Surface Mine Methane Emissions and Project Opportunities

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Select Country SMM Emissions

Country	Estimated Surface Mine Methane Emissions (Million cubic meters)	% of Total CMM Emissions	Year	Source
Russia	1,056	33%	2009	UNFCCC CRF
United States	903	18%	2009	USEPA (2011)
Indonesia	34	100%	2005	GMI (2010)
Mongolia	3.7	100%	2008	GMI (2010)
Philippines	0.22	92%	2008	GMI (2010), IPCC (2006)
India	43	2%	2008	GMI (2010), IPCC (2006)
Viet Nam	3.2	6%	1994	GMI (2010)

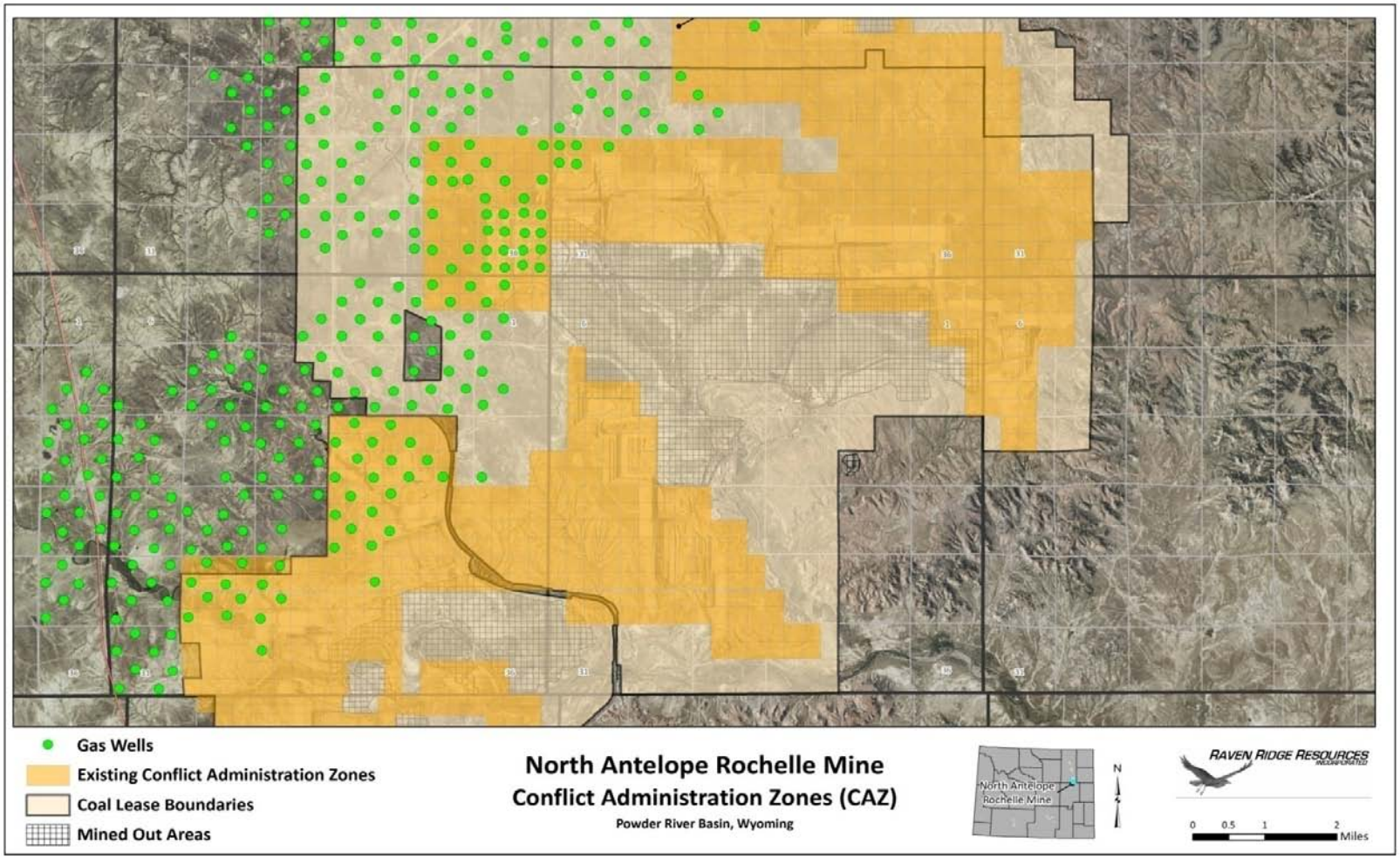
GMI (2010): Coal Mine Methane Country Profiles. Global Methane Initiative. December, 2010. http://globalmethane.org/tools-resources/coal_overview.aspx; IPCC (2006): 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 2: Energy, Chapter 4: Fugitive Emissions. http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_4_Ch4_Fugitive_Emissions.pdf; UNFCCC Common Reporting Format, August 21, 2011; USEPA (2011): Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2009. USEPA #430-R-11-005. April, 2011. http://www.epa.gov/climatechange/emissions/usinventoryreport.html

Initiatives for Surface Mine Methane Drainage

Initiatives for Surface Mine Methane (SMM) Drainage

- 2003: U.S. Bureau of Land Management (U.S.BLM)
  - Conflict Administration Zones (CAZs)
- 2005: EPA Surface Mine Methane Assessment (internal report)
- 2009: U.S. Verified Carbon Standard (VCS) methodology
- 2010: Clean Development Mechanism (CDM) methodology
  - ACM0008 version 7 now includes opencast/surface mines

U.S. Surface Mine showing CAZ



Accommodating the Variability in Surface Mine Design

Variability in Surface Mine Design

Challenges to Pre-Mine Drainage

- Strip Mine
  - Mine develops along strike of the coal seam
  - Mine can be developed in tiers or contours parallel to strike
  - As each strip is mined, the waste rock is placed in the excavation produced by the previous strip.

Strip Mine

Strip mine near Palangka Raya, Central Kalimantan, Indonesia.

http://www.kalimantancoal.com/2011/01/coal-indonesia/

Variability in Surface Mine Design

Challenges to Pre-Mine Drainage

- Open-Pit Mine
  - Numerous levels or benches (stepped from surface to bottom of pit
  - Pit walls designed for slope stability and prevention of rock falls or wall failure
  - Haulage road located along side of pit to remove coal and waste rock
  - Waste rock is piled at surface near edge of pit

Open-Pit Mine

Panian Mine, Semirara Island, Philippines

Approaches to Drainage

Vertical in Advance of Mining

- Boreholes are shut-in as mining approaches/evidence of air in produced gas
- Surface equipment and casing is removed prior to mine-through
- Timing – producing as far in advance of mining as possible
- Applicable to strip mines

Figure 1: Pre Mine Drainage

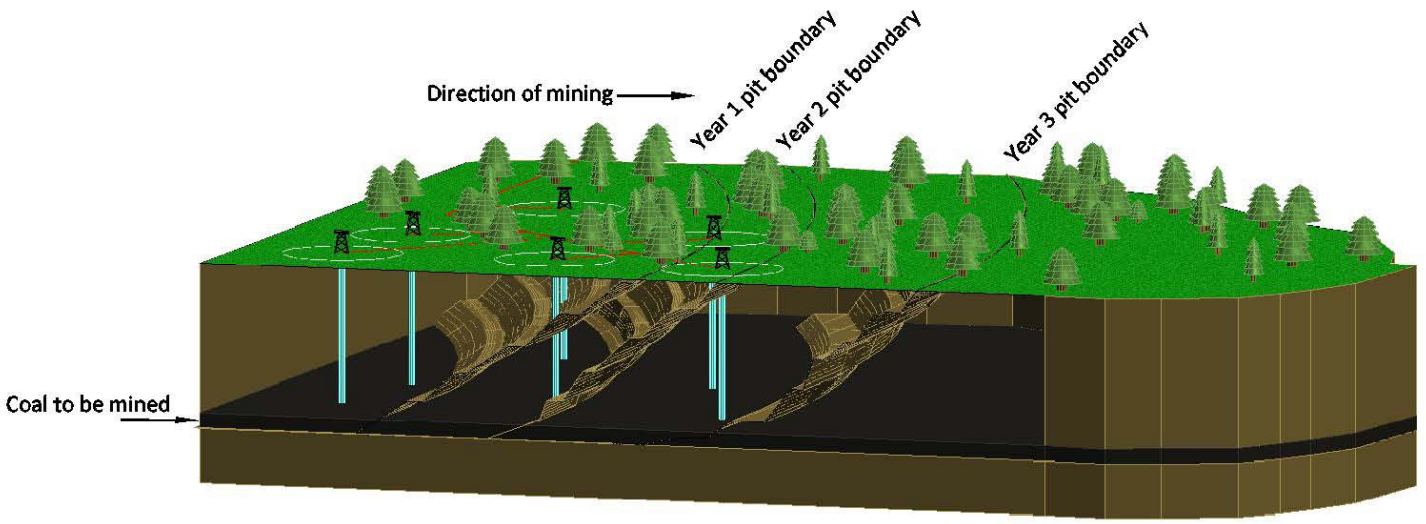
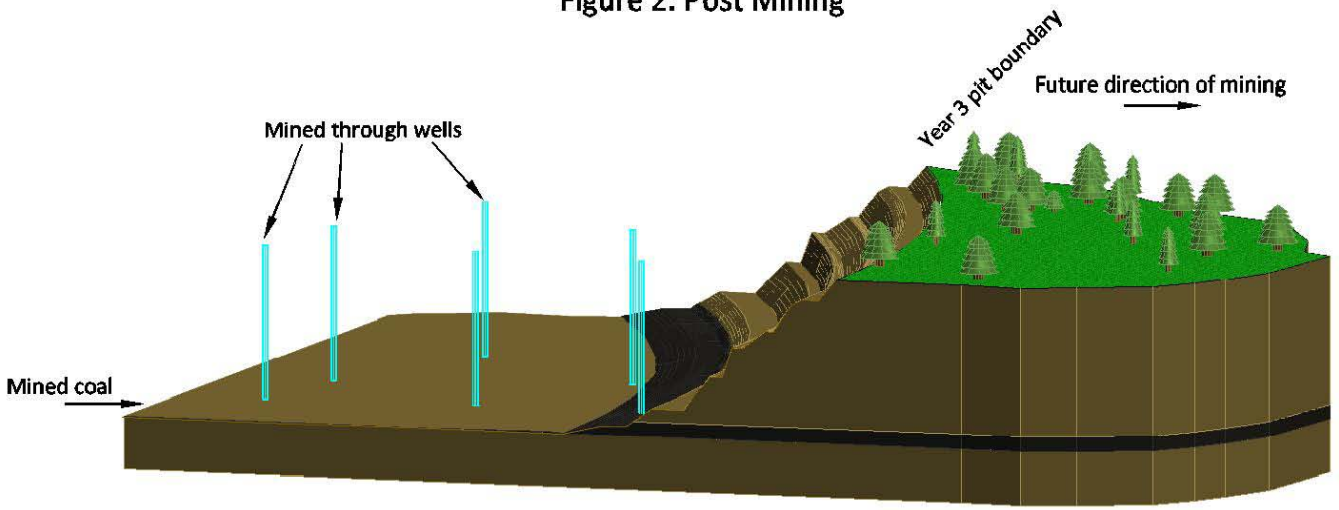


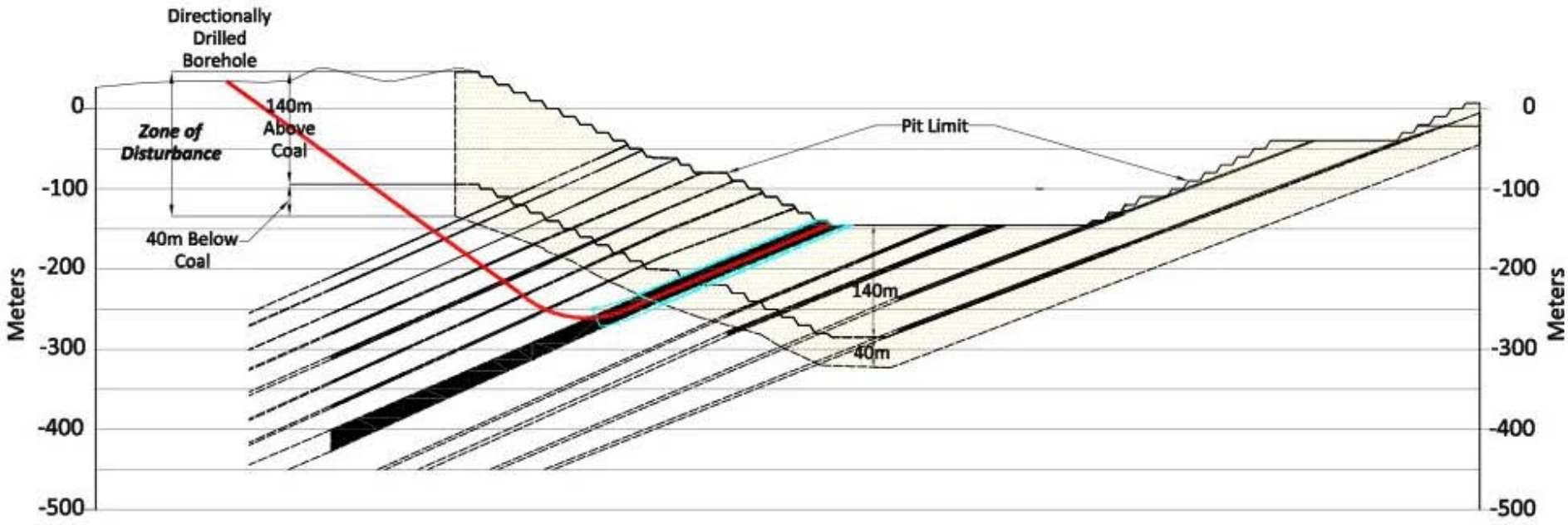
Figure 2: Post Mining



Lateral in Advance of Mining

- Depending on placement, boreholes may continue to produce during mining and post mining
- Applicable to some single seam strip mines and to open pit mines
- May access more coal if sidetracks are employed

Laterally-drilled Borehole



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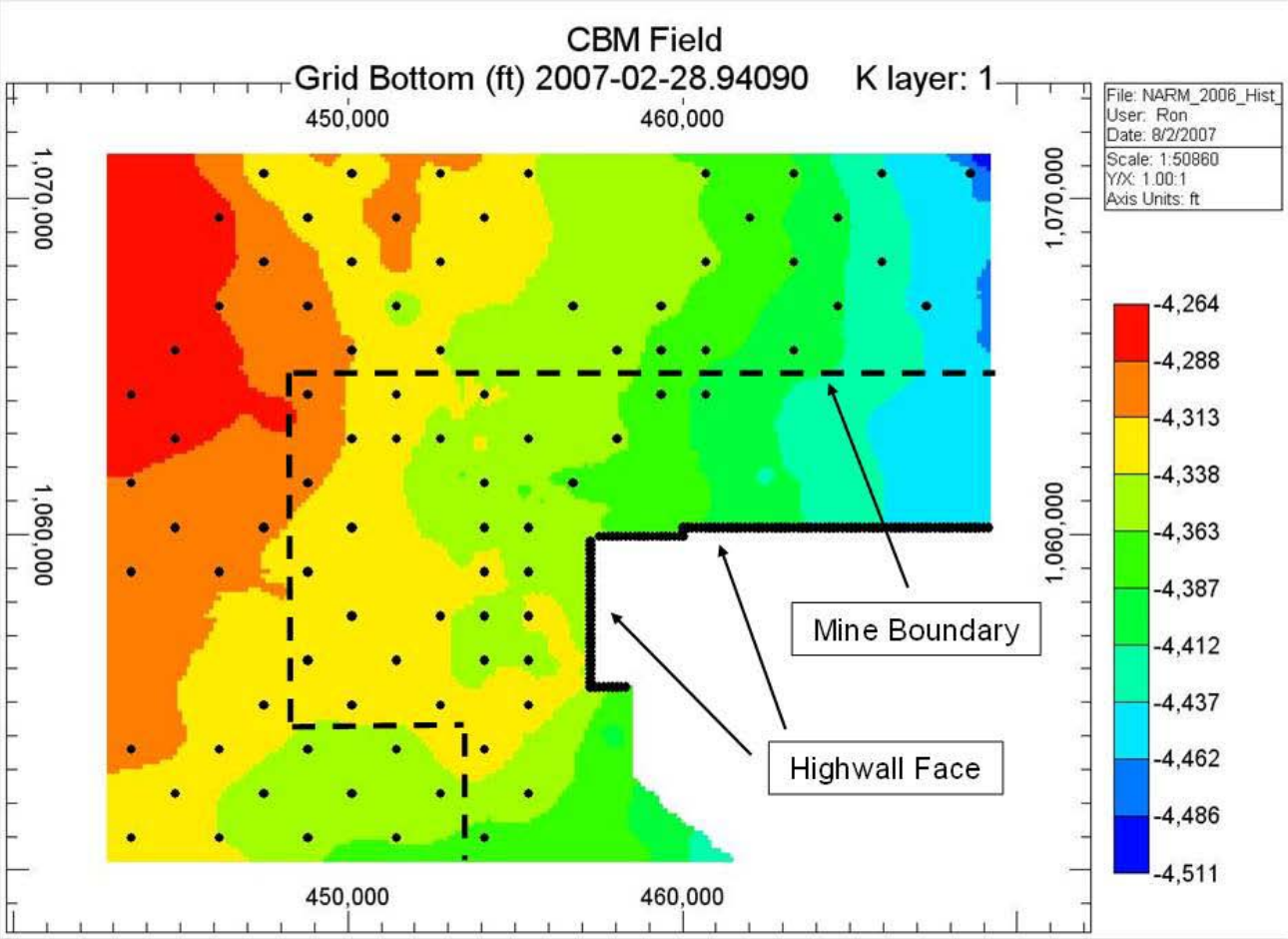
Surface Mine Drainage Considerations

- Coordination of gas drainage project development with mining operations is essential
- Surface logistics
  - Waste piles, storage, space issues
  - Gas transportation
    - Permanent vs. temporary gathering lines

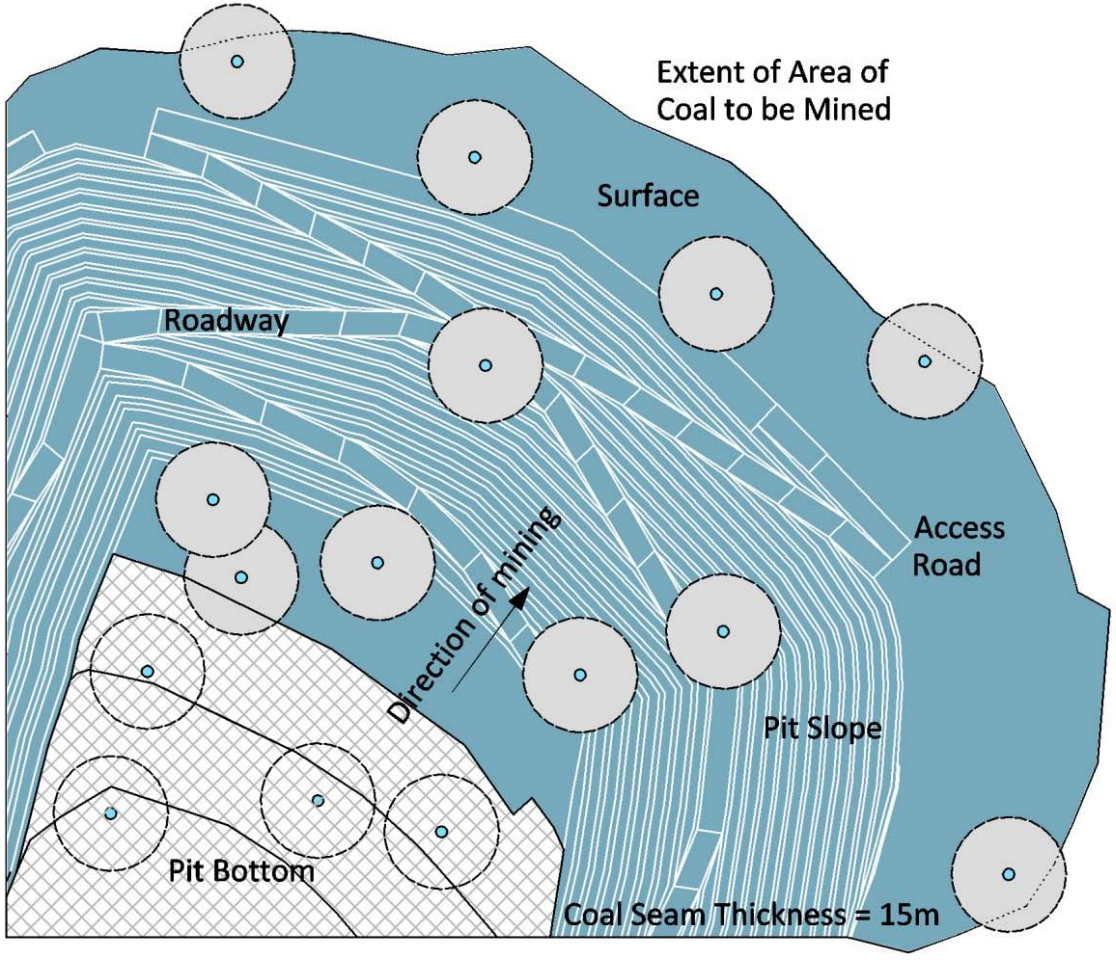
Qualifying Surface Mine Methane Production

Qualifying Production Under VCS



NARM PDD:
https://vcsprojectdatabase1.apx.com/mymodule/ProjectDoc/Project_ViewFile.asp?FileID=70&IDKEY=niquwesdfmnk0iei23nnm435oiojnc909dsflk9809adlkmlkf496530

Qualifying Production Under CDM



ACM0008: http://cdm.unfccc.int/methodologies/DB/OA37XAW7EI9WHJVZ97RGH2EZ5S9E93/view.html

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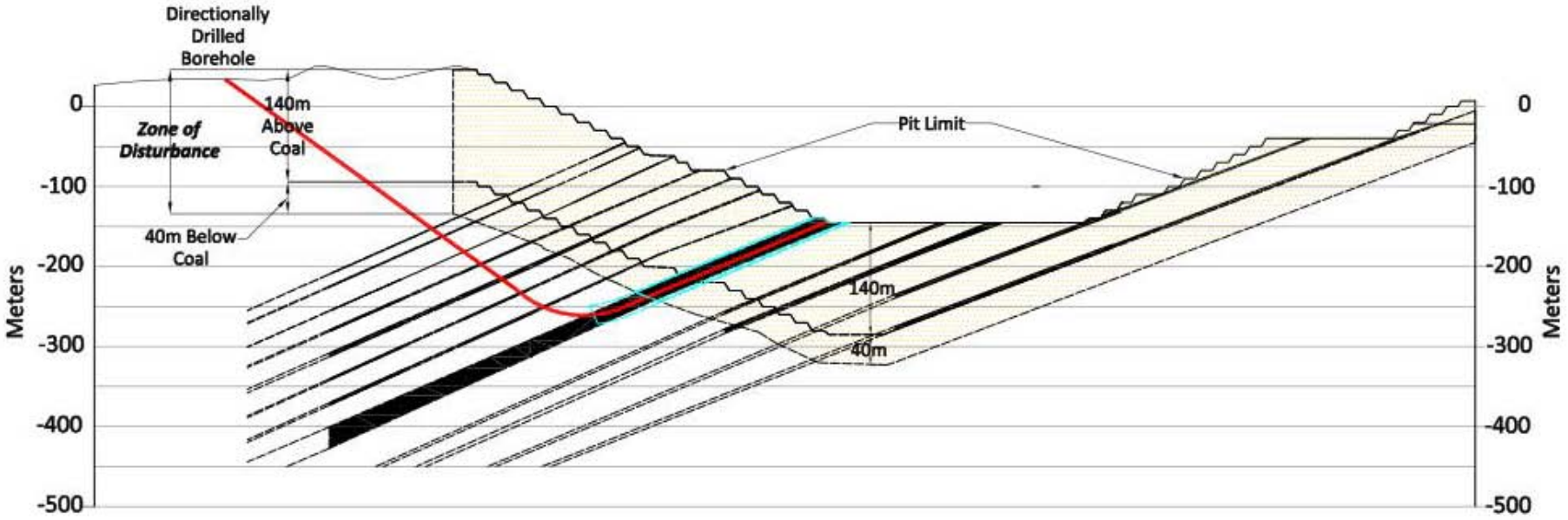
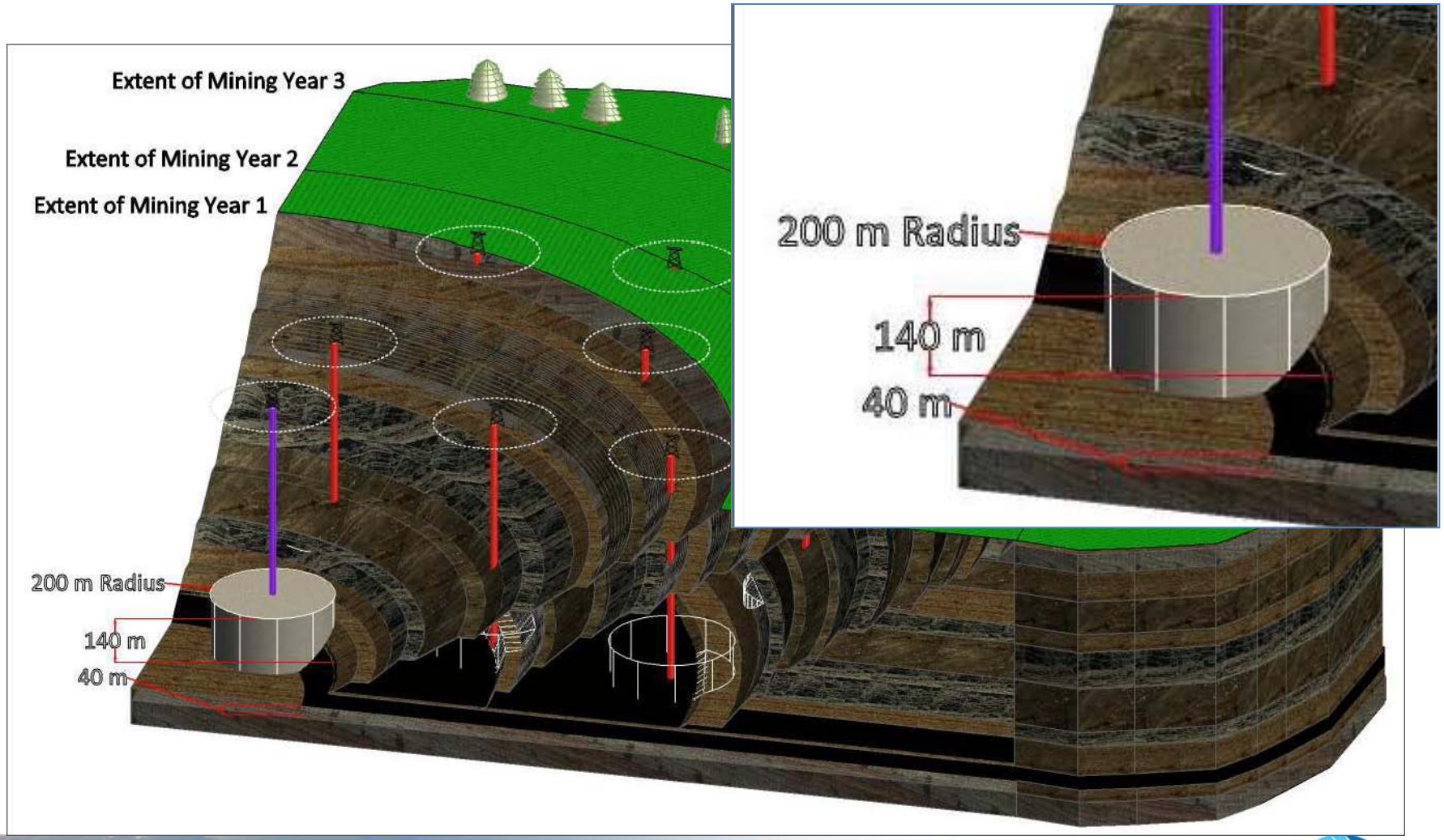
Understanding the Zone of Disturbance

The Zone of Disturbance

- Drilling into the Zone of Disturbance using a laterally drilled borehole
- According to ACM0008, the zone of disturbance is "typically 140 m above and 40 m below the targeted coal seam"



The Zone of Disturbance

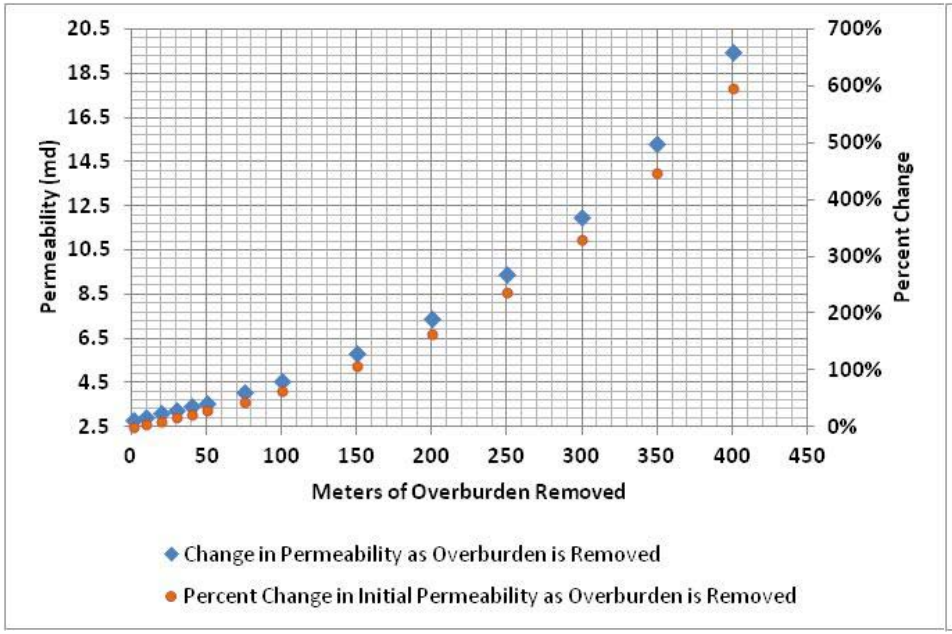


Overburden Removal Increases Permeability

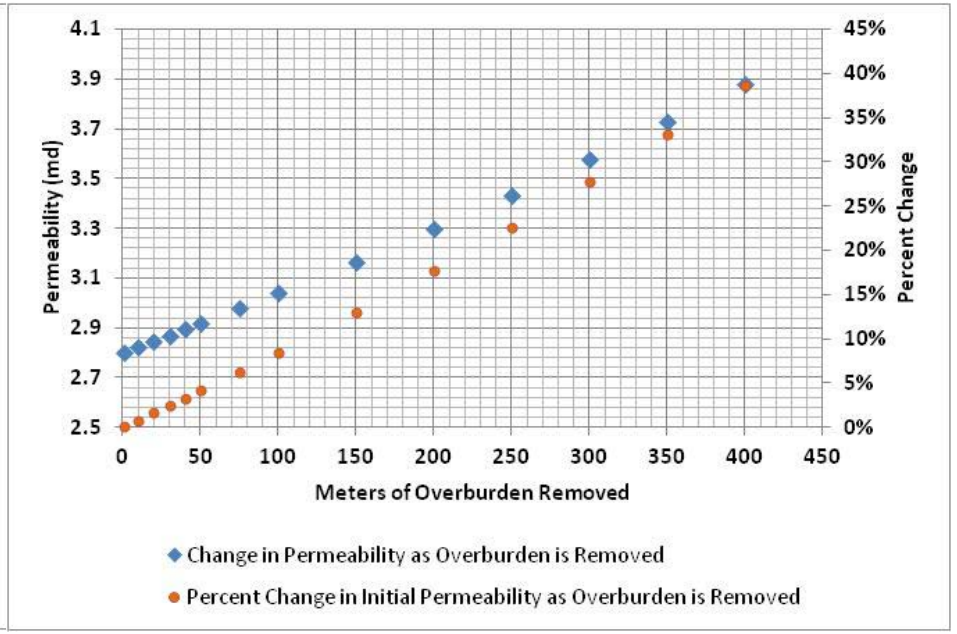
- Permeability increases exponentially with decreasing effective stress
- Effective stress is diminished as overburden is removed during mining
- Permeable pathways occurring in geologic structures such as breached folds or faults are enhanced as overburden is removed.
- Matrix and fracture permeability is enhanced as a function of the stiffness of the rock mass, density of fracturing and thickness of overburden removed.

Impact of Rock Stiffness on Increases in Permeability as Overburden is Removed

Medium-Volatile Bituminous Coal



Sub-bituminous Coal



Fracture compressibility for bituminous coal from *A New Coal-Permeability Model: Internal Swelling Stress and Fracture-Matrix Interaction* by Hui-Hai Liu and Jonny Rutqvist, Transp Porous Med (2020) 82: 157-171.

Fracture compressibility for sub-bitumious coal , high volatile bituminous and equation for relationship between overburden removal and permeability increase from *Improvements in Measuring Sorption-Induced Strain and Permeability in Coal* by E.P. Robertson, SPE 116259, 2008 SPE Eastern Regional/AAPG Eastern Section Joint Meeting held in Pittsburgh, Pennsylvania.

Opportunities for Emissions Reductions

Estimated Emission Reductions from Surface Mine Projects

Project	Average Annual Emission Reductions (tCO_2e)	Emission Reductions for Crediting Period (tCO_2e)
Wahana Baratama, Indonesia	207,111	1,449,778
Semirara, Philippines	385,478	2,698,346
North Antelope Rochelle, Wyoming, USA	90,463	904,628

Wahana Baratama Coalbed Methane Generation Project PDD: http://cdm.unfccc.int/Projects/Validation/DB/9Y4C1SLSOQIMHIZGRXF053RFNRQERO/view.html; Semirara Coalbed Methane Generation Project PDD: http://cdm.unfccc.int/Projects/Validation/DB/YCCWHT4J05P2A4OSN6LGDGK9RYEBXQ/view.html; NARM PDD: https://vcsprojectdatabase1.apx.com/mymodule/ProjectDoc/Project_ViewFile.asp?FileID=70&IDKEY=niquwesdfmnk0iei23nnm435oiojnc909dsflk9809adlkmlkf496530

End-Use Options

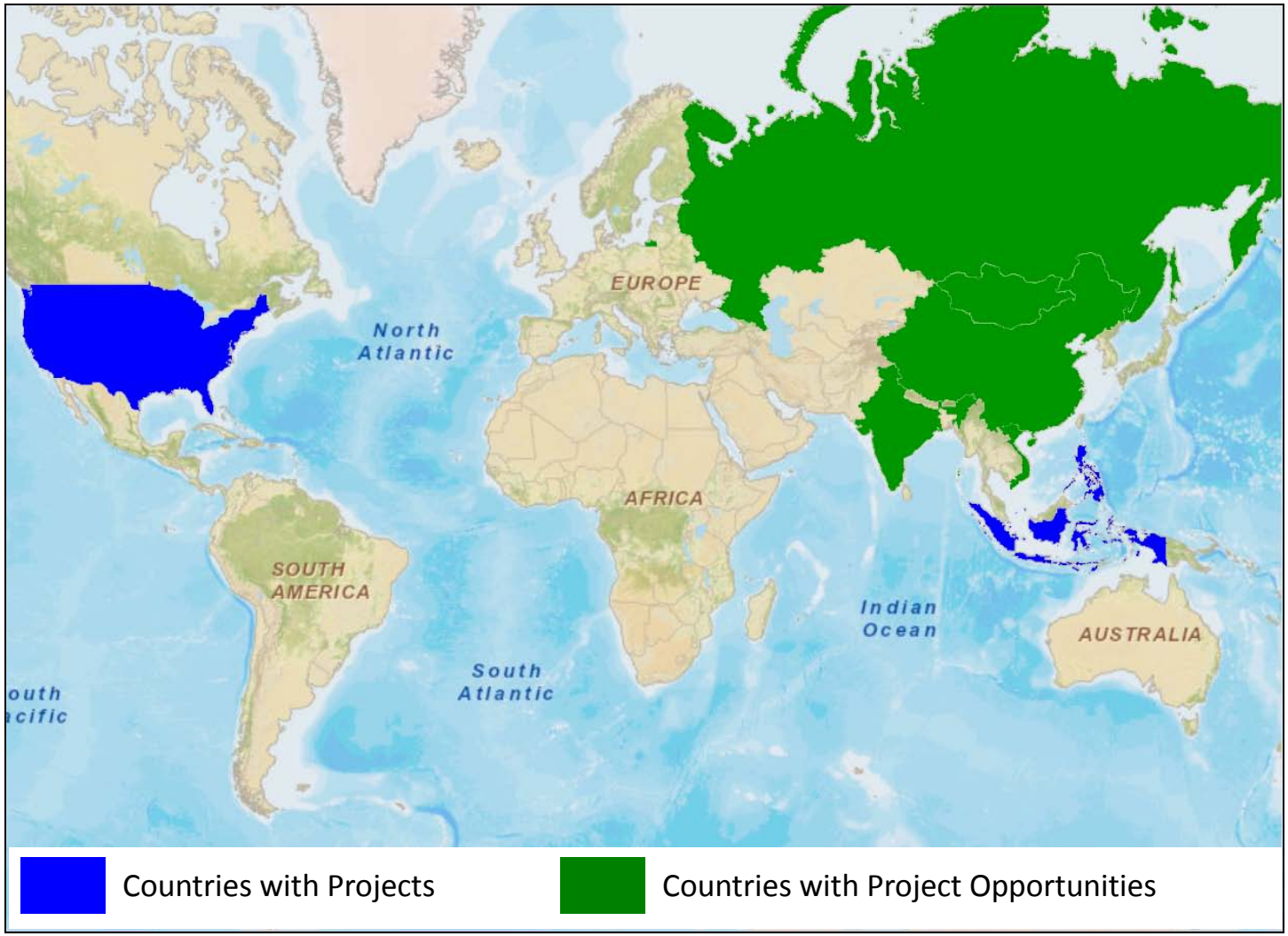
Pipeline Sales

Power Generation

Flaring

CNG/LNG

Prospective Opportunities



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Conclusions

Conclusions

- Revision to ACM0008 and voluntary carbon market opportunities have put the spotlight on SMM
- Worldwide SMM market is untapped
- SMM development considerations vary greatly
  - Mining method
  - Location
  - End use market

Thank You

For more information…

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US EPA Coalbed Methane Outreach Program

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http://epa.gov/cmop/resources/active_surface_mines.html