressed.**

Gas Resources of Two Different Reservoirs are Commingled

- Two different reservoir types (AMM and VCBM) exist within the resource estimation area.
- As long as an AMM gas production method planned to be used, a significant contribution of desorbed gas from the VCBM reservoir is unlikely due to low permeability (typical of the USCB), and this portion of total gas resource should not be considered recoverable.



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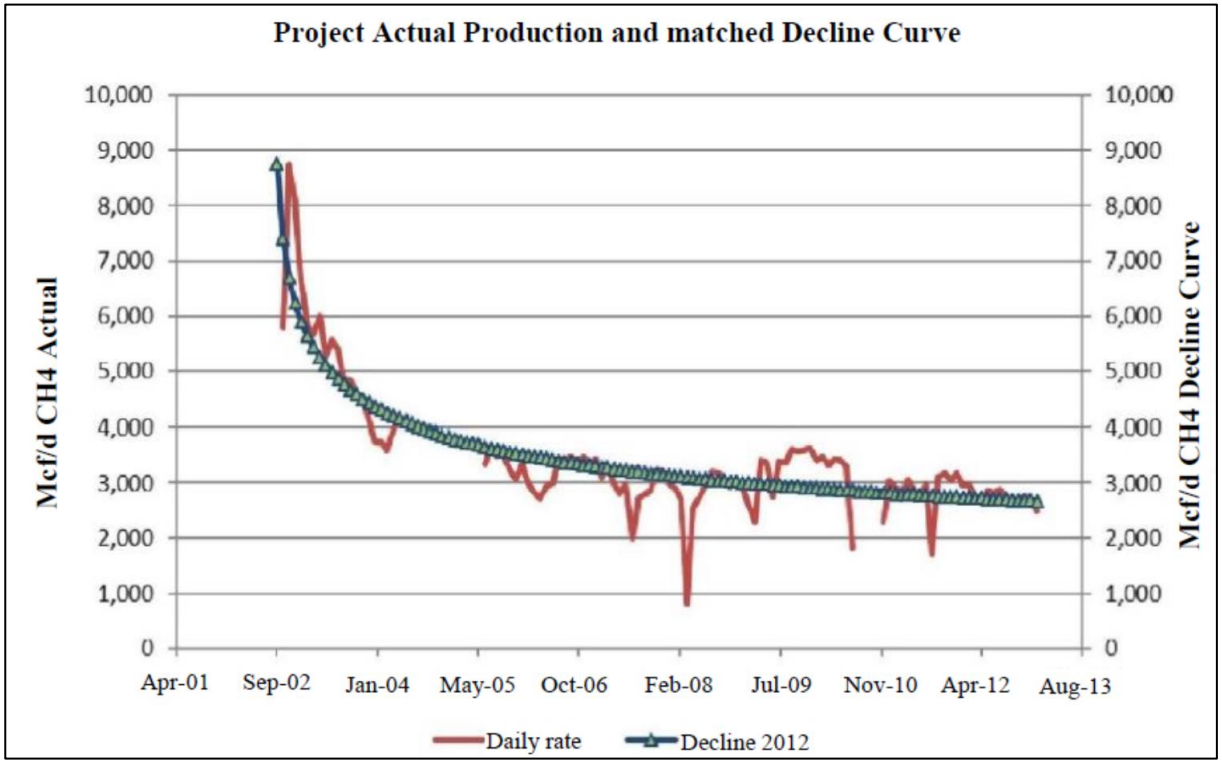
Declining Methane Emission after Mining is not Considered

- **The existing approach does not take into account declining rates of gas flow from unworked coal after mining, which may impact reserves estimates.**
- **Gas production prognosis should be optimized based on the volume of gas accessible for drainage determined using simulated gas emission data (e.g. exponential or hyperbolic decay curves).**



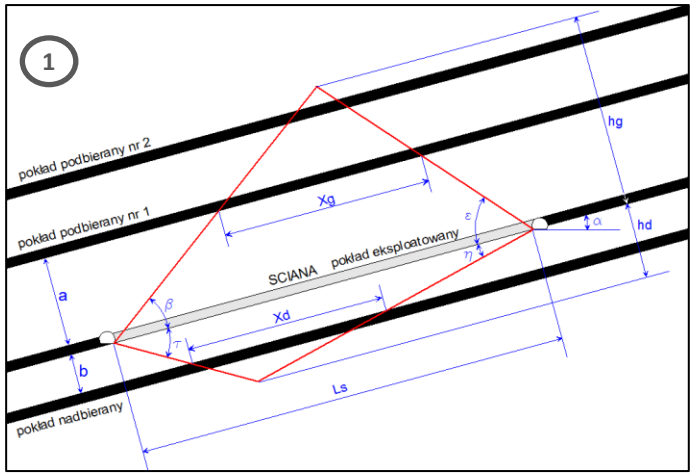
From „Best Practice Guidance for Effective Methane Recovery and Use from Abandoned Coal Mines" (UNECE, 2019)

A Modified Approach to AMM Resources/Reserves Estimation – Main Principals

- There are two types of gas reservoirs within the abandoned coal mining area that should be treated separately: AMM and VCBM.
- VCBM gas is not considered accessible for drainage as long as AMM production technology is planned to be used.
- AMM reservoir boundaries are defined by the extent of longwall de-stressing zones.
- Free gas and desorbable gas remaining in unworked coal that has been disturbed by longwall extraction is available for drainage.
- Based on these assumptions, free gas and desorbable gas of coal within the AMM reservoir boundaries is moveable gas, considered as technically recoverable resource.
- Reserves are estimated using reservoir simulation to predict the volume of gas accessible for drainage, taking into account measured gas emission data from the mine.

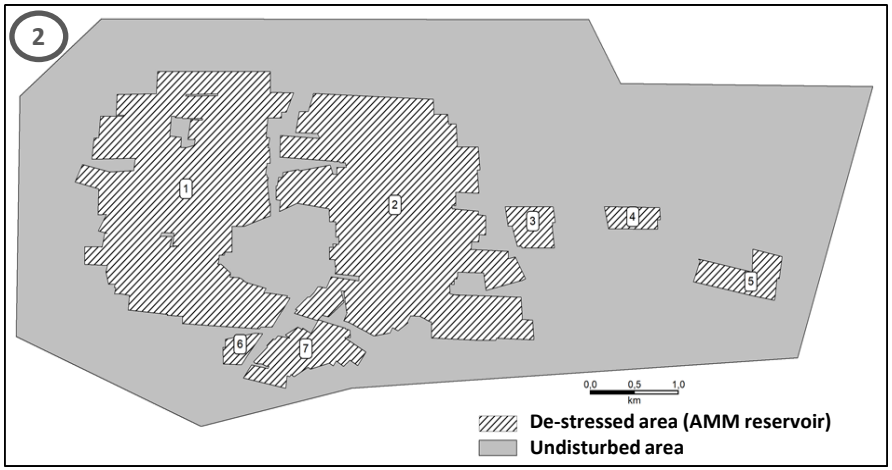
Definition of AMM Reservoir Boundaries

Determination of de-stressed zones for longwalls – cross-section

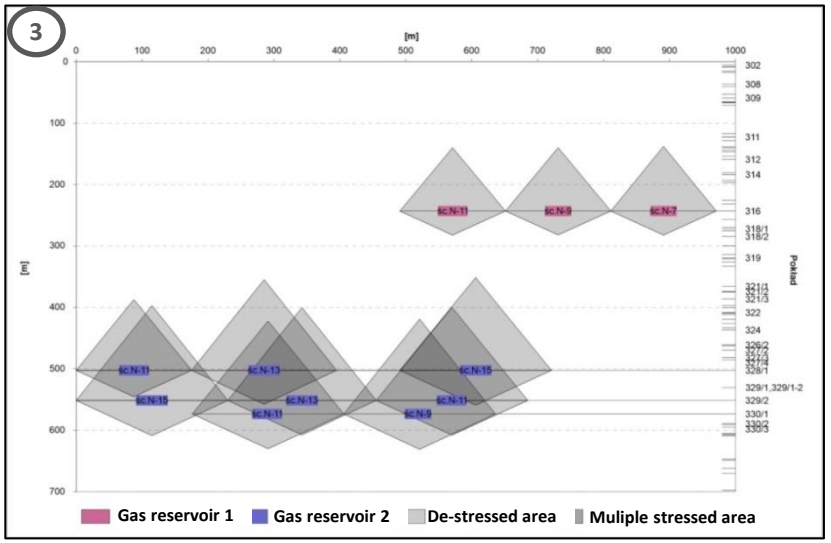


1) **De-stressed zone around an individual longwall is determined using the CMI methodology**
2) **De-stressed zones are then grouped to form mining disturbed areas in planar view**
3) **Gas reservoir - aggregated de-stressed zones which are interconnected enabling gas drainage**

Identification of mining disturbed areas – planar view



Gas reservoirs within a particular area – schematic cross-section



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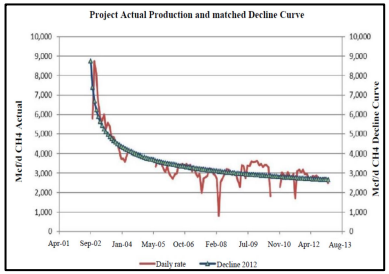
Estimation of AMM Resources and Reserves

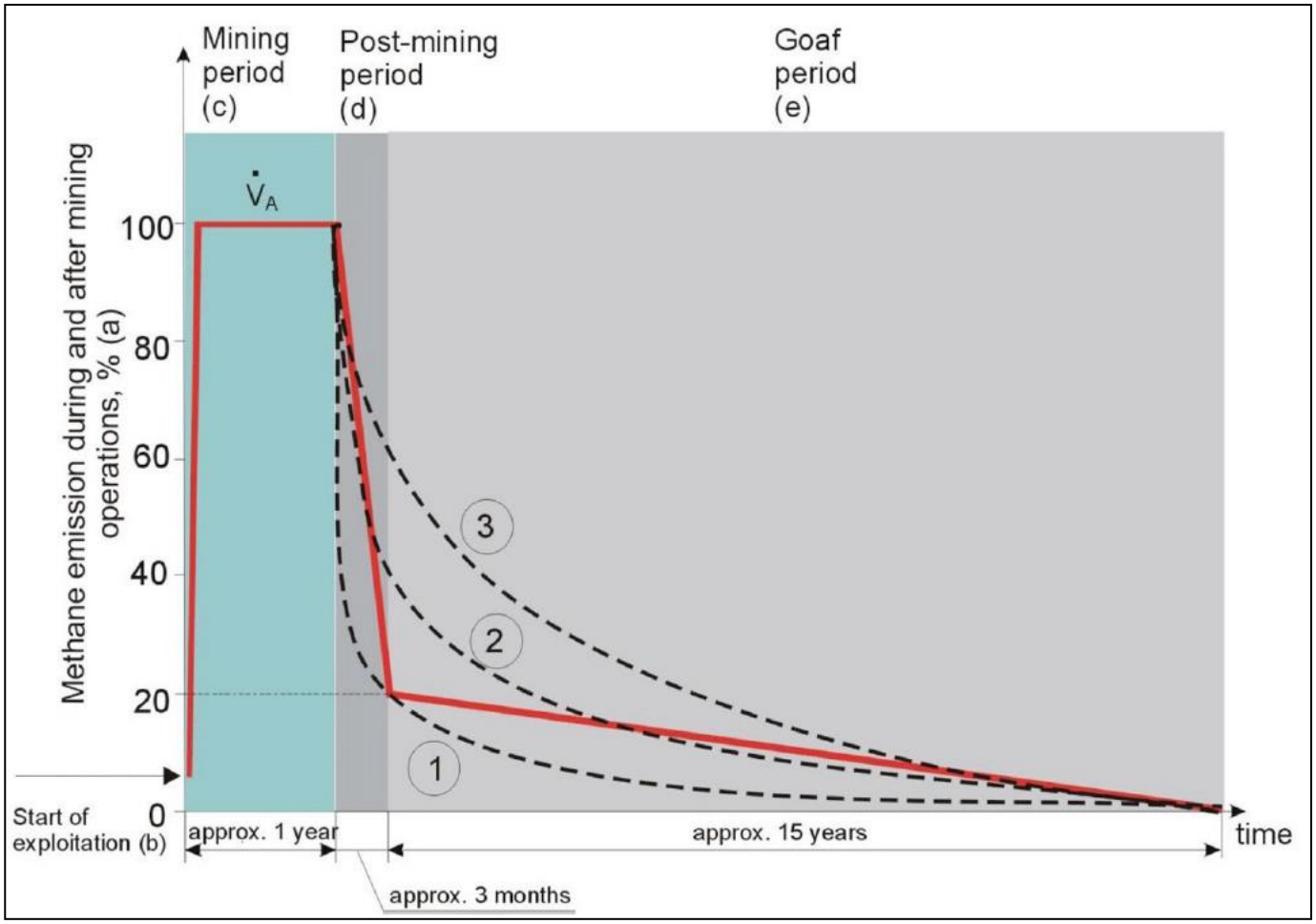
- AMM recoverable resources: *QMt = QMs (free methane) + QMd (desorbable methane).*
- Free methane gas resource (*QMs*) is estimated based on the total void volume (mine workings, gob zone, fractures and porous rocks) within the AMM reservoir boundaries.
- On the assumption that the source of methane emission is limited to the extent of gas reservoirs defined by de-stressed zone boundaries, desorbable methane resource (*QMd*) is estimated as a difference between the original desorbable methane resource (*QMo*) before mining and the total emission of methane (*Ec*) during and after mining (*QMd = QMo – Ec*).
- Original desorbable methane resource (*QMd*) is estimated using original coal gas content data and original coal resources prior to mining.
- Total emission of methane: *Ec = Ee +Ez*

  Ee – total emission of methane during coal extraction (cumulative emission as measured for each longwall)

  Ez - total emission of methane after coal extraction (cumulative emission as estimated for each longwall using CMI methodology).
- AMM reserves – prediction of commercial gas production based the total emission of methane after coal extraction for the post closure period, taking into account mine closure plans (e.g. flooding) and gas production technology.



Post Mining Methane Emission to Longwall Gobs (CMI methodology)



Model of methane emission to coal mine gobs *(After Krause and Pokryszka, 2013)*

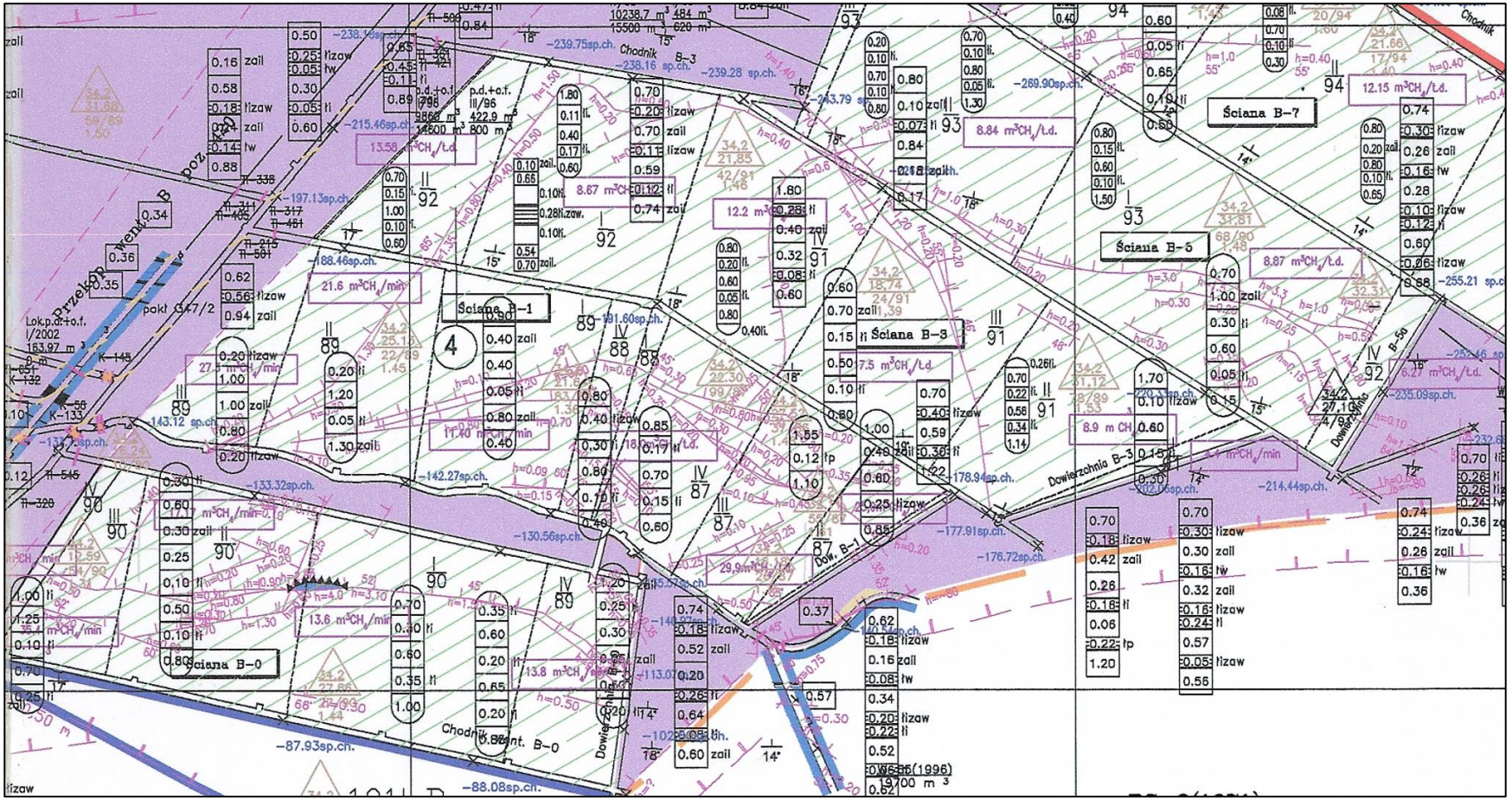
Case Study of AMM Resources/Reserves Estimation

- The Krupiński coal mine was active from 1983 to 2017, 16 coal seams were mined, within the depth range from 140 m to 1050 m; all coal seams were gassy with methane drainage.
- The most important task was to define AMM reservoir boundaries (=extent of de-stressed zones) as well as to estimate methane emission during and after longwall extraction with acceptable confidence and accuracy.
- AMM reservoir definition was performed based mining map data:
  - ✓ De-stressed zones were determined for 132 longwalls;
  - ✓ 7 mining disturbed areas were identified and mapped (in planar view);
  - ✓ 17 AMM gas reservoirs were identified, containing from 1 to 38 longwalls.
- Original CBM desorbable methane volume was estimated within the AMM reservoir (de-stressed zones) for each individual longwall based on CBM gas content data from coal appraisal wells drilled before mining, supplemented with in-mine boreholes and mine workings data.
- Methane emissions during and after coal extraction were estimated for each individual longwall and then aggregated to make the total emission of the AMM gas reservoirs.

Case Study Results

- The total emission of methane (*Ec*) from all the longwalls is 2,7 times greater than the original CBM gas resource (*QMo*) within the AMM reservoir boundaries. Therefore, desorbable methane resource (*QMd*) would be a negative value (*Ec* > *QMo*).
- As a result, we have been unable to determine AMM recoverable resources using this methodology because of one the following reasons (or their combinations):
  - ✓ Methane emissions are overestimated due to erroneous archive mining data;
  - ✓ Orginal coalbed methane content is underestimated due to poor quality or lack of coal gas content data;
  - ✓ There are additional gas drainage pathways, beyond the defined AMM reservoir, such as tectonic fractures with increased permeability due to mining.
- There are strong indications that the latest factor makes the greatest contribution. It is estimated that only 40% of the original coal resources which is a source of methane emission is within the AMM reservoir boundaries.
- This mine is known to have numerous faults and fractures cutting across longwalls, especially in the southern portion of the mine, near the Żory-Jawiszowice fault zone.

Possible Additional Gas Drainage Pathways - Faults and Fractures



Heavily faulted part of the mine near the Żory-Jawiszowice fault zone

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Conclusions

- Existing approach in AMM resources/reserves estimation leads to the following issues:
  - ✓ AMM and VCBM accumulations are commingled, while VCBM is unlikely to make any contribution to future gas production;
  - ✓ declining emission of methane after coal extraction is not taken into consideration making reserves estimation unreliable.
- In order to eliminate these issues, the existing approach to AMM resources/reserves estimation has been modified and applied to the recently closed mines.
- The presented case study showed that the total emission from longwalls (during and after mining) considerably exceeds the original CBM resource volume identified within the AMM reservoir boundaries.
- Additional gas drainage pathways extended beyond the defined AMM reservoirs are created in certain areas of the mine which are heavily faulted and fractured.
- The extent of the tectonically induced gas drainage zones, beyond the defined AMM reservoir, is too complicated to be determined.
- In this particular case, recoverable resources cannot be determined using volumetric methods, but they are assumed to be equal to total emission of methane during and after mining.
- The proposed new approach to AMM resources/reserves estimation should be used on a case by case basis and modified accordingly depending on geological and mining conditions.