Pre-Feasibility Study for Methane Drainage and Utilization at the San Juaquin Mine, Antioquia Department, Colombia

Workshop on Best Practices in Coal Mine Methane Capture and Utilization

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Outline

1. Study Overview and Objectives
2. Mine Characteristics
3. Technical Assessment
4. Project Economics
5. Recommendations and Next Steps

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Study Overview and Objectives

- Mina San Juaquin De Propiedad De Carbones San Fernando S.A.S (San Juaquin Mine), a subsidiary of Grupo Corporativo Vatia S.A.S (Vatia), was selected as the recipient for a pre-feasibility study in 2016 for CMM drainage at their San Juaquin Mine in Amagá Basin.
- Sponsored by Global Methane Initiative (GMI), published June, 2017.
- Principal objective of study is to determine the feasibility of a CMM capture and utilization project at San Juaquin Mine.
- Specifically, study aims to evaluate the technical and economic viability of methane drainage.
- Study also highlights some reservoir data deficiencies that create uncertainty in many resource and reserve assessments in Colombia.

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San Juaquin Mine, Colombia

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Mine Characteristics

- The San Juaquin Mine currently produces approximately 180,000 tons of coal per year.
- Existing mine boundary of the San Juaquin Mine currently covers an area of 1,207 acres; estimated operational life span of over 50 years.
- Coal mines in this region are notoriously gassy and prone to constant explosion related accidents, and the San Juaquin Mine is one of the gassiest.
- While the mine has implemented ventilation techniques for mine gas management, there is currently no methane drainage system in place.

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Mine Characteristics (continued)

- The Manto 1 (~2m), Manto 2 (~1.5m), and Manto 3 (~1.5m) coal seams at the San Juaquin Mine are considered to be gassy with gas contents estimated to range from 248 to 251 scf/ton within the project area.
- Based on these gas content values, it is estimated that the mine holds approximately 8.1 Bcf of gas resources.
- The mine primarily uses a non-mechanized longwall mining method to extract coal along the strike of the coal seams.
- Production is carried out at two separate longwall faces at a time (in different seams) utilizing a longwall mining system designed for panels 2,297 ft in length by 591 ft in width.
- Current mine plans include mining only in the Manto 1 and Manto 2 seams.

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Technical Assessment

- Based on a detailed review of data provided by the mine, the following drilling options are proposed for methane drainage.
  - **Vertical Pre-Drainage Boreholes**: These boreholes will target all three coal seams and five well spacing cases will be assessed, ranging from 10-ac to 160-ac per well.
  - **In-Seam Pre-Drainage Boreholes**: In-seam gas drainage boreholes will be drilled in parallel to advance and flank the gate road developments. Long, directionally drilled boreholes will cover the entire length of each panel from a single setup location to shield and drain gas ahead of development galleries.

Summary of Drainage Scenarios Evaluated

Scenario	Drainage Approach	Seam(s)	Spacing Case
1 (V1)	Vertical	Manto 1, 2 & 3	10-ac
2 (V2)	Vertical	Manto 1, 2 & 3	20-ac
3 (V3)	Vertical	Manto 1, 2 & 3	40-ac
4 (V4)	Vertical	Manto 1, 2 & 3	80-ac
5 (V5)	Vertical	Manto 1, 2 & 3	160-ac
6 (H1)	In-Seam	Manto 1	1-bh/panel
7 (H2)	In-Seam	Manto 1	2-bh/panel
8 (H3)	In-Seam	Manto 1	3-bh/panel
9 (H4)	In-Seam	Manto 2	1-bh/panel
10 (H5)	In-Seam	Manto 2	2-bh/panel
11 (H6)	In-Seam	Manto 2	3-bh/panel

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Reservoir Simulation

- Separate reservoir models were constructed to simulate gas production volumes from vertical pre-drainage boreholes and long in-seam pre-drainage boreholes.
- For the vertical wells, a total of five, three-layer models were constructed to accommodate each of the well spacing cases. The models were each run for 30 years in order to simulate gas production.
- For the in-seam boreholes, a total of six single-layer models were constructed. All boreholes are drilled into a coal block with a dip angle of 15 degrees and are assumed to be 2,296 ft in lateral length. The models were each run for five years.

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Reservoir Simulation (continued)

- While reservoir simulation requires the input of more than 20 parameters, several key reservoir parameters control about 80% of the production potential of a coal seam reservoir:
  - Permeability: ~40%
  - Gas Content/Gas Saturation: ~40%
  - Other Parameters: ~20

    (Porosity, Cleat Density, Sorption Time, Matrix Shrinkage, etc.)

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Reservoir Parameters for San Juaquin Mine

Reservoir Parameter	Value(s)			Source / Notes	Confidence
	Manto 1	Manto 2	Manto 3		
Coal Depth (Top), ft	1641	1723	1772	Mine data	High
Coal Thickness, ft	5.9	4.6	4.6	Mine data	High
Coal density, g/cc	1.3	1.3	1.3	Assumption; Clean coal	High
Pressure Gradient, psi/ft	0.433	0.433	0.433	Assumption; Hydrostatic	Moderate
Initial Reservoir Pressure, psia	712	747	768	Calculated from midpoint depth and pressure gradient	Moderate
Initial Water Saturation, %	100	100	100	Assumption	High
Langmuir Volume, scf/ton	301	301	301	Assumption; Typical for High-Volatile A Bituminous	Low
Langmuir Pressure, psia	153	153	153	Assumption; Typical for High-Volatile A Bituminous	Low
In Situ Gas Content, scf/ton	248	250	251	Calculated from reservoir pressure and isotherm	Low
Desorption Pressure, psia	712	747	768	Desorption pressure equal to initial reservoir pressure (fully saturated conditions)	Low
Sorption Times, days	36	36	36	Assumption	Low
Fracture Spacing, in	2.56	2.56	2.56	Assumption	Moderate
Dip Angle of Face, degrees	15	15	15	Mine data	High
Absolute Cleat Permeability, md	0.5; 1.0; 5.0	0.5; 1.0; 5.0	0.5; 1.0; 5.0	Unknown; Three cases evaluated	Low
Cleat Porosity, %	2	2	2	Assumption; Typical for coal rank	Low
Pore Volume Compressibility, psi $^{-1}$	4.00E-04	4.00E-04	4.00E-04	Assumption	Moderate
Matrix Shrinkage Compressibility, psi $^{-1}$	1.00E-06	1.00E-06	1.00E-06	Assumption	Moderate

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Missing or Unreliable Key Data for the San Juaquin Mine

- Permeability: Not measured.
- Gas Content Data: Not representative of in-situ conditions; vertical core well only sampled to a depth of 140 m, whereas the mine is 500 m deep; core samples from within the mine were taken from only 15 to 20 m back from a long exposed coal face.
- Isotherms: Unreliable due to their irregular shape (see next slide).
- Gas Saturation: Unknown without reliable gas content and isotherm data.

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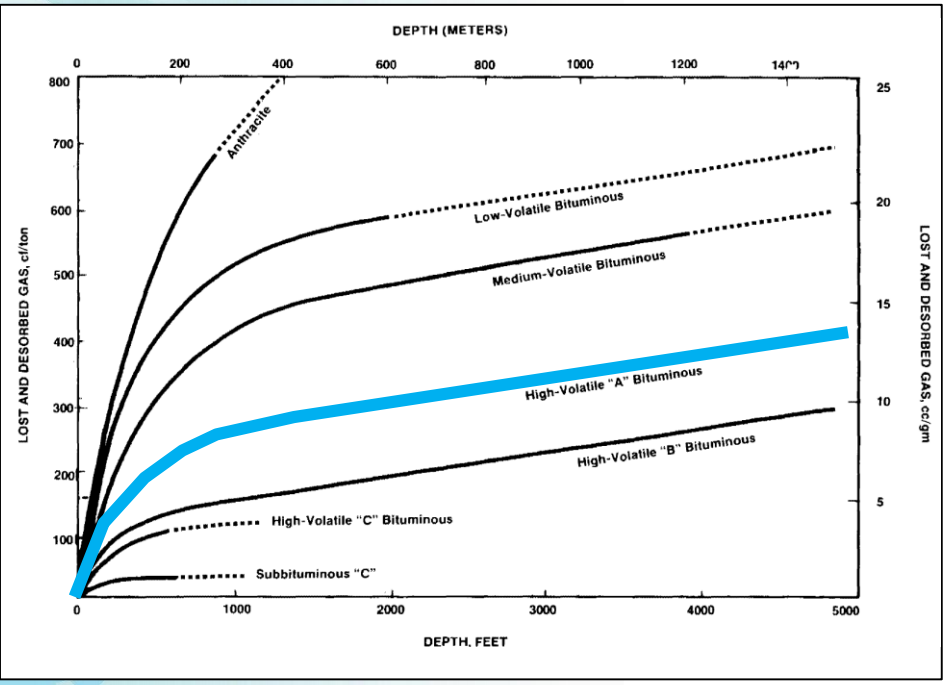
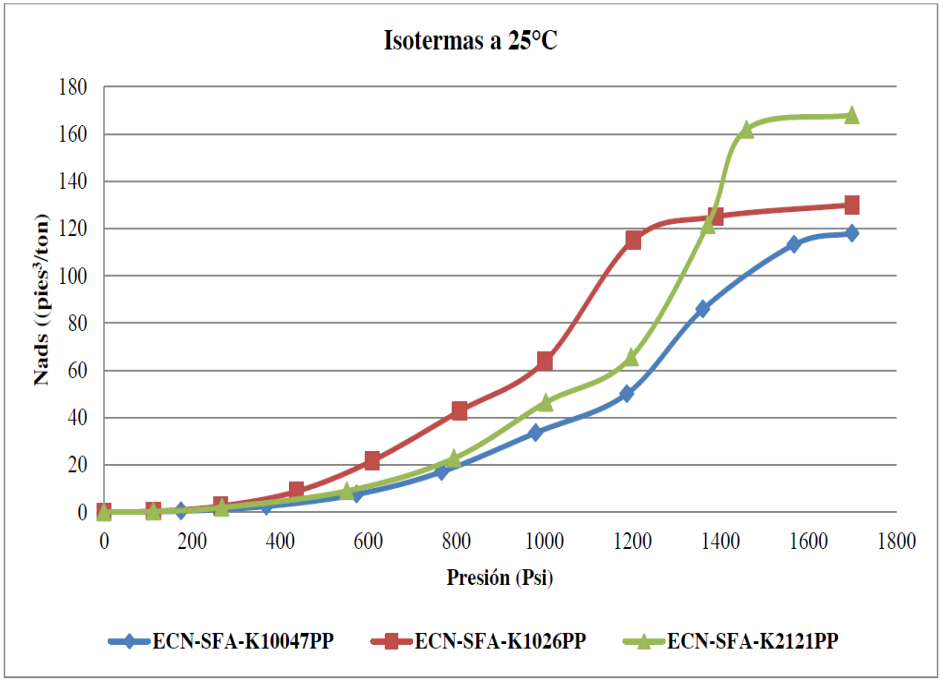
Comparison of Standard Isotherm Data with Isotherms Generated for the San Juaquin Mine

Gas Content vs. Depth Curves



Reliable laboratory measured Langmuir volumes and pressures for the study area were not available. As a result, Langmuir volume and pressure values for isotherms typical of high-volatile A bituminous coal were utilized in the current study.

CH_4 Isotherm for Manto 2



Methane isotherms provided do not fit traditional isotherm shape. Data not reliable.

Eddy, G. E., Rightmire, C. T., & Byrer, C. W. (1982, January 1). Relationship of Methane Content of Coal Rank and Depth: Theoretical vs. Observed. Society of Petroleum Engineers. doi:10.2118/10800-MS

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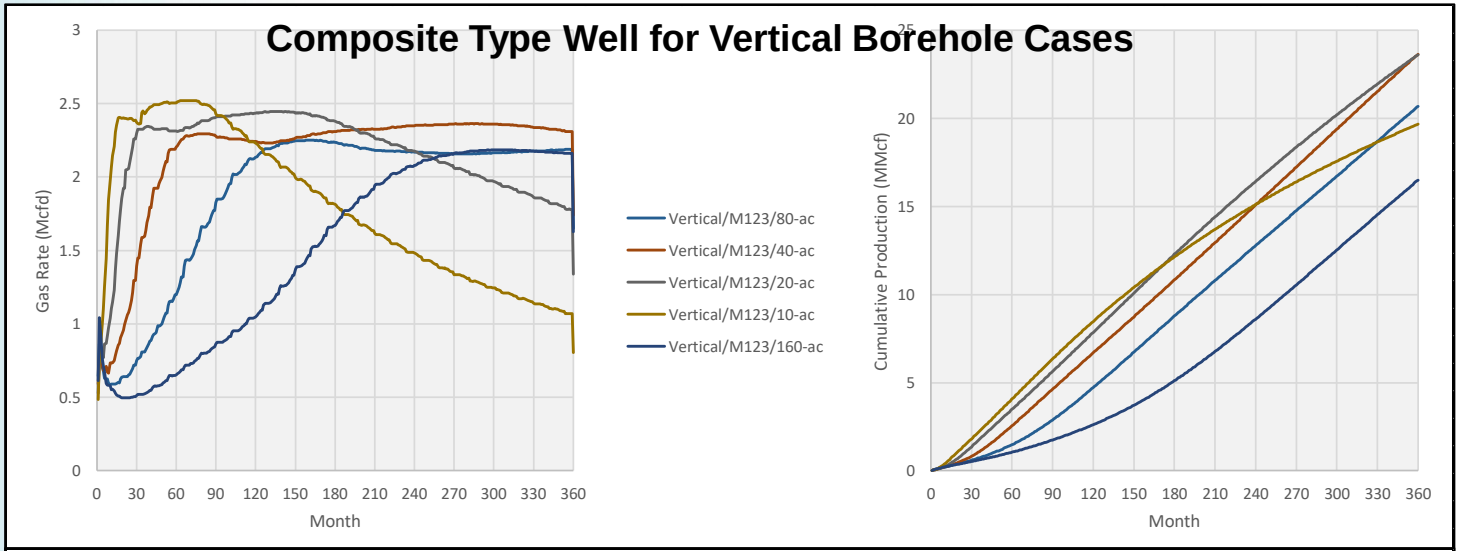
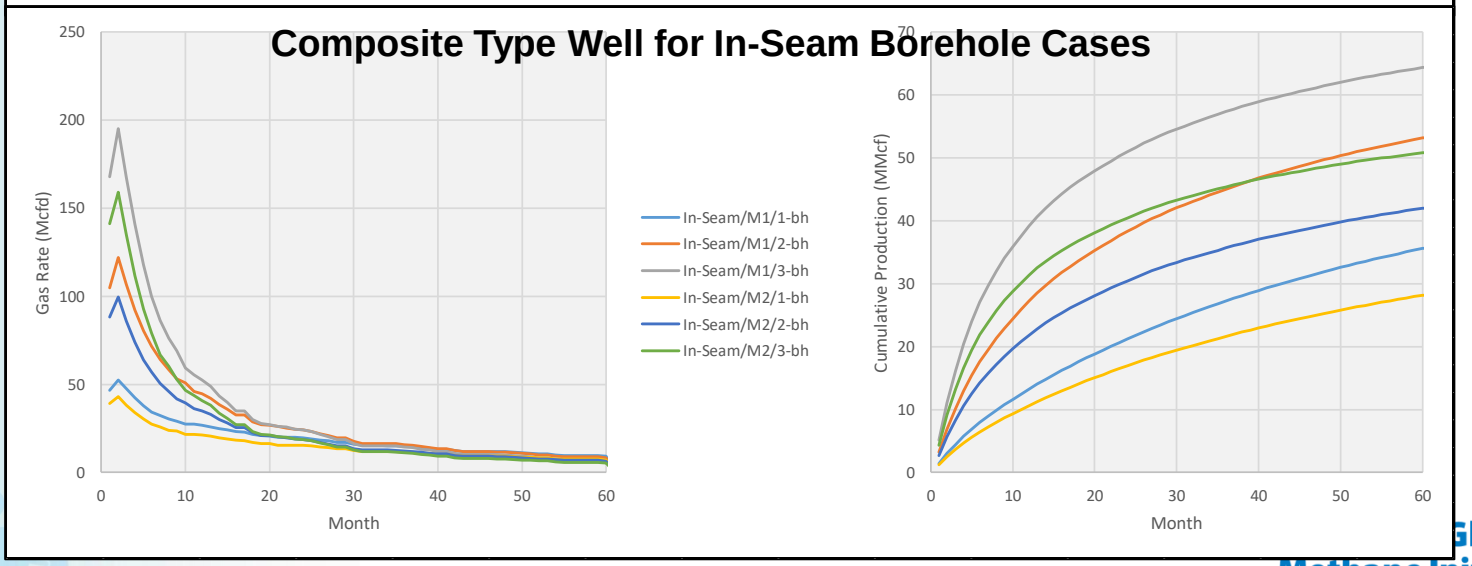
Type Well Production





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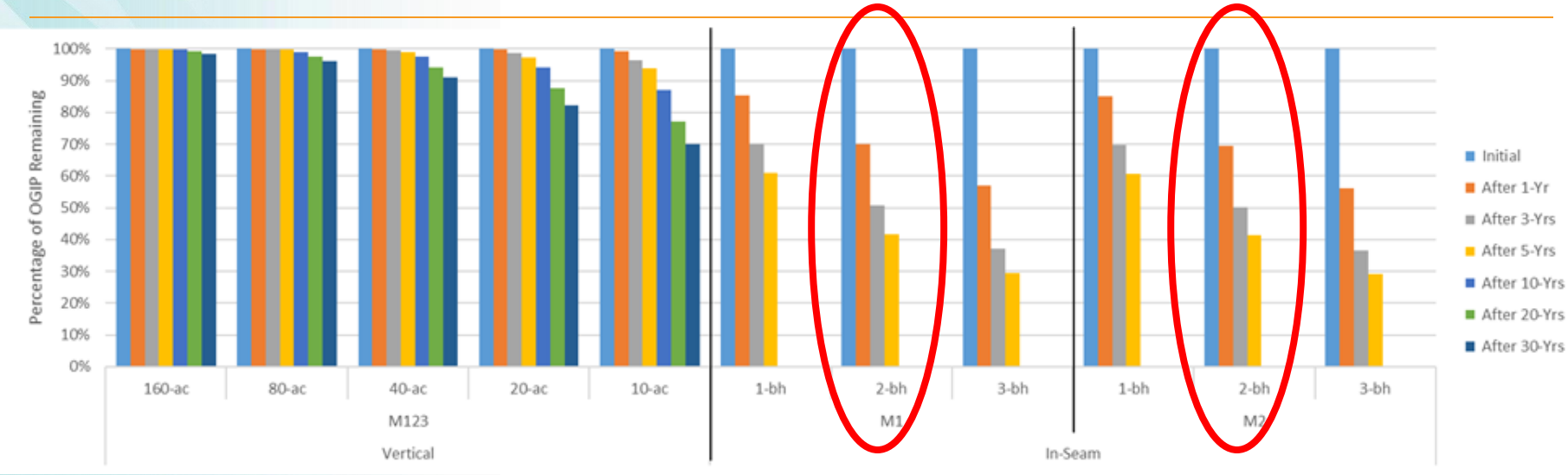
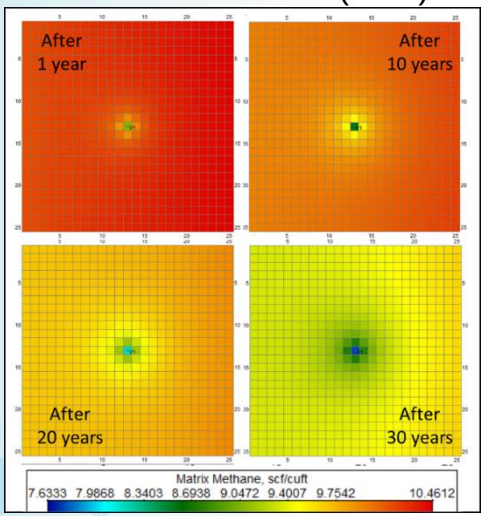
Reduction of Coal Seam Gas Content Over Time

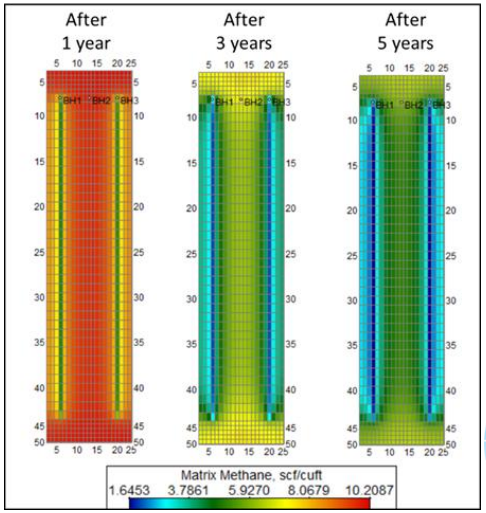
Based on the results of the drainage technology screening study, the optimal development scenario for the CMM project at the San Juaquin Mine incorporates the use of two in-seam pre-drainage boreholes per panel.



Ex: GC Reduction using Vertical Boreholes (40ac)



Ex: GC Reduction using In-Seam Boreholes (2-bh/panel)



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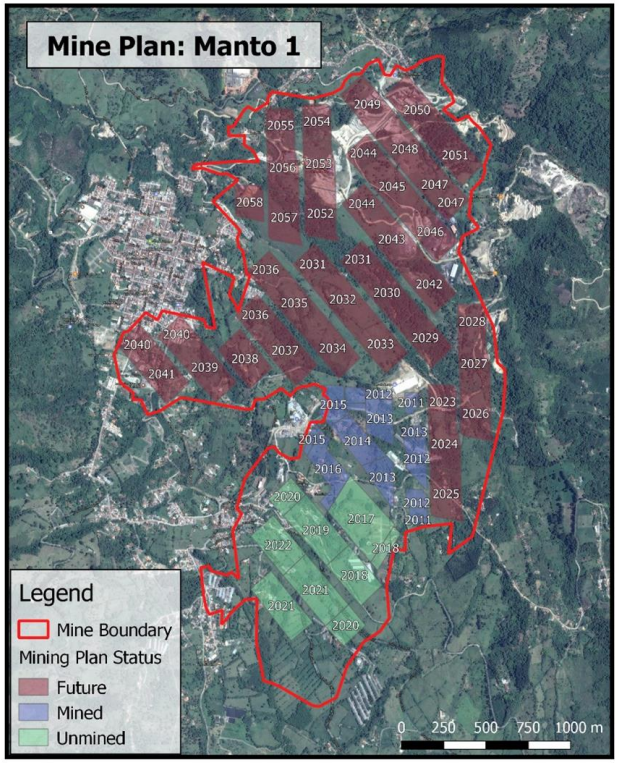
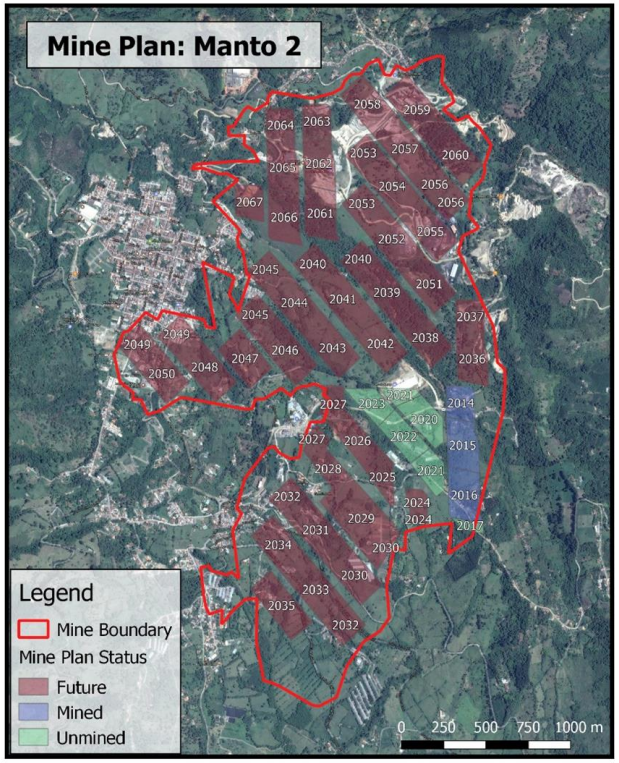
Project Development Scenario

- Conceptual mine layouts and development plans for the Manto 1 and Manto 2 seams shown below. Each mine plan shows mined panels (shaded in blue), panels that have been delineated for mining but have yet to be mined (shaded in green), and possible panels for future mining (shaded in red).





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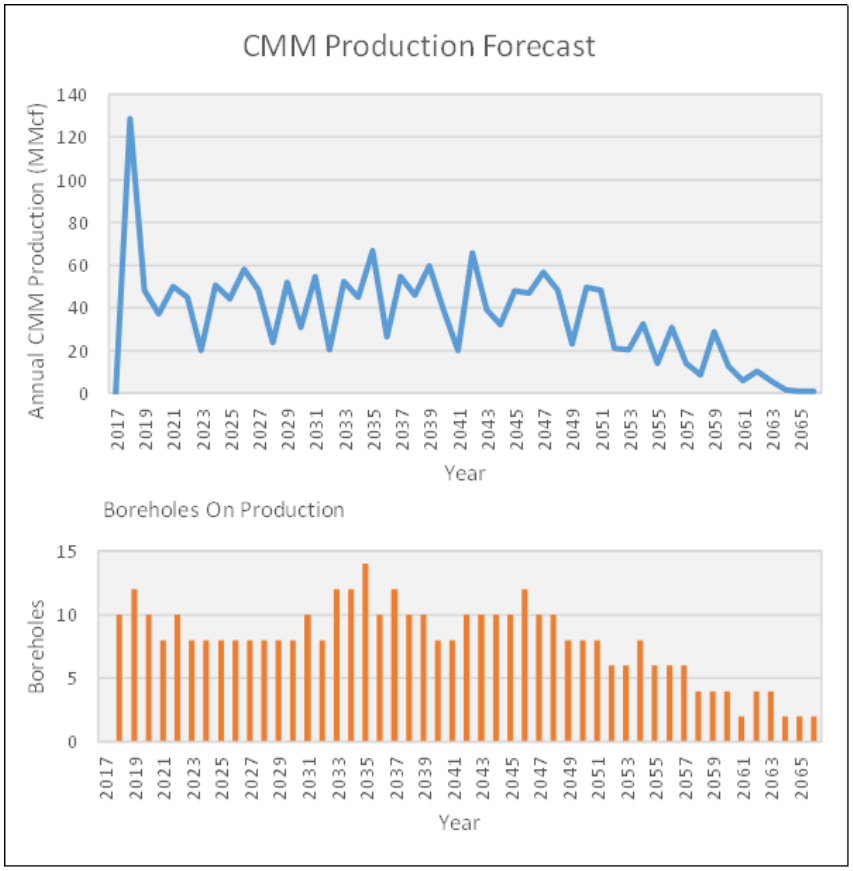
Gas Production Forecast

- A gas production forecast was developed using the type wells and the proposed project development scenario.
- Based on this forecast, total gas production over the 50-year life of the CMM project is anticipated to be 1,789 MMcf, with an average annual gas production rate of 35.8 MMcf per year.



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Economic Inputs and Assumptions

PHYSICAL & FINANCIAL FACTORS	Units	Value
Royalty	%	4.8
Price Escalation	%	3
Cost Escalation	%	3
Calorific Value of Gas	Btu/cf	928
Power Sales Price	$/kWh	0.126
Generator Efficiency	%	35
Run Time	%	90
Global Warming Potential of CH_4	tCO_2e	25
CO_2 from Combustion of 1 ton CH_4	tCO_2	2.75
CAPITAL EXPENDITURES	**Units**	**Value**
Drainage System		
Well Cost	$/ft	40
Surface Vacuum Station	$/hp	1000
Vacuum Pump Efficiency	hp/Mcfd	0.035
Gathering & Delivery System		
Gathering Pipe Cost	$/ft	40
Gathering Pipe Length	ft/well	1000
Satellite Compressor Cost	$/hp	1000
Compressor Efficiency	hp/Mcfd	0.035
Pipeline Cost	$/ft	55
Pipeline Length	ft	500
Power Plant	$/kW	1300
OPERATING EXPENSES	**Units**	**Value**
Field Fuel Use (gas)	%	5
In-Seam Pre-Drainage O&M	$/Mcf	0.1
Power Plant O&M	$/kWh	0.02

- The drained methane can be used to fuel internal combustion engines that drive generators to make electricity for use at the mine or for sale to the local power grid.
- Major cost components for the power project are the cost of the engine and generator, as well as costs for gas processing to remove solids and water, and the cost of equipment for connecting to the power grid.

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Summary of Economic Results

- Based on results of the economic analysis, a CMM-to-power utilization project at the mine is economically feasible, and the proposed project would generate a positive NPV-10 equal to $689,000.
- Although power combined with CMM drainage is already economic, removing the cost of mine degasification from the economics as a sunk cost would further reduce the marginal cost of power.
- In addition, net emission reductions associated with the destruction of drained methane are estimated to total 631,000 tonnes of carbon dioxide equivalent (tCO_2e) over the life of the project.

Project Description	CMM Drained (MMcf)	Max Power Plant Capacity (MW)	Fuel Cost ($/MMBtu)	NPV-10 US$000	IRR (%)	Net CO_2e Reductions (Million metric tons)
2 in-seam horizontal boreholes per panel with up to 5 years of pre-drainage	1789	1.4	6.39	689	13%	0.631

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Recommendations & Next Steps

- It is recommended that San Juaquin Mine management pursue development of a small (i.e., less than 1-MW) power project using CMM from a pilot project focused on a few longwall panels. The power plant could grow as gas availability increases, as more panels are developed in the future. The following steps are recommended for project development:
  - Drill several core wells over the license area and conduct isotherm and gas desorption analyses to obtain accurate measure of gas content and gas saturation, and perform well tests to determine permeability to inform a more thorough gas production forecast.
  - Conduct pilot tests for in-mine drainage boreholes, as proposed, to develop more accurate forecasts for methane concentration and volumetric throughput.
  - Investigate and analyze more thoroughly all utilization options including power production to confirm the economic and technical feasibility of CMM-to-power and viability of alternatives and their competitiveness with power generation.
  - Begin investigation of financing options to confirm available sources of project finance to determine appropriate sources and mix of financing, including the mix of debt and equity.

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