Pre-feasibility Study for Fuhong Coal Mine, Guizhou Province

U.S. Environmental Protection Agency

March 2013

Pre-Feasibility Study for Coal Mine Methane Recovery and Utilization at Fuhong Mine

In Support of the Global Methane Initiative

Sponsored by: US Environmental Protection Agency, Washington, DC USA

Prepared by: Raven Ridge Resources, Incorporated

March 2013

Global Methane Initiative

United States Environmental Protection Agency

Table of Contents

List of Tables

List of Figures

Plates

Cover Photos: Right – View looking North from gas drainage plant, across mine surface facilities. Portal to mine in lower left. Left – New portal under construction at Fuhong Mine.

Acknowledgements

This publication was developed at the request of the United States Environmental Protection Agency. Through the Coalbed Methane Outreach Program, Raven Ridge Resources, Incorporated team members: Raymond C. Pilcher, James S. Marshall, Candice L. M. Tellio, Charlee A. Boger, Julia Traylor, Martin Weil, and Boni Jiang authored this report. Raven Ridge Resources, Incorporated wishes to thank Fuhong Mine for their assistance in developing this report.

Acronyms and Abbreviations

CFD	Computational Fluid Dynamics
cm	Centimeters
CMM	Coal mine methane
CO_2e	Carbon dioxide equivalent
CSPGC	China Southern Power Grid Company
g	Grams
GMI	Global Methane Initiative
IRR	Internal Rate of Return
Kg	Kilogram
kPa	Kilopascal
kWh	Kilowatt hour
LNG	Liquefied Natural Gas
m	Meters
m^3	Cubic meter
md	Millidarcy
MJ	Megajoule
MWh	Megawatt hour
NDRC	National Development and Reform Commission
NEA	National Energy Administration
NPV	Net Present Value
p10	Indicates a 10% chance that forecast will be ≥ to the p10 amount
p50	Indicates a 50% chance that forecast will be ≥ to the p50 amount
p90	Indicates a 90% chance that forecast will be ≥ to the p90 amount
RMB	Renminbi, Chinese currency
s	Second
t	Metric Ton
USD	United States Dollar
USEPA	United Stated Environmental Protection Agency
VAM	Ventilation Air Methane
VAT	Value Added Tax

Disclaimer

With funding from USEPA, under the auspices of the Global Methane Initiative (GMI), Raven Ridge Resources, Incorporated performed a prefeasibility study at Fuhong Coal Mine, located in southwest China within Guizhou Province, to examine the potential for implementing a methane recovery and utilization project. The proposed project consists of a cross-measure borehole drainage program, drilled from within the mine workings into the roof of the mineable coal seams to capture methane gas and reduce the potential for coal and gas outbursts. Drained methane can be used in one of two ways: power generation for use at the mine or, combined power generation and on-site use in a coal dryer.

The mine plans to increase the present rate of mining from 140,000 metric tons annually to 300,000 metric tons per year in the near future, with the addition of a mechanized continuous miner. Presently the mine has an operating gas drainage station producing at a rate of 140 cubic meters per minute with a maximum methane concentration of 20 percent; however, the current drainage and ventilation systems will be insufficient for maintaining safety with the increased production plans of the mine. Three Permian age coals of the Longtan Formation are being targeted for mining, where the calculated coal reserves within the Fuhong mining lease block are estimated at 9.4 million metric tons.

A methane adsorption isotherm test, which provides an estimate of the maximum gas capacity of the coal at a given depth, was conducted to provide a frame of reference within which the potential gas content for the coal seams could be estimated. The Raven Ridge team estimated the gas resources for each of the coal seams by multiplying the volume of coal resources at 30 meter depth intervals to the equivalent gas content value indicated by the adsorption isotherm. The methane resource for the Fuhong mine is estimated to be 122.7 million cubic meters. Reservoir simulation was performed utilizing a Computational Fluid Dynamics simulator, GEM, to develop a typical production decline curve for a series of cross-measured boreholes proposed at the mine. The reservoir simulation study indicates that the borehole array selected by RRR will be effective in draining the gas emitted from the roof and floor strata.

The energy market in the Guizhou region was assessed to determine the proper end-use options for the Fuhong mine's CMM. China's electricity consumption grew at a robust average rate of 11.1 percent from 2005-2011. Electricity consumption within Guizhou has likewise followed the national/regional pattern, and it is reasonable to assume that Guizhou's economy and its electricity consumption will grow within the projected eight to ten percent range for the country as a whole in the medium term.

RRR proposes that the mine consider two end use options: power generation by internal combustion engines for use at the mine; or combined power generation by internal combustion engines and on-site use for drying of low quality coal. The optimal use will be decided by mine management as dictated by the energy needs of the mine. In the power generation only option, 56,279 MWh of electricity will be generated annually; and it is assumed that all power generated will be used by the mine. The capital costs are estimated to be $7.13 million USD with an IRR of 66.9 percent and a payback period of 2.5 years. Carbon emissions would be reduced by 246.2 thousand tons of CO_2e over the project's 10 year life. In the combined power generation and coal drying option, in addition to fueling the equipment to dry the low grade coal using 1.595 million cubic meters of the available gas, 46,798 MWh of electricity will be generated annually for use at the mine. The capital costs are estimated to be $6.3 million USD with an IRR of 74.2 percent and payback period of 2.75 years. Carbon emissions would be reduced by 504.0 thousand tons of CO_2e over the project's 10 year life.

This document reports the findings of a pre-feasibility study that was conducted as a part of a larger initiative funded by the US EPA. This initiative supports US EPA's efforts under the Global Methane Initiative (GMI).

This work was conducted with the cooperation of the Fuhong mine in Guizhou Province, southwest China.

The present study is the result of investigations that entail:

- field visits to the mine, ventilation shafts, and gas pumping and storage facilities;
- translation and review of technical documents;
- forecast of production based on statistical analysis of coal mine methane drainage (CMM) and ventilation air methane (VAM); and
- economic analysis based on quotes from vendors and gas sales prices based on current markets.

The Fuhong mine is located in Xishui County, northwest of the city of Zunyi in Guizhou Province. See **Figure 2**. The mine is privately owned. Fuhong is currently mining at a rate of 140,000 metric tons per year, with plans to increase to 600-900,000 metric tons per year in the coming years. All coal is sold to a local power plant. Historically, the method of mining has not been mechanized, but they have ordered a longwall which has recently been installed. As the rate of mining increases, pre-mine drainage will be necessary. The mine has a methane drainage station operating at a rate of 140 cubic meters per minute with 20 percent methane. Fuhong is classified as a gassy mine with potential for coal and gas outbursts. The mine is currently mining from three seams, the C5, C8, and C12, with average thicknesses of 1.2 m, 2.0 m and 1.6 m, respectively; with guaranteed reserves of 9.17 million metric tons. The mine is also considering installation of a wash plant for some of the mine's production.

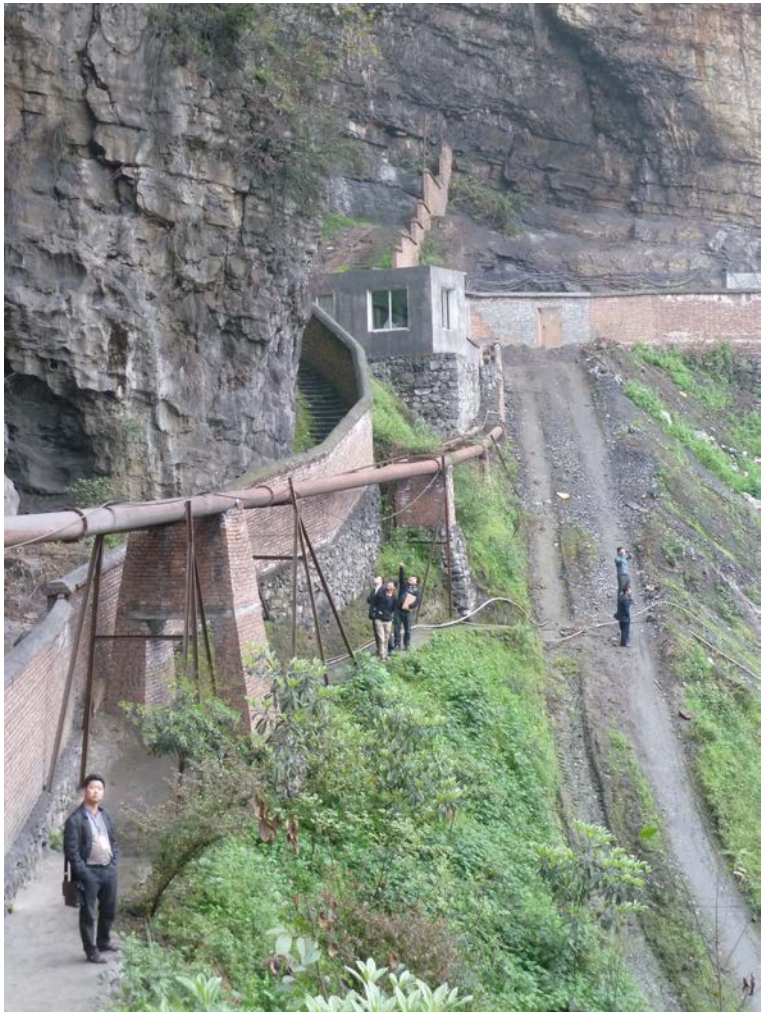


Figure 1: View of gas pipeline coming from coal seam #5 at Fuhong Mine. Rock strata in background comprise mine overburden.

Geologic Setting

The Fuhong mine area is located in northern Guizhou. The mine sits just to the south of Xishui City in Xishui County, in the remote mountains north of Kunlun South Road - S208 (**Figure 2**).

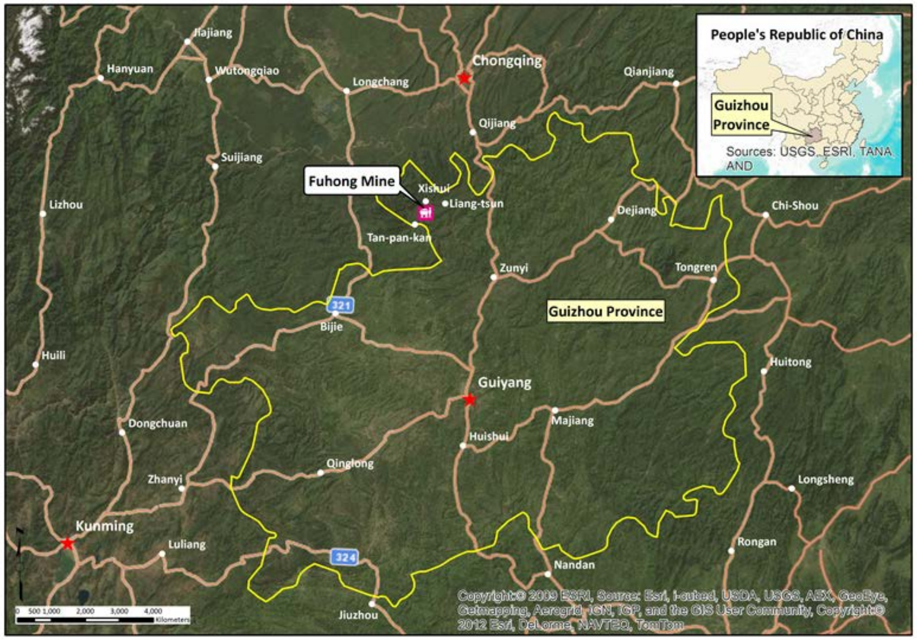


Figure 2: Overview area map

Sitting on the northern Guizhou region of the Yunnan-Guizhou Plateau (**Figure 3**) the Fuhong mine is situated in Permian and Triassic Formations exposed at the surface within the mine area, see **Plate 1: Geologic Map**.

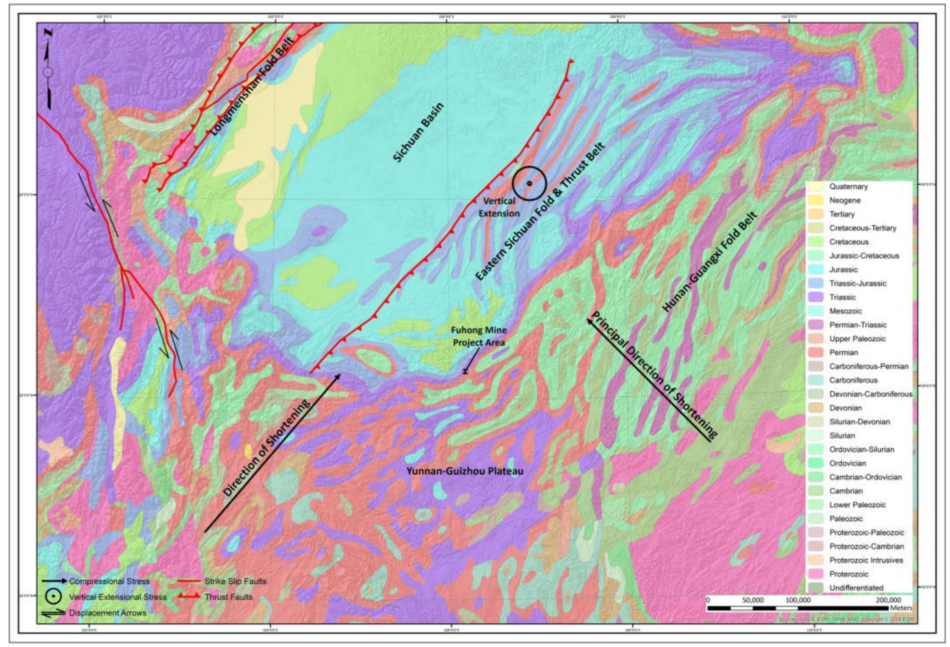


Figure 3: Regional geology overview map

The mountains comprise steep limestone cliffs dominated by erosional features such as karst topography, narrow ridges and deep and narrow valleys, as is shown in **Figure 4** below.

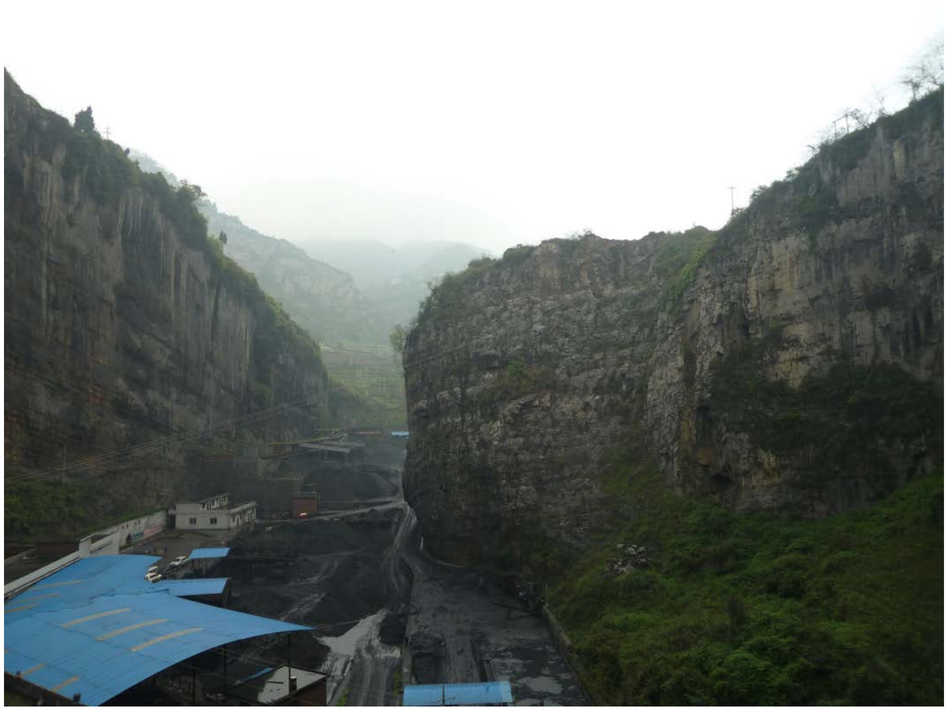


Figure 4: Fuhong mine

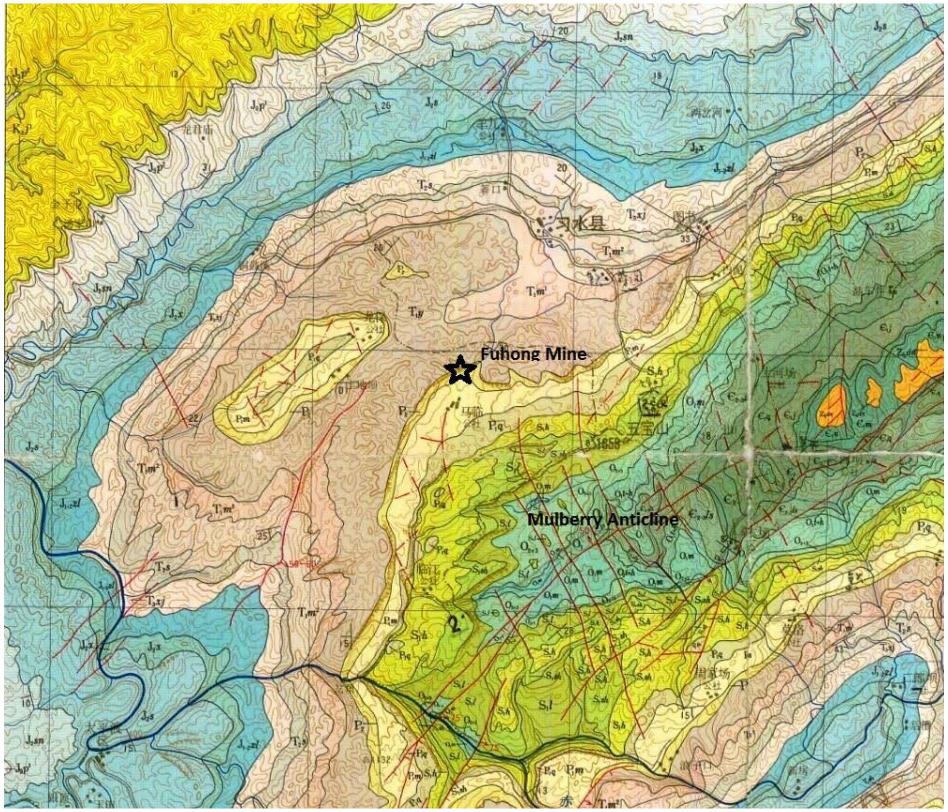


Figure 5: Regional geologic map

The mine is positioned on the northeast margin of the South China paraplatform that is an ancient remnant of large scale geologic deformation that occurred in the early Paleozoic. Overall the geologic structures in the area trend northeast - southwest and are comprised of a series of alternating anticlines and synclines. Large and small scale fractures appear on satellite images, one very large prominent lineation passes east to west through the mining area. Fractures are mapped to the south of the mining area but not at the mine itself, which can be seen in **Figure 5**. This appears to be an artifact of less intense geologic exploration and not representative of actual mining conditions. To the south of the mine is the axis of the Mulberry anticline, where a series of northeast and southwest trending - southeast dipping normal faults are developed. These faults range 200 - 400 meters in length, with a maximum of 700 meters. The mine is located on the more gently dipping northwest limb of the Mulberry anticline, where larger scale fractures are less apparent.

Geologic Structures

Geologic exploration campaigns have been conducted to determine the extent of the coal resource and to collect sufficient geologic data for designing a coal mine. Work commissioned by the Xishui Fuhong coal mine in December of 2010 and completed by Xuzhou Great Wall of Basic Engineering Co., Ltd. was used to prepare the Xishui Fuhong Coal Production Geology Report completed in January 2011. Fuhong provided the entire text of this report including cross sections, coal thickness and geologic structure maps.

Below, **Figure 6** depicts a cross-sectional view of the mine entryways and an existing mining panel projected onto this plane. This example cross-section runs north to south through approximately the middle section of the mining area, and **Plate 1** is marked with the line of section (B - B').

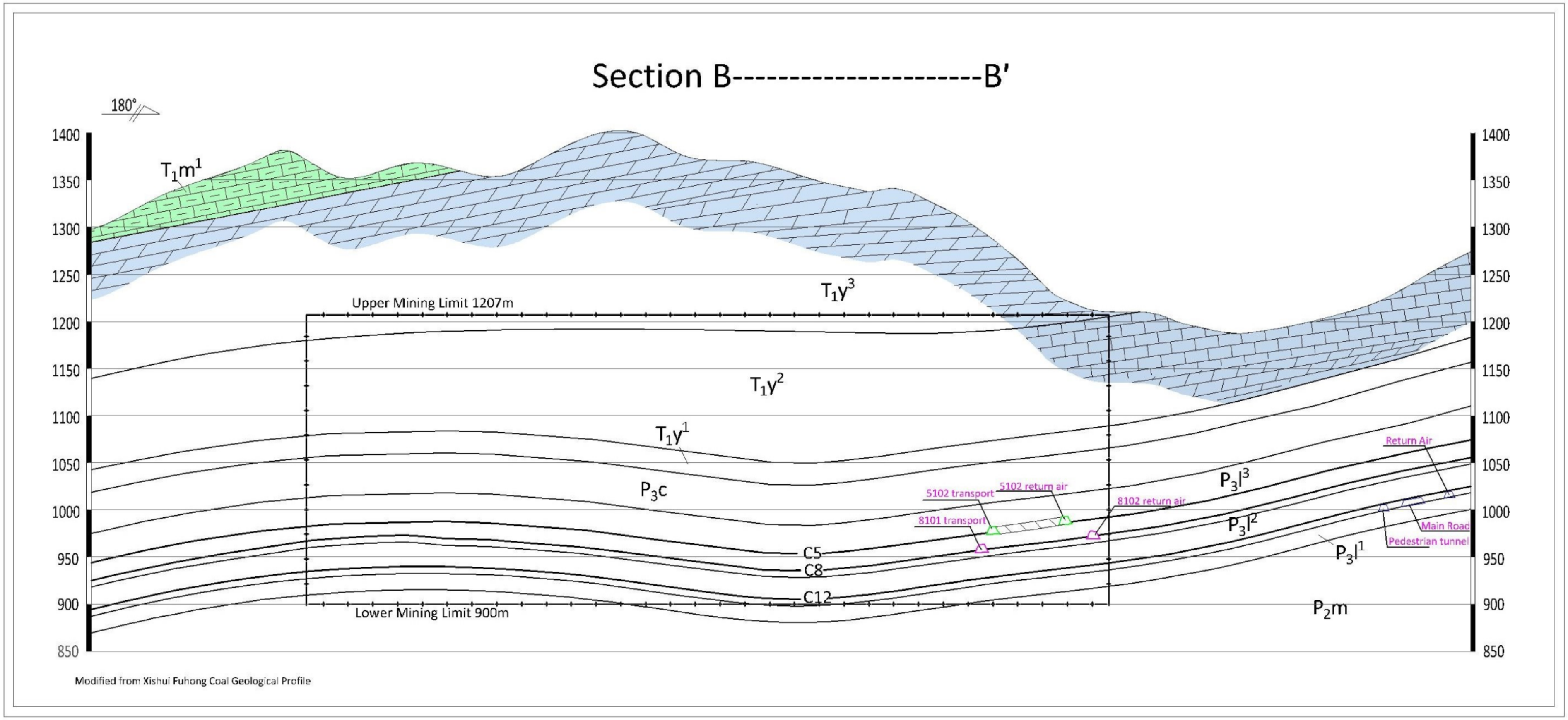


Figure 6: Example cross-section within the mining area

The general trend of the strata in the mining area falls along the same trend as the overall Mulberry anticline structure, northeast - southwest. The beds generally dip to the northwest by 8 to 13 degrees. According to the Xishui Fuhong Coal Production Geology Report, in-mine exploration wells discovered minor faulting with displacement no greater than 5 meters. According to a mining classification used in China this mine is considered to be of medium structural complexity.

Kinematic Analysis

The information provided in the reports and maps was insufficient for the Raven Ridge team to perform kinematic analysis. The Raven Ridge team utilized the geologic report, maps given by the mine and regional geologic trends in order to assess the potential structural impediments to a degasification system.

The Raven Ridge team made the following general conclusions based on the analysis:

- The principal axis of shortening is occurring in a northwest-southeast trend. The secondary axis of shortening trends from the north-northeast to south-southwest, and is generally horizontal although slightly inclined.
- The principal axis of extension is vertical, allowing the compressed structure to move upward and accommodate the folding and fracturing.
- **Plate 1: Geologic Map** shows the moderate structural complexity of the mining area.

Impact of the Geologic Structures on Pre-mine Drainage

The impact of the orientation of the geologic structures present in the Fuhong mining area appears insignificant. Coal mines are designed to facilitate ease of mining and transport of product while providing the safest possible working environment for miners. It is necessary for the safety of the miners and to limit the mine emissions to remove the methane from the coal seams in advance of mining activities. Based on the analysis of the geologic report and maps performed by the Raven Ridge team, the following considerations have been taken into account in preparing the proposed pre-mine drainage plan:

- Proposed boreholes should be oriented and drilled up dip of the coal seams - from northwest to southeast.
- Overburden above minable coal seams is as great as 400 meters.
- Mining depths, bedding inclination and coal properties are analogous to mines studied in China, where in-mine cross measure boreholes are successfully employed to efficiently drain gas from the coal seam being mined and the surrounding strata.

An example of the proposed borehole drainage layout is shown in **Figure 7**.

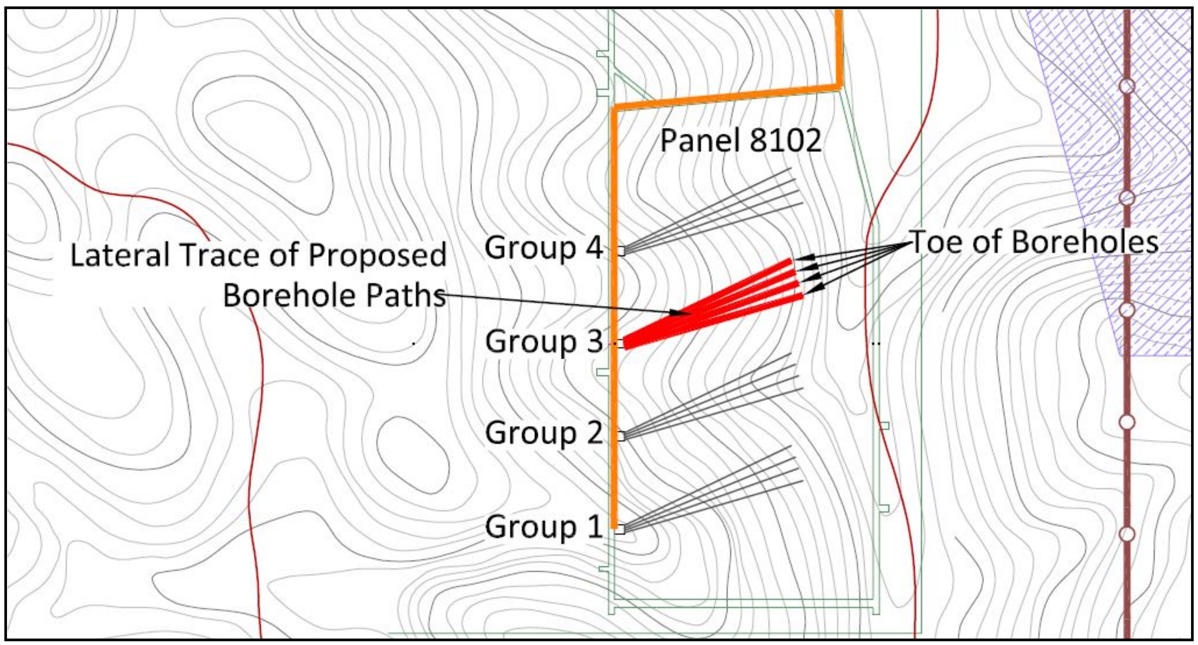


Figure 7: Example in-mine cross measure borehole layout

The following short summary highlights the characteristic attributes of each of the major stratigraphic units (**Plate 2**) that occur within the Fuhong mining block.

Quaternary

The Quaternary sediments are found on the northern cliff edge of the mining area. These sediments comprise clay, sand and gravel eroded from the mountains surrounding the location. The Geologic Map shows the location of two circular deposits of Quaternary sediments which range in thickness between 0 to 12 meters.

Lower Triassic

The predominant bedrock formations exposed above the mining area are the lower Triassic Maocaopu and Yelang formations, as shown on **Plate 1** and **Figure 3**. The Maocaopu formation has two members composed mainly of gray to light gray microcrystalline, argillaceous and dolomitic limestones and dolomite. The upper member is greater than 200 meters in thickness, while the lower member ranges in thickness between 200 - 260 meters. The Yelang formation has three members, all of which are exposed in the southern mining area. The upper Yelang member consists of gray-green to purple argillaceous limestones and mudstones and ranges in thickness between 22.9 to 140.0 meters. The middle Yelang member ranges in thickness between 148.2 to 160.0 meters, and is comprised of light gray to gray crystalline limestones and calcareous mudstones. The lower Yelang member is gray to purple-gray calcareous mudstones interbedded with microcrystalline marl, showing significant horizontal bedding. The lower member ranges in thickness between 6.9 to 10.0 meters.

Upper Permian

Within the mining area, the upper Permian Changxing formation is exposed at the surface. The Changxing formation is comprised of gray and dark gray microcrystalline limestones and calcareous mudstones, ranging in thickness between 40 to 60 meters. Underlying the Changxing and also exposed at the surface in the mining area is the Longtan formation. The Longtan formation is composed of three members that include yellow-gray to gray mudstone, siltstone, sandstone, limestone, and coal. The upper Longtan ranges in thickness between 37.5 to 68.1 meters, while the middle Longtan ranges in thickness between 24.8 to 37.8 meters and the lower Longtan ranges in thickness between 2.3 to 20.3 meters. The Longtan coals are the source of mining activities in the region and are the source rock for methane in the mining area. There are three coal seams which are of minable thickness and quality. The three mineable coal seams are the C5, C8 and the C12. **Table 1** below is a summary of the mineable coal seam thicknesses.

Table 1: Coal seam thickness summary

Coal Seam	Minimum Thickness (m)	Maximum Thickness (m)	Average Thickness (m)	Stratigraphic Layer
C5	0.95	1.94	1.41	P_3l^3
C8	2.00	2.65	2.22	P_3l^2
C12	0.98	1.92	1.52	P_3l^2

Thickness and Physical Properties

Twelve coal seams are found within the Longtan Formation across the mine property, varying in quality, thickness and distribution. The mineable coal seams found within the project area are the C5, C8 and C12; with the C8 having the greatest average thickness of 2.22 meters (**Table 1**).

Using the work completed by the Xuzhou Great Wall of Basic Engineering Co., Ltd. in 2011, **Table 2** describes the coal quality of the minable coal seams. According to the coal quality data, the coal ranges in heating value between 27.87 MJ/kg and 28.71 MJ/kg, and has a range of fixed carbon varying between 76.58% to 82.76%. The ash content ranges between 10.22% to 15.47% and the range of the volatile content is 7.82% and 9.40%. According to the Chinese classification of coals (GB/T5751-1986) the average percentage content of volatile matter on a dry-ash free basis of the Fuhong coals falls within the WY-03 anthracite class.

Table 2: Average coal quality of mineable coal seams at Fuhong Mine

Coal Seam Number	Coal Quality Analysis: Water (Moisture air-dried) %	Ash (Air-dried) %	Volatile (Dry ash-free) %	Total Sulfur (Standard) %	Fixed Carbon %	Heat (MJ/kg)
C5	1.60	15.47	9.40	0.47	76.58	27.87
C8	2.22	10.22	7.82	1.01	82.76	28.71
C12	0.46	14.55	8.92	2.78	77.83	27.95

According to the geologic report prepared for the mine, the Fuhong minable reserves are categorized based on the Solid Mineral Resource / Reserve Classification (GB/T17766-1999) document. The mine has designated portions of the mine for which their historic drilling campaign can measure the accuracy of their reserves estimations. The three types of reserves classifications are the 332, 333 and 334; 332 refers to measured intrinsic economic reserves, 333 represents indicated intrinsic economic reserves, 334 represents inferred intrinsic economic reserves.

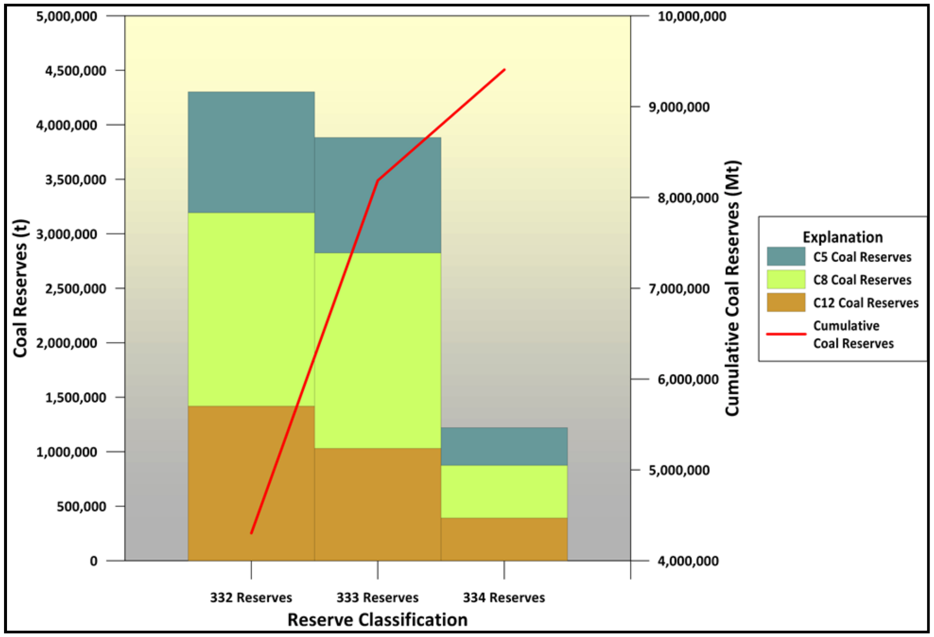


Figure 8: Coal reserves based on reserve classification schemes

Using the coal reserve blocks designated by the mine along with the block area, coal seam dip angle, coal thickness and coal density data supplied on the mine reserve maps and within the geologic report, the Raven Ridge team calculated the mine's total coal reserves for each seam and within each reserves classification category. **Figure 8** depicts the coal reserves the Raven Ridge team calculated using the GB/T17766-1999 reserves classification scheme. The Fuhong mining lease covers the surface area outlined and shown on **Plate 3: Proposed Drainage Map**. The surface elevation within the mining area ranges from 900 to 1207 meters above mean sea level as shown on **Figure 6**. The following table, **Table 3**, shows the total coal reserves for each seam and classification, within the total Fuhong mining area.

Table 3: Coal reserves by seam and reserves classification

Coal Seam	332 Reserves (t)	333 Reserves (t)	334 Reserves (t)	Total (Mt)
Seam C5	1,109,549	1,060,099	345,100	2.5
Seam C8	1,774,196*	1,793,001	483,100	4.1
Seam C12	1,418,655*	1,029,999	392,001	2.8
Total (Mt)	4.3	3.9	1.2	9.4

***NOTE: Reserves calculations include coal lying below 900 meter lease boundary. (C8 - 55,100t; C12 - 176,921t)**

Coal resources estimates served as the basis for calculating in-place gas resources at the Fuhong mine. Methods for calculating the coal resources are described in the previous section. A widely accepted method of estimating the gas resource associated with the coal is to multiply the coal mass by the gas content; however, in situ gas content measurements are not routinely taken at the Fuhong mine. A methane adsorption isotherm test was conducted to provide a frame of reference within which the potential the gas content for the coal seams could be estimated. The test was conducted on a coal sample taken from the working face in seam C8, which provides an estimate of the maximum gas capacity of the coal at a given depth. An adsorption isotherm mathematically describes the relationship between pressure and gas capacity under equilibrium conditions at a stable temperature representing the reservoir temperature of the coal seam at the depth of the sample. For the purposes of this study, we converted pressure into depth by assuming a normal hydrostatic gradient. The curve shown in red on **Figure 9** relates gas content of coal sample to the expected content at a given mining depth.

In order to estimate gas resources for each of the seams, the Raven Ridge team segregated coal resource by depth interval and multiplied by the gas content value indicated by the adsorption isotherm. The values reported as coal resource include not only the coal, but the ash contained in partings or as finely distributed non coal material, in other words, the actual coaly material that is extracted for supplying customers will later be separated by washing or some other method to provide the customer with a suitable product. In order to represent the in situ conditions of the coal seam the team used the gas content values reported on an as received-equilibrium moisture basis, thus accounting for the diminished gas content associated with the contained ash.

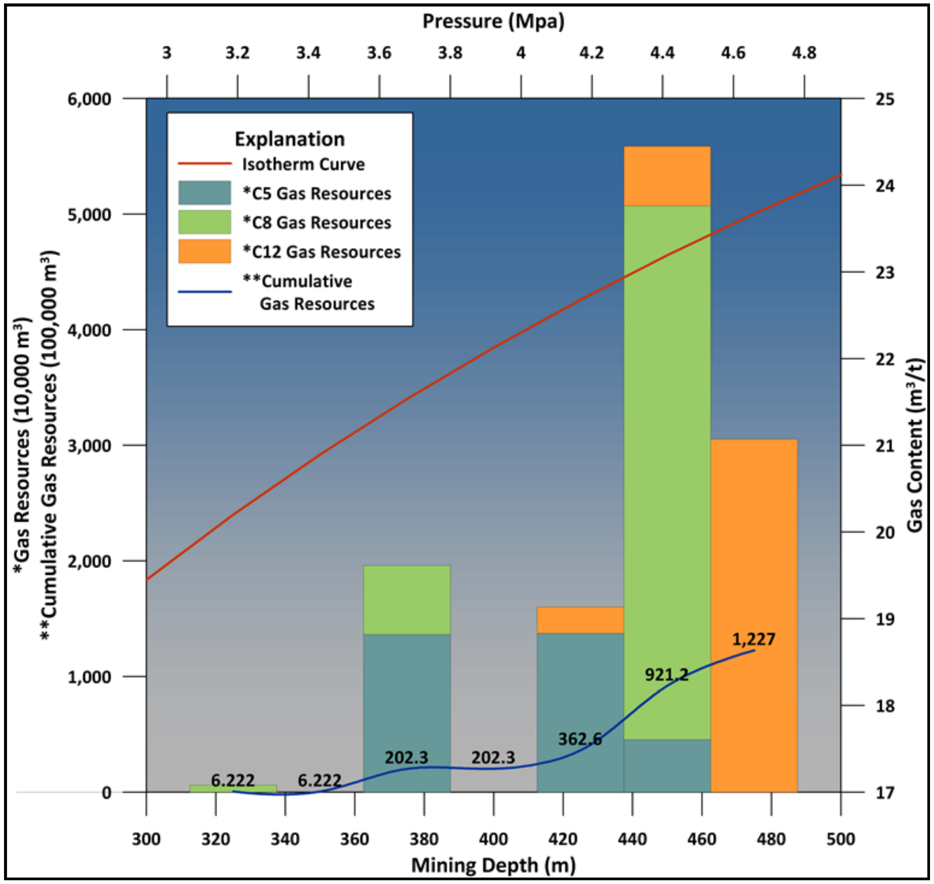


Figure 9: Potential gas resources of coal reserves at Fuhong mine shown by coal seams

The Raven Ridge team recognizes that this adsorption isotherm indicates the gas capacity of the sample taken from the C8 seam and may not accurately depict the situation for other coal seams. However, the rank and coal quality of other mineable seams as indicated by the volatile matter and ash content are similar. Therefore, it is assumed that the isotherm may be broadly indicative of the gas capacity of any of the seams being mined in the Fuhong mine. The gas resource estimate depicted for each of the coal seams in **Figure 9** is the total in-place gas resources associated with the minable coal resources of the Fuhong mine. In **Figure 10** the gas resource is segregated by coal resource class 332, 333, and 334. The gas resource for the Fuhong mine is estimated to be 122.7 million cubic meters, and as can be seen in **Figure 10**, all of the estimated gas resource occurs above 500 meters depth. It should be noted when considering the estimate of the gas resources and how they relate to potential gas production that variations in the gas capacity of coal are governed by local pressure, temperature and coal composition. Coal seams are not uniform and the gas contained by the coal is not uniformly distributed.

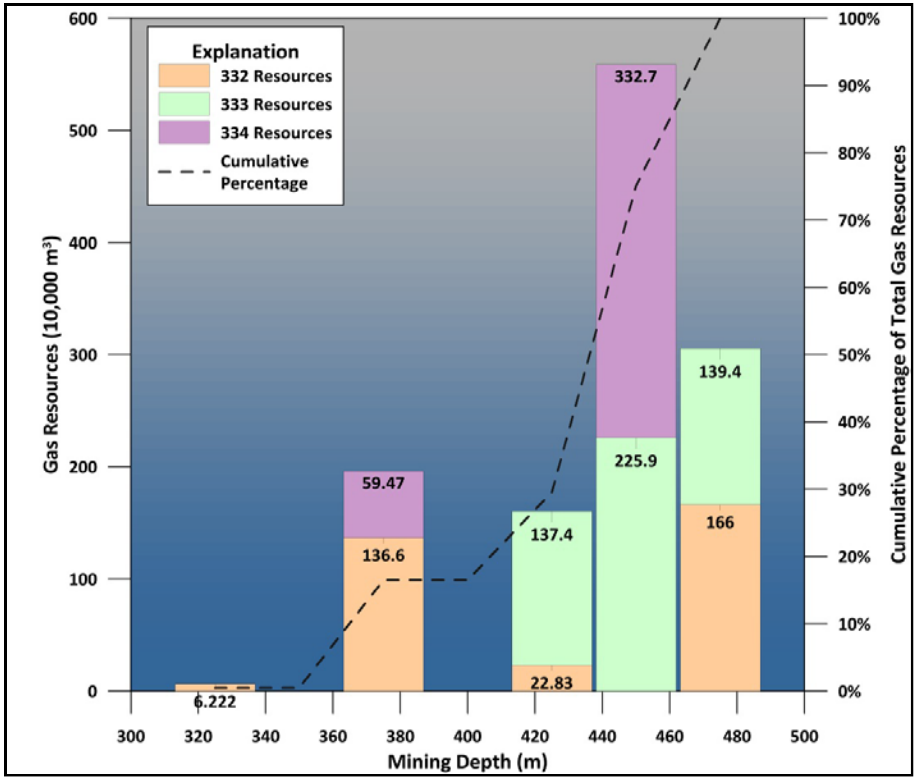


Figure 10: Potential gas resources of coal reserves at Fuhong mine shown by coal reserve classification

China's electricity consumption grew at a robust average rate of 11.1 percent from 2005-2011. With the exception of 2008-2009, during which the economy slowed down significantly in response to the world financial crisis and to tighter controls on real estate in China, growth in electricity consumption surpassed overall economic growth by an average margin of 19 percent.

The combination of increasingly strong mandates from the Chinese government through the National Development and Reform Commission (NDRC) to utilize rather than waste CMM, with the prospect of significant carbon credit revenue opened up by the implementation of the CDM under the Kyoto Protocol in 2004, resulted in a wave of CMM power projects sponsored by coal mines and Western purchasers/brokers of carbon credits. An aggregate 750 MW of CMM power generation capacity at coal mines around the country came into operation from 2006-2010, including 120 MW at a flagship station in Jincheng, Shanxi Province funded by the Asian Development Bank (NEA, 2011). The great majority of this capacity consisted of 0.5 MW internal combustion engines with approximately 30 percent thermal efficiency made in China. These burn CMM of 20 – 40 percent methane concentration and are installed in highly distributed fashion adjacent to the vacuum pumping stations which remove the CMM from the various mines.

The National Energy Administration's Twelfth Five-year Plan for Development of CBM/CMM calls for CMM power generation capacity to quadruple to 2,850 MW between 2010 and 2015, and reiterates that, while the power should be consumed by the mines themselves when possible, the policies regarding off-take by the grid should be implemented. Given the limited ability of the mines to absorb all of the power, the fulfillment of the Twelfth Five-year Plan targets will depend on more rigorous adherence by the grid to the off-take policies (NEA, 2011).

Although Guizhou is one of China's smallest, poorest, and least urbanized provinces, its interconnections with the rest of the country have grown stronger in recent years, and its economic growth has closely tracked that of China as a whole. Electricity consumption within Guizhou has likewise followed the national/regional pattern, with strong double digit growth during 2005-2007 giving way to a temporary decline in the second half of 2008 and the first half of 2009 under the impact of the global economic slowdown, followed by a rebound carrying through into 2010. Given this history, it is reasonable to assume that Guizhou's economy and its electricity consumption will grow within the projected eight to ten percent range for the country as a whole in the medium term.

The Guizhou power grid is one of five interconnected provincial grids which are controlled by the state-owned China Southern Power Grid Company (CSPGC). Guizhou has become an important electricity supplier to nearby Guangdong and it is expected that Guangdong will continue to depend on significant volumes of electricity purchase from Guizhou and other CPSGC provinces for the foreseeable future.

Guizhou's disproportionate economic dependence on energy-intensive extraction and manufacture of commodities such as coal and aluminum, however, creates the potential for some volatility in local electricity demand. Industry as a whole has consistently accounted for close to 80 percent of Guizhou's electricity consumption. Extraction of coal and manufacture of chemical fertilizer and associated products accounts for an estimated 55 percent, and a single massive aluminum smelter near Guiyang for about 15 percent of electricity demand.

Guizhou regulatory authorities have not yet taken concrete measures to enforce NDRC requirements[1]. Virtually all power generated by Guizhou CMM plants, therefore, is being distributed through the mining companies' grids for their own consumption. Some mining companies with the capability to generate excess power have been forced to idle capacity due to their inability to reach interconnection and sales agreements.

[1] NDRC April 2007 *Opinions Regarding Use of Coalbed Methane and Coalmine Methane*: public grid companies purchase all power generated in excess of mining companies' own needs by CMM generation plants, pay the purchase price in a "timely manner," and pay the CMM power generators the same prices as for power from biomass generation plants, equivalent to the regulated wholesale purchase prices for power from new coal-fired plants, plus a 0.25 RMB per kwh surcharge.

Reservoir simulation was performed for this project utilizing a Computational Fluid Dynamics (CFD) simulator, GEM, developed by The Computer Modeling Group. Information and data were incorporated into the model to develop a typical production decline curve for a series of cross-measured boreholes (**Plate 4**).

The information was collected and collated from the following sources:

- General mine plan and degasification scheme provided by the mine.
- Adsorption isotherm performed on a single sample from seam 8, performed by the Xi'an Research Institute of China Coal Technology & Engineering Group, in Xi'an, People's Republic of China (**Figure 11**).
- Information provided by the Fuhong Mine.

Technical Inputs and Assumptions

Listed below are key inputs and assumptions used or considered in the reservoir study.

- Matrix Porosity: 0.005 volume fraction
- Fracture Porosity: 0.01 volume fraction
- Matrix Permeability: 0.0001 md
- Natural Fracture Permeability: 1 md, 10 md, or 100 md
- Fracture spacing: 0.5 m
- Diffusion coefficient in coal: 0.33 cm^2/s
- Induced permeability in the siltstone: varies (1 md to 100 md)
- Pressure Gradient: 9.79 kPa/m
- Adsorption Parameters:
  - Langmuir Storage Capacity: 18.53 cm^3/g
  - Langmuir Pressure: 2,760 kPa
  - Assume the coal layers are initially saturated and the equilibrium pressure equals to the reservoir pressure

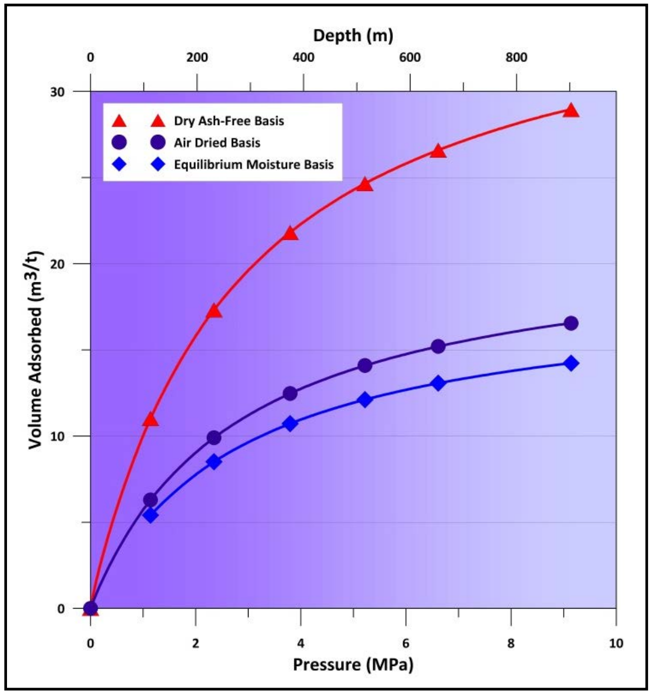


Figure 11: Adsorption isotherm measured for a coal sample taken from the Fuhong Mine, seam 8

For the purposes of the reservoir simulation, we have assumed that the coal layers are saturated and the equilibrium pressure is equal to the reservoir pressure.

The model was also set up with these additional assumptions:

- Each borehole was modeled as a straight uni-directional well.
- Wellbore Radius: 0.075 m.
- Each group of wells includes six wells: four upwards into the roof rock, two into the floor rock.
- The dipping angle for the upwards wells is around 20°.
- The length of the upwards wells is around 80 m.
- There are three groups in the model, and the space between was 40 m.
- The production pressure was set to the 1 atm.
- The roof coal layer is saturated with CMM.
- The amount of free gas is very limited before the degassing.
- The amount of mobile formation water is insignificant.
- The only exit way for gas flow is in the drilled holes.

See **Plate 4** for Proposed Borehole Array.

The reservoir simulation study indicates that the borehole array proposed will be effective in draining the gas emitted from the roof and floor strata. The range of permeability values selected as inputs for the reservoir simulation range from 1 md to 100 md, which represents the range in permeability that could be expected during mining of longwall panels in the Fuhong mine. Permeability will change through time, spanning the range used, as the roof and floor strata are disturbed by the passing longwall. Strata relaxation causes fractures to open that otherwise would remain closed if left undisturbed, thus increasing permeability and allowing gas to flow to the borehole.

The results of the study indicate that the greater the induced permeability, the sooner the CMM is drained for each group of wells:

- When the overburden permeability equals 1 md, it will take less than 117 days for the gas rate to drop to 1000 m^3/day,
- When the overburden permeability equals 10 md, it will take less than 60 days for the gas rate to drop to 1000 m^3/day ,
- When the overburden permeability equals 100 md, it will take less than 14 days for the gas rate to drop to 1000 m^3/day.

No matter what the induced permeability becomes, total cumulative gas production for the three-group model will be around 0.9 million m^3.

The simulation assumes that there is no other pathway for gas to escape; however, in practice that is not the case. A small percentage of the gas in-place will be pulled through cracks or fractures in the strata into the ventilation pathways. However, if drilling is completed soon after longwall panels are blocked out for mining, drainage efficiency could easily achieve 30 percent or greater, meaning 60 percent of the gas-in-place will be emitted to the atmosphere via the ventilation system. Yet greater drainage efficiency can be achieved by employing lessons gained through experience and by fine tuning the drilling techniques that are applied.

The simulation used in the economic evaluation is the mid-case scenario where the permeability is assumed to be 10 md.

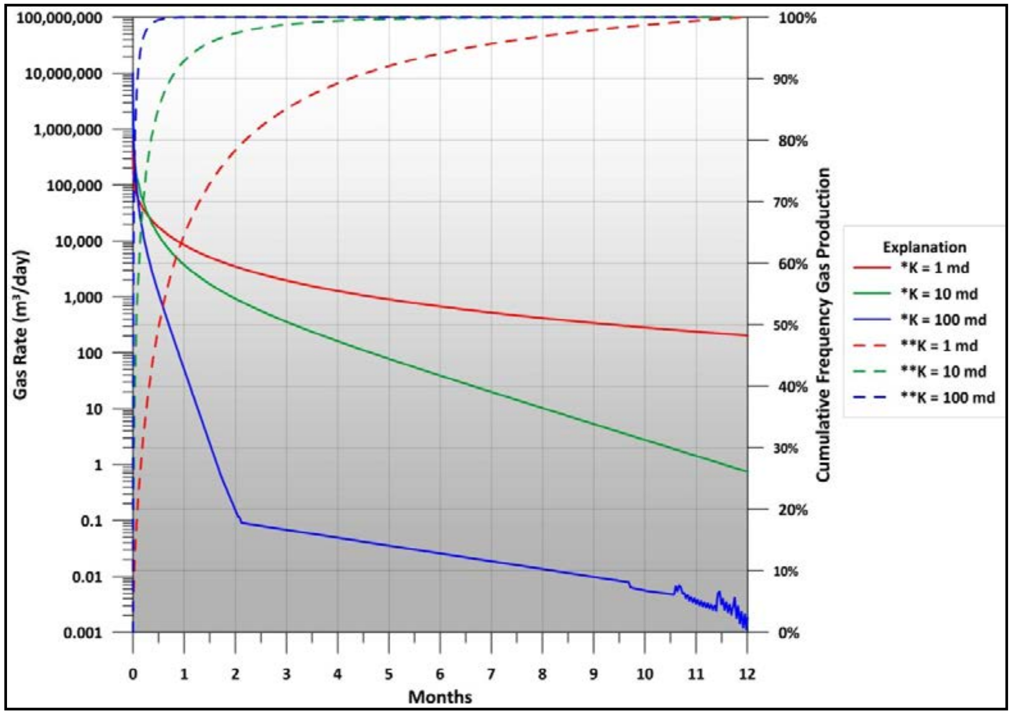


Figure 12: Gas Production Rate Based on Permeability

Two end-use scenarios were evaluated based on the premise that coal mine methane is produced from a series of in-mine boreholes drilled into the overlying strata in advance of mining. The two end-use options evaluated are described below.

- *Power Generation Option*- This option entails installing a CMM-fueled internal combustion power generation facility in close proximity to the mine's surface facilities, which would be designed to supply power to the mine as well as sell any unused electricity to the grid.
- *Combined Power Generation and On-site Use Option* - Under this scenario, all of the needs of the mine to dry the low quality coal (rejected for sale to customers, but used at the mine) will be met by utilizing drained gas, where all remaining gas will be used to fuel internal combustion engines to generate electricity to be used at the mine.

Each option is discussed in the following subsections, where background information and conceptual design is provided, and the economic performance of each end-use project is discussed. The final subsection compares the economic performance of the two end-use options.

Inputs and Assumptions

There are certain inputs and assumptions used in the economic model that are applicable to both scenarios. These are listed in **Table 4.**

The project duration is designed for ten years, where the drilling and installation of the gas gathering system will be completed in the first year. Drilling and completion costs total $202,500 per well, and the total costs for gas gathering and transmission is $261,459. All electricity generated will be used by the mine, so the sales price of electricity used in this analysis is 0.60 RMB/kWh, which is the price that the mine would otherwise have to pay to the grid. Annual project operating costs are twenty-five percent of the capital costs.

Table 4: Inputs and Assumptions Used in Economic Model

Project Duration	2013 – 2022	
Project ownership and financial structure	Power plants and LNG plant are profit centers, independent from the Fuhong Mining operations.	IRR is calculated against entire project investment. Base case assumes that 80 percent of capital costs would be financed at a five percent interest rate with a ten-year term.
Gas flows to project	According to 10 md production decline	
Drilling & Completion costs, and gas gathering	$0.30/ton of coal mined	Quote from drilling engineer with extensive experience in China.
Gas transmission line	100,000 USD per kilometer	Move the gas out of the mine; includes all compression
Depreciation Method	15 year straight line	
Verified Emission Reduction (VER) Sales Price	1.00 USD per tonne of CO_2e	VER sales in years 2013-2022.
Project Emissions	0.1784 metric tons/MWh	Factor used to determine project emissions resulting from CMM fueled power generation.
Conversion of methane to CO_2 equivalent	0.01428 metric tons CO_2e per m^3 of methane	
Electricity price	0.60 RMB/kWh	Avoided cost if the mine supplanted its electricity demand with electricity generated from the project
Project Operating Hours	7,000 hours	
VAT Taxes	VAT taxes were not applied, nor were VAT refunds	
Income Tax	25 percent per year	

Technology and Deployment Options

A power generation project was the first end-use option evaluated by the Raven Ridge team. The project is conceptually designed to utilize all available CMM drained from the Fuhong Mine to generate power for use at the mine and to sell any unused electricity to the national grid.

Power generating equipment from two western suppliers was evaluated based on price and performance. Average costs from the two systems (RMB/kWh installed) were used in the analysis. This equipment has a fuel consumption factor of 0.2475 cubic meters per kWh installed; therefore, assuming that all remaining coal mine methane drained will be used for power generation, with 7,000 operating hours, 56,279 MWh of electricity will be generated annually. It is assumed that all power generated will be used by the mine. This equates to an installed capacity of just over 8 MW of combined electrical and thermal generating capacity.

The unit costs for this equipment were derived from correspondence with a representative of a western company with offices in China. Included in the capital cost (CAPEX) estimates are equipment purchase, installation and testing, gas gathering, as well as all drilling and completion costs. Installation of the internal combustion power generation facilities was done in the first year, 2013.

Risk Factors and Mitigants

As with any project there are risks associated with developing a successful project. **Table 5** lists the risks that have been identified, an assessment of the level of risk, and possible mitigants to each identified risk. Overall, the Raven Ridge team has determined that the risks associated with technology and implementation are low to moderate, while the risk of not gaining access to the grid to dispatch any unused electricity may be high.

Table 5: Risk Factors and Mitigants: Power Generation and Electricity Sales Options

Risk	Assessment	Mitigant
Market:		
Access to and the ability to dispatch all available generated power to the grid	High	Use power on-site and avoid sale to national grid.
Access to national electricity market	High	Use power on-site and avoid sale to national grid.
Ability to get rational prices for power sold to grid	High	Use power on-site and avoid sale to national grid.
Technology:		
Reliability and dependability of equipment:	Low	Very dependable equipment, train local technicians to monitor, maintain, and repair engines and associated systems.
Fluctuations in gas concentrations	Low	The concentrations of gas drained in advance of mining should not fluctuate significantly.
Implementation:		
Fluctuation in pricing of equipment and services	Moderate	Current trend for prices is downward; procure contracts that lock in favorable prices.
Procurement of permits and right-of-ways	Low	Develop timeline that incorporates time necessary to secure all necessary permits and right-of-ways, allow for delays.
Delays in deliverability of equipment	Low	Detailed planning; incorporate necessary lead time into orders.
Delays in installation	Low	Detailed planning.

Economic Analysis

This CMM end-use option was modeled to determine its economic performance. Below is a list of the assumptions and inputs used for the modeling, followed by reporting the resulting estimates of economic performance.

Inputs and Assumptions: Power Generation Option

When available, actual costs and pricing are used in the model. Otherwise reasonable estimates based on industry standards were used. The following assumptions were used to model this option.

Table 6: Inputs and Assumptions for Combined Power Generation and Option

Project Duration	2013-2022	
Plant construction	Site construction and installation is conducted in 2013	
Capital Investment for p50 scenario (million RMB)	Power Stations & auxiliary facilities: 45.3 million RMB (7.13 million USD)	Power station investment based on unit costs 5,820.7 RMB per kilowatt (916.23 $/kilowatt)
Annual Power Sales	Electricity sales to mine: 56,279 MWh	
Annual operating hours	7,000 per year	
Gas Consumption efficiency	0.2475 m^3 per kWh generated Utilizes 5.0% of gas stream as fuel for engines	Based on manufacturer's representatives.
Power sales price, sold to mine	0.60 RMB per kWh	Avoided cost that mine would have paid to grid.
Annual project operating costs	25 percent of capital costs	Based on information provided by manufacturer's representative.

Probabilistic Forecast Results

Table 7 summarizes the results of the modeling performed to determine the economic performance of a power generation option. Using the 10 md modeled production decline, a set of internal combustion engines are installed at the mine, totaling 8 MW, fueled by all available CMM. At the modeled 10 md production decline rate, the project returns a positive value for the NPV at 8.11 million USD and an IRR of 66.9 percent.

Table 7: Power Generation Option Base Case Forecast Results

Power Generation Option	
Evaluation Scenario	Base Case
Annual Operating Hours	7,000
Gas Forecast-Project (million m^3)	94.6
Total CAPEX (million USD)	7.13
Tons of CO2e (x thou.)	246.2
Carbon Sales Price (USD)	1.00
Plant Size (MW)	5.30
CAPEX/Tons CO_2e	0.03
Electricity Sales Price (RMB/kWhr)	0.600
NPV/Tons CO_2e	0.03
NPV (Million USD)	8.11
IRR (%)	66.9%

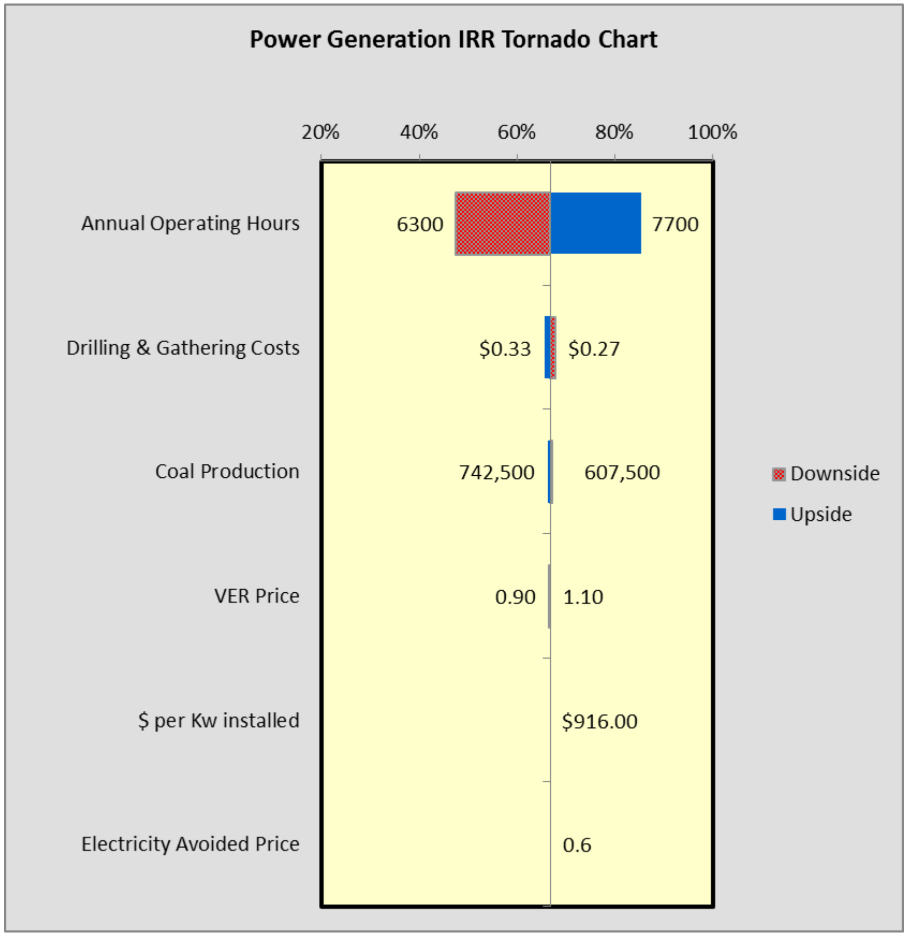


Figure 13: Power Generation Sensitivity Analysis, Tornado Chart

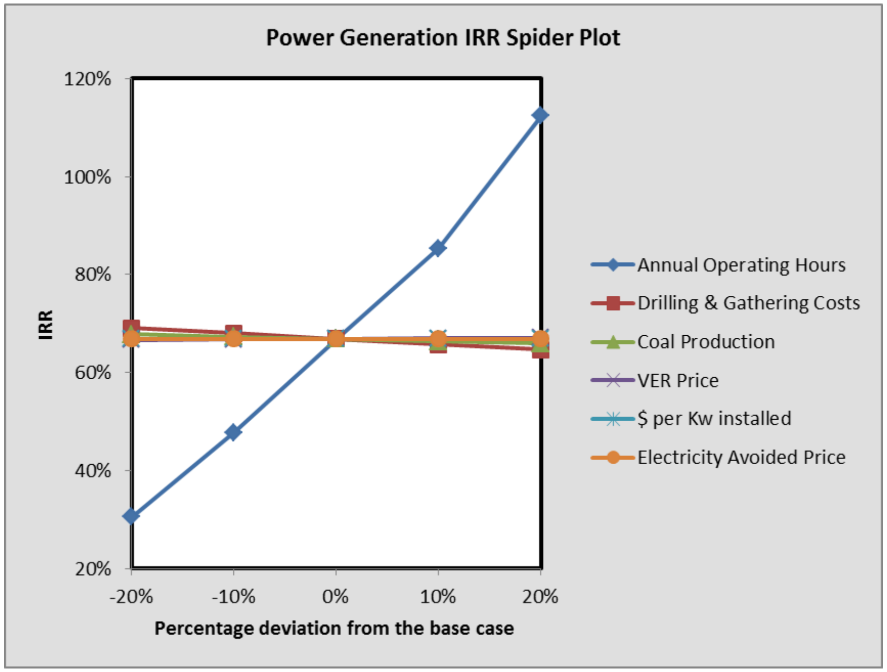


Figure 14: Power Generation Sensitivity Analysis, Spider Plot

Sensitivity Analysis of Power Generation Option

The Raven Ridge team performed a sensitivity analysis on this option using the 10 md production decline utilizing Crystal Ball™ to generate a Tornado Chart and Spider Plot (**Figures 13 & 14**). Both of these figures indicate that varying the amount of operational hours that the project operates annually would have a significant impact on the economic performance of the project, while varying all other variables would have little impact.

Technology and Deployment Options

The second methane use option evaluated was to first use the drained CMM to supply all of the energy needs to dry the low grade coal, and to generate electricity for use at the mine with all remaining gas.

The annual heat requirement to dry the low grade coal at the Fuhong Mine is 60.3 million MJ; with one cubic meter of methane equivalent to 37.8 MJ the volume of gas required annually is 1.595 million cubic meters. The remaining volume of CMM that is available for power generation is 7.749 million cubic meters. Again, assuming a fuel consumption factor of 0.2475 cubic meters per kWh installed, 46,798 MWh of electricity will be generated for use at the mine.

Risk Factors and Mitigants

Table 8 lists the associated risks that are identified for using CMM for drying coal and generating electricity at the Fuhong Mine site. The table includes an assessment of the level of risk, and possible mitigants to each identified risk. Overall, the Raven Ridge team has determined that the risks associated with technology and implementation are low to moderate, with the exception of the risk associated with gaining access to the grid, which is likely to be high.

Economic Analysis

This CMM end-use option was modeled to determine its economic performance. Below is a list of the assumptions and inputs used for the modeling, followed by reporting the resulting estimates of economic performance.

Table 8: Risk Factors and Mitigants: Power Generation and Electricity Sales Options

Risk	Assessment	Mitigant
Market:		
Access to and the ability to dispatch all available generated power to the grid	High	Use power on-site and avoid sale to national grid.
Access to national electricity market	High	Use power on-site and avoid sale to national grid.
Ability to get rational prices for power sold to grid	High	Use power on-site and avoid sale to national grid.
Ability to use gas on-site for coal drying	Low	Use of gas on-site is very low risk; no transportation of CMM off-site is required.
Technology:		
Reliability and dependability of equipment:	Low	Very dependable equipment, train local technicians to monitor, maintain, and repair engines and associated systems.
Fluctuations in gas concentrations	Low	The concentrations of gas drained in advance of mining should not fluctuate significantly.
Implementation:		
Fluctuation in pricing of equipment and services	Moderate	Current trend for prices is downward; procure contracts that lock in favorable prices.
Procurement of permits and right-of-ways	Low	Develop timeline that incorporates time necessary to secure all necessary permits and right-of-ways, allow for delays.
Delays in deliverability of equipment	Low	Detailed planning; incorporate necessary lead time into orders.
Delays in installation	Low	Detailed planning.

Inputs and Assumptions: Combined Power Generation and On-site Use Option

The following inputs and assumptions were used as a basis for the economic analysis of this end-use option.

Table 9: Inputs and Assumptions for Combined Power Generation and On-site Use Option

Capacity	1,595,000 m^3 used for coal drying; 7,749,400 m^3 used for power generation – 4.4 MW thermal capacity installed with 1.5 MW steam capacity.	Full operation by end of 2013.
Project ownership	The Power plant is a profit center, independent from the Fuhong Mining operations.	IRR is calculated against entire project investment, including drilling.
Capital investment	6.3 million USD	Cost of converting boiler from coal-fired to gas fired is considered nominal and is not included.
Hours of operation	7,000 hours per year	
O & M costs for power plant and	25% of capital costs annually	Includes all operating and maintenance expenditures, including labor.
Gas consumption efficiency	0.2475 m^3 per kWh generated; Utilizes 5.0% of gas stream as fuel for engines	Based on manufacturer's representatives.
Power sales price, sold to mine	0.6.0 RMB per kWh	Avoided cost that mine would have paid to grid.
Annual project operating costs	25 percent of capital costs	Based on information provided by manufacturer's representative.

Probabilistic Forecast Results

Table 10 below summarizes the results of the modeling performed to determine the economic performance of a combined power generation and on-site use option. Using the 10 md CMM production decline, all drained CMM is used to supply all of the energy requirements for drying coal and for generating electricity for use at the mine. The project returns a positive value for the NPV of 7.46 million USD and an IRR of 74.2 percent.

Table 10: Combined Power Generation and On-site Use Option Forecast Results

Power Gen & On-Site Use Option	
Evaluation Scenario	Base Case
Annual Operating Hours	7,000
Gas Forecast-PowerGen (million m^3)	78.6
Gas Forecast-Coal Drying (million m^3)	16.0
Total CAPEX (million USD)	6.3
Tons of CO2e (x thou.)	504.0
Carbon Sales Price (USD)	$1.00
Plant Size (MW)	4.40
CAPEX/Tons CO_2e	0.01
Electricity Sales Price (RMB/kWhr)	0.6
NPV/Tons CO_2e	0.01
NPV (Million USD)	7.46
IRR (%)	74.21%

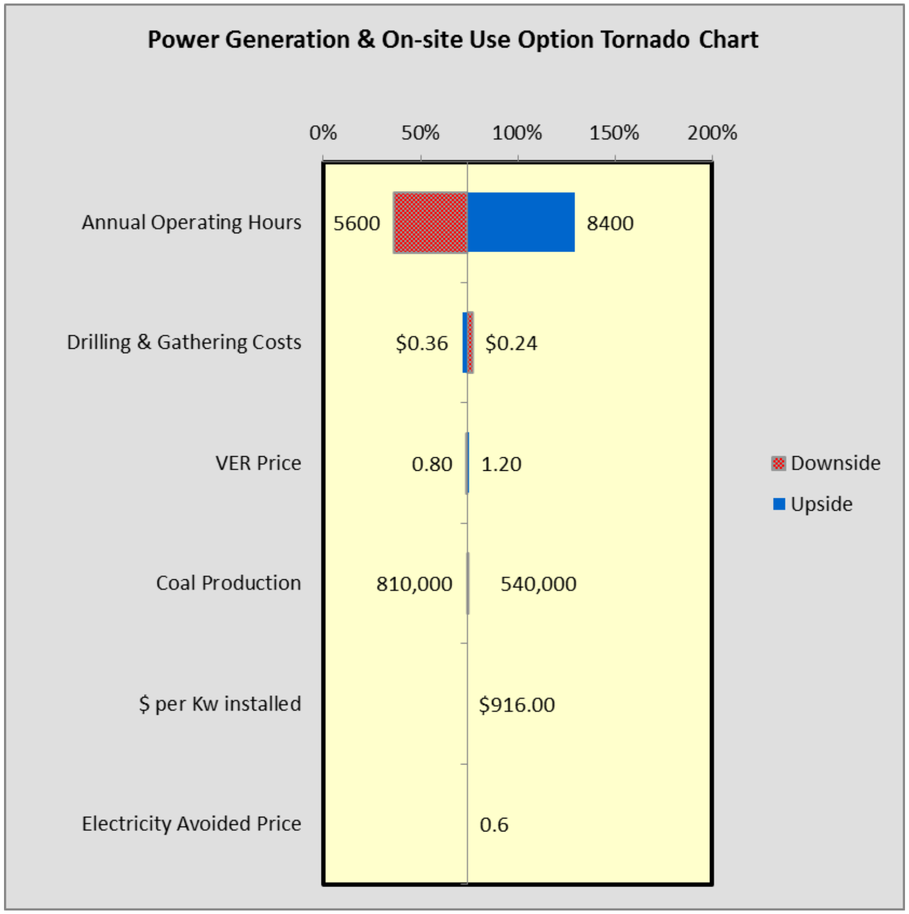


Figure 15: Combined Power Generation and On-site Use Sensitivity Analysis, Tornado Chart

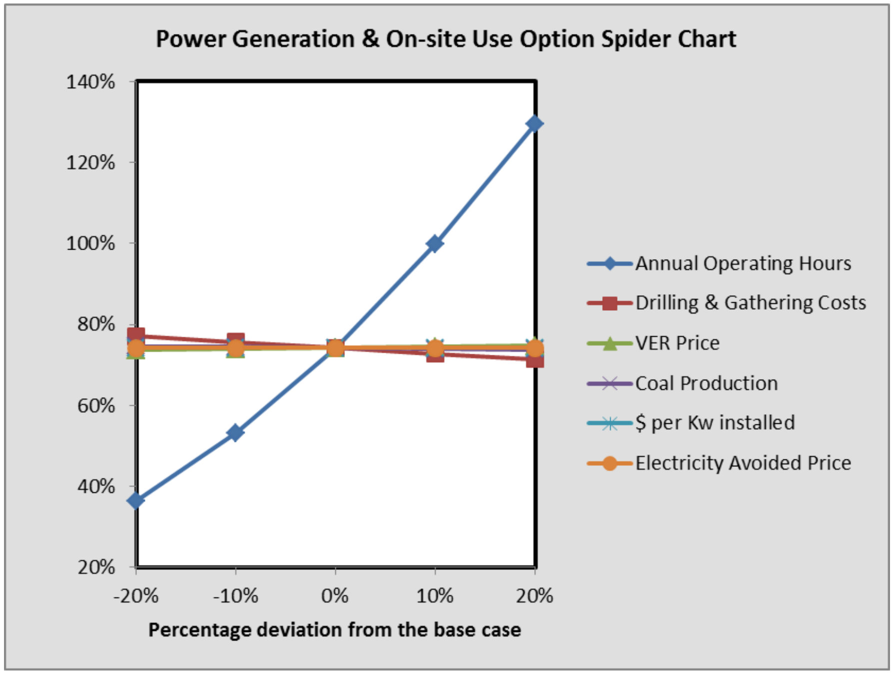


Figure 16: Combined Power Generation and On-site Use Sensitivity Analysis, Spider Plot

Sensitivity Analysis of Power Generation and On-site Use Option

The Raven Ridge team performed a sensitivity analysis on this option using the 10 md production forecast utilizing Crystal Ball™ to generate a Tornado Chart and Spider Plot (**Figures 15 & 16**). Both of these figures indicate that varying the amount of hours that the project operates annually would have a significant impact on the economic performance of the project, while varying all other variables would have little impact.

Comparison of Economic Performance of End-use Options

The Raven Ridge team recommends either end-use option as each option's economic indicators look favorable (**Table 11**). The optimal option for the Fuhong mine will be decided by mine management as determined by access to finance and the energy needs of the mine.

Table 11: Comparison of End-use Options

Comparison of Economic Performance for Two End-Use Options		
Evaluation Scenario	Power Gen	Power Gen & On-site Use
Gas Forecast-Project (million m3)	94.6	94.6
Total CAPEX (million USD)	7.13	6.3
Tons of CO2e (x thou.)	246.2	504.0
Carbon Sales Price (USD)	$1.00	$1.00
Plant Size (MW)	5.30	4.40
CAPEX/Tons CO2e	0.03	0.01
NPV/Tons CO2e	0.03	0.01
NPV (Million USD)	8.11	7.46
IRR (%)	0.67	0.74
Payback Period (yrs)	2.50	2.75

Conclusions and Recommended Next Steps

The Fuhong Mine plans to increase the present rate of mining from 140,000 metric tons annually to 300,000 metric tons per year in the near future, with the addition of a mechanized continuous miner. Presently the mine has an operating gas drainage station producing at a rate of 140 cubic meters per minute with a maximum methane concentration of 20 percent; the current drainage and ventilation systems will be insufficient for maintaining safety with the increased production plans of the mine. The total gas resources estimated for the Fuhong Mine are 122.7 million cubic meters. Based on plans to increase production, sufficient methane could be recovered and utilized to fuel a power generation facility and/or coal drying system. Delivering CMM in sufficient quantity and quality will depend on developing a drainage system that provides adequate safety while producing a usable fuel.

Conclusions and Recommended Next Steps

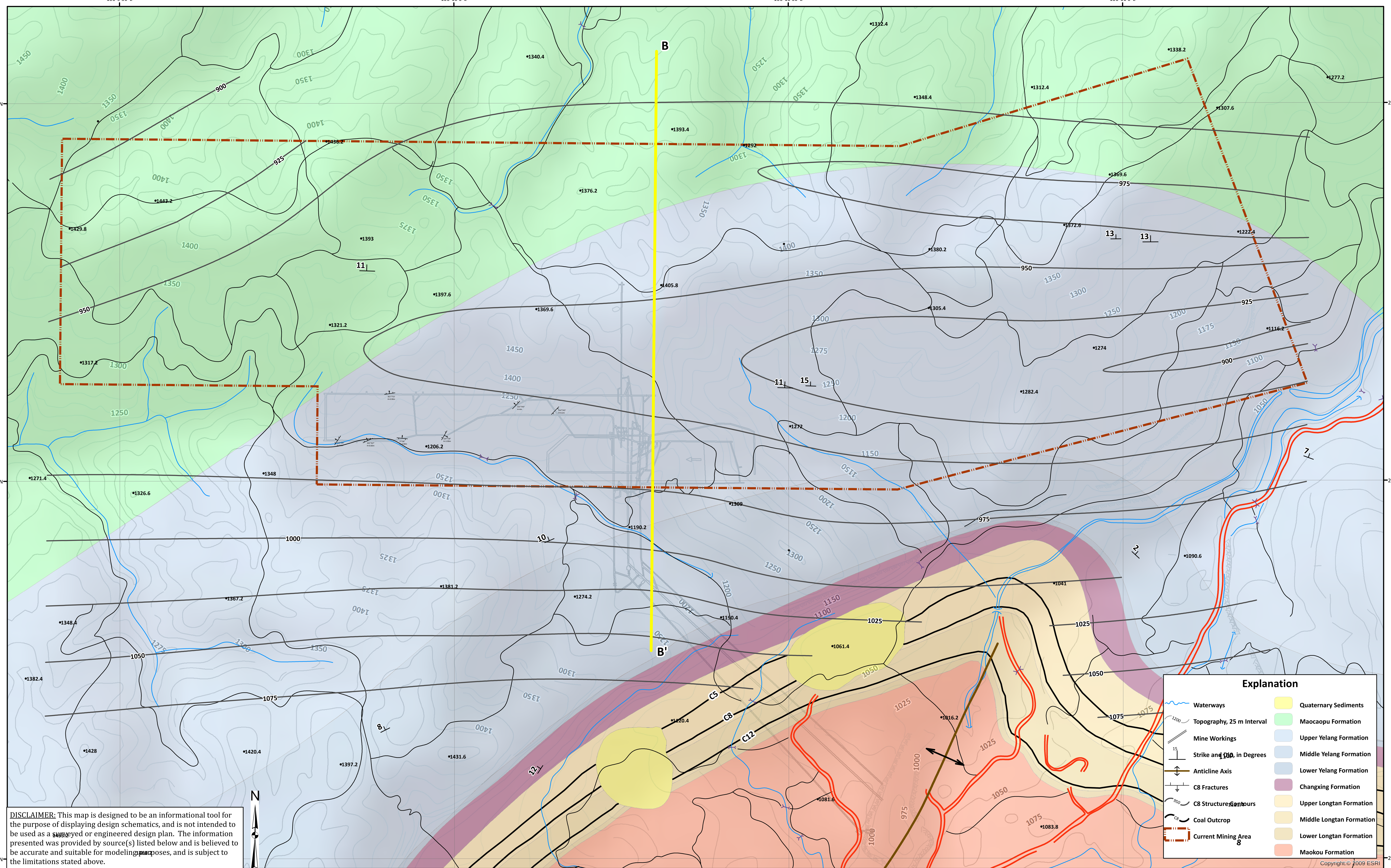
Current projections show that installation of a CMM drainage system could produce 94.6 million cubic meters over 10 years. RRR proposes that the mine consider two end use options: power generation by internal combustion engines for use at the mine; or combined power generation by internal combustion engines and on-site use for drying of low quality coal. The greatest risks for either end use are those related to the dispatch and sales of surplus power generated by the project. However, it is assumed that all power generated will be used by the mine. In the power generation only option, 56,279 MWh of electricity will be generated annually. The total capital expenditures for this opportunity are 7.13 million USD, with a payback period of 2.5 years. Carbon emissions would be reduced by 246.2 thousand tons of CO_2e over the project's 10 year life. In the combined power generation and coal drying option, in addition to fueling the equipment to dry the low grade coal using 1.595 million cubic meters of the available gas, 46,798 MWh of electricity will be generated annually for use at the mine. The total capital expenditures for this opportunity are 6.3 million USD, and the payback period is 2.75 years. Carbon emissions would be reduced by 504.0 thousand tons of CO_2e over the project's 10 year life.

Recommended next steps to mine management are:

- Commission a feasibility study that will determine the potential for developing a cost effective plan to construct and operate a CMM-fueled power production and coal drying facility;
- Engage with local NDRC to obtain necessary endorsements to advance plans for CMM recovery and use;
- Contract with a design institute to provide final engineering design and identify contractors to construct the CMM drainage and utilization system; and,
- Secure project financing.

NEA (2011): "Development and Utilization of CMB and CMM During the Twelfth Five-Year Plan," (Chinese), National Energy Administration, December 2011. http://www.nea.gov.cn/131337364_31n.pdf

Figure 17: View of pump house for gas drainage system at Fuhong Mine



DISCLAIMER: This map is designed to be an informational tool for the purpose of displaying design schematics, and is not intended to be used as a surveyed or engineered design plan. The information presented was provided by source(s) listed below and is believed to be accurate and suitable for modeling purposes, and is subject to the limitations stated above.

Project Name: Fuhong Pre-Feasibility Study EPA	
Map Document: PFS - Geologic Map.mxd	
Drawn By: Candice L.M. Tellio	Date: 16 October 2012
Approved By: Raymond C. Pilcher	Date: TBD
Source: Xuzhou Great Wall of Basic Engineering Co., Ltd	Date: April 2012
Current Revision No.: Original	Date: 16 October 2012
Revised By: N/A	

U.S. EPA Coalbed Methane OUTREACH PROGRAM

RAVEN RIDGE RESOURCES INCORPORATED

Exploration & Development Of Natural Resources

584 25 Road - Grand Junction, Colorado 81505
(970) 245-4088 - FAX (970) 245-2514

Global Methane Initiative

Plate 1: Geologic Map

SCALE 1:5,000

0 50 100 200 300 400 500 Meters

Xian 1980 3 Degree GK Zone 35

The Xishui Fuhong Coal Hydrological Geologic Column

Age of the Strata: Era	Period	Series	Stratigraphic Name: Formation	Member	Stratigraphic Code	Scale 1:200	Thickness Minimum ~ Maximum / Average (m)	Lithology Description	Hydrogeological Characteristics
Cenozoic	Quaternary				Q		0 ~ 12 / 6	Sallow, and khaki-colored clay, loam, sand, gravel and sediment fall mostly in the terrain mutation, thickness 0 ~ 12m. Unconformable contact with underlying strata.	Porosity aquifer, water, weak
Mesozoic	Triassic	Lower	Maocaopu Formation	2	T_1m^2		>200	Light gray, gray thin to thick-bedded limestone, dolomitic limestone, argillaceous dolomite and dolomite, the top and bottom of the mottled dolomitic dissolution collapse breccias. Thickness of> 200m.	With cave fissure water, rich water
				1	T_1m^1		200 ~ 260 / 230	Gray thin to thick layer micro-fine crystalline limestone, argillaceous limestone; argillaceous limestone, from top to bottom, the clay content gradually increased, local with oolitic, bamboo-like, within the debris and suture construct. Thickness of 200 ~ 260m.	Weak with bedrock fissure water, rich water
			Yelang Formation	3	T_1y^3		22.9 ~ 140.0 / 81.45	Gray-green, purple, dark purple thick layered microcrystalline argillaceous limestone, mudstone and silty mudstone, and a little marl, calcareous bands and a lot of muddy layers. Thickness of 22.9 to 140.0m.	Weak with bedrock fissure water, rich water
				2	T_1y^2		148.2 ~ 160.0 / 154.1	Light gray, gray,thick layer of fine grained limestone, calcareous mudstone, marl microcrystalline intermittent folded muddy layers and secondary calcite veins, local small individual fossils. Thickness of 148.2 to 160.0m.	With cave fissure water, rich water
				1	T_1y^1		6.8 ~ 10.0 / 8.45	Gray, purple-gray calcareous mudstone and bedded microcrystalline marl interbedded, local folder silty calcareous mudstone, significant levels of bedding and vein-like bedding thickness of 6.9 ~ 10.0m.	Weak with bedrock fissure water, rich water
Paleozoic	Permian	Upper	Changxing Formation		P_3c		35.7 ~ 50.0 / 42.85	Gray, purple-gray, dark gray thick-bedded microcrystalline argillaceous limestone, siliceous limestone, calcareous mudstone and bedded microcrystalline marl, interbedded local folding containing the bands of silty calcareous mudstone and argillaceous carbon, with sutured structure, significant horizontal bedding and stockwork layers. 35.7 ~ 50.0m	Including karst fissure water, rich water-based medium
			Longtan Formation	3	P_3l^3		37.5 ~ 68.12 / 52.81	Yellow gray, light gray, dark gray, thin to thick-bedded silty mudstone, muddy siltstone, silty mudstone, mudstone, argillaceous limestone, calcareous mudstone, carbonaceous mudstone and coal lines, local folded Ling iron siltstone, claystone, pyrite nodules and other plant leaf fossils.This section containing only the C5 mining seam, with a seam thickness of 0.95 to 1.94m, and an average of 1.41m, pulverized coal-based, showing stable thickness. Thickness 37.5 ~ 68.12m.	Weak with karst fissure water, rich water
				2	P_3l^2		24.80 ~ 37.75 / 31.28	Yellowish gray, light gray, dark gray claystone and fine sandstone, mudstone, carbonaceous mudstone, silty mudstone, partly with a siderite seam with pyrite nodules, and plant debris fossils.This section containing C8, C12, two layers of coal, with C8 seam enterprising 2.00 ~ 2.65m, and an average of 2.22m, C12 coal seam thickness of 0.98 ~ 1.92m, and an average of 1.52m. Thickness of 24.80 to 37.75m.	Including karst fissure water, rich water-based medium
				1	P_3l^1		2.34 ~ 20.30 / 11.32	Gray microcrystalline limestone lumps, clay, pyrite and yellow iron ore, the underlying strata was the unconformity contact. Thickness 2.34 ~ 20.3m.	Weak with karst fissure water, rich water
		Middle	Maokou Formation		P_2m		>700	Light gray, dark gray, gray to thick-bedded microcrystalline to fine crystalline limestone, intermittent gravel pyrite clay rocks and limestone breccia. Local folding of dark gray limestone, see calcite veins, and see the dissolution phenomenon. Brachiopod fossils and other small individual fossil debris is present. Greater than 700m. Contact with the unconformity on the underlying strata.	Cave fissure water, rich water

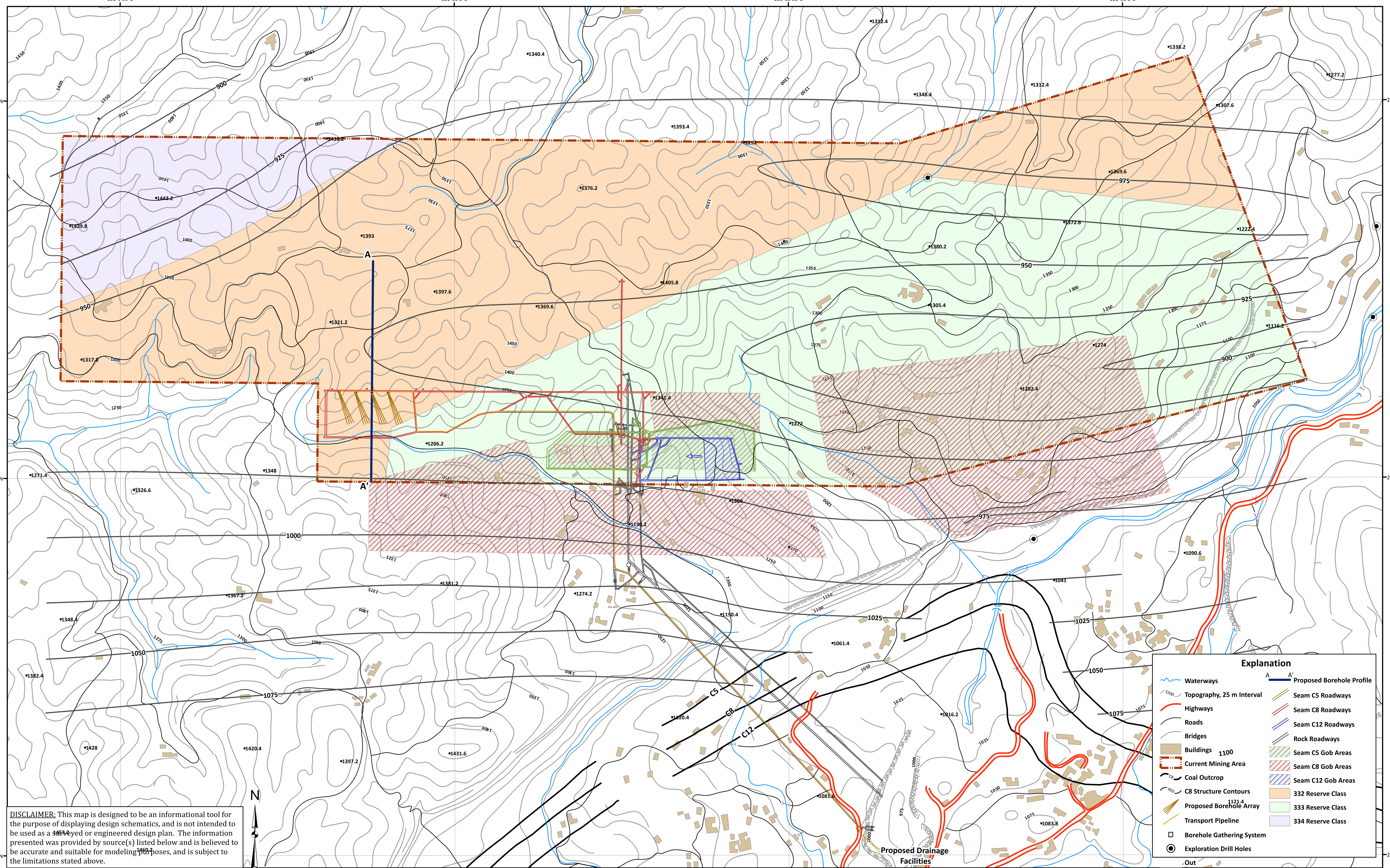
Modified From Geologic Report
Institute Coal Geology

Raven Ridge Resources Incorporated
Exploration & Development
Of Natural Resources
584 25 Road • Grand Junction, Colorado 81505
(970) 245-4088 • FAX (970) 245-2514

U.S. Environmental Protection Agency

Plate 2: Fuhong Prefeasibility Study

Stratigraphic Column



DISCLAIMER: This map is designed to be an informational tool for the purpose of displaying design schematics, and is not intended to be used as a surveyed or engineered design plan. The information presented was provided by source(s) listed below and is believed to be accurate and suitable for modeling purposes, and is subject to the limitations stated above.

Project Name: Fuhong Pre-Feasibility Study EPA	
Map Document: PFS - Proposed Drainage Map.mxd	
Drawn By: Candice L.M. Tellio	Date: 17 October 2012
Approved By: Raymond C. Pilcher	Date: TBD
Source: Xuzhou Great Wall of Basic Engineering Co., Ltd	Date: April 2012
Current Revision No.: Original	Date: 17 October 2012
Revised By: N/A	

U.S. EPA Coalbed Methane OUTREACH PROGRAM

RAVEN RIDGE RESOURCES INCORPORATED

Exploration & Development Of Natural Resources

584 25 Road - Grand Junction, Colorado 81505
(970) 245-4088 - FAX (970) 245-2514

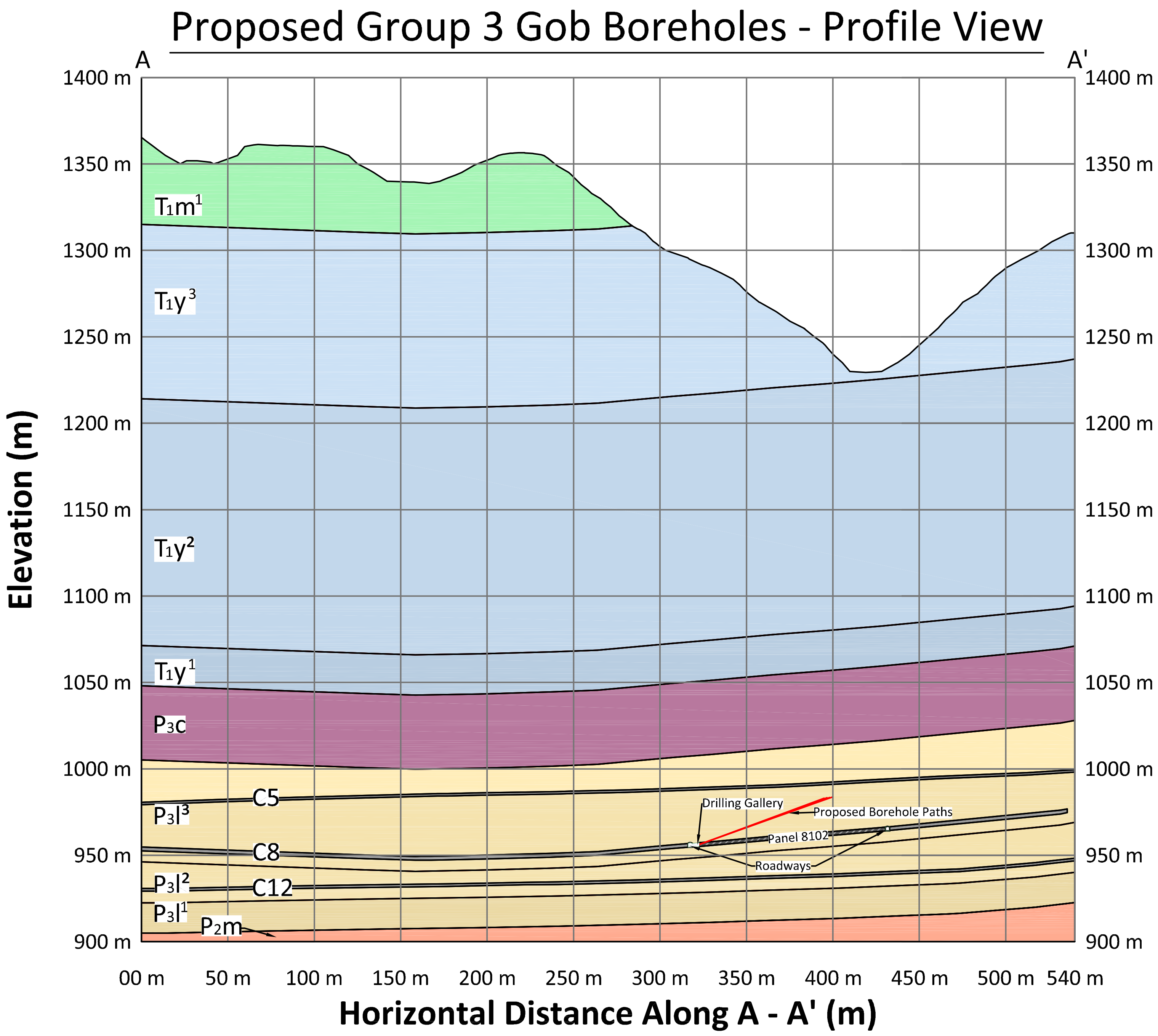
Global Methane Initiative

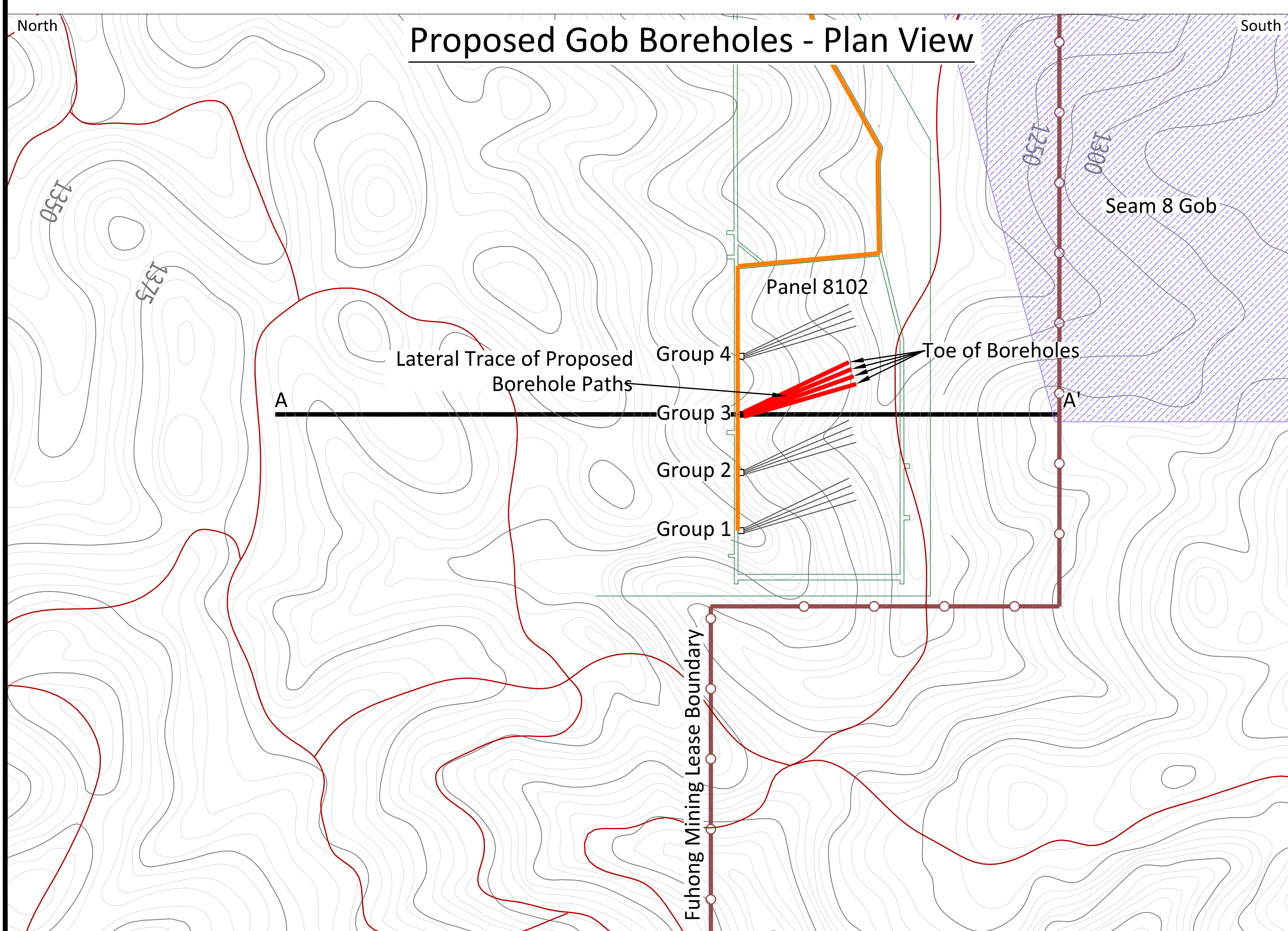
Plate 3: Mine Plan with Proposed Drilling Layout

SCALE 1:5,000

0 50 100 200 300 400 500 Meters

Xian 1980 3 Degree GK Zone 35





EXPLANATION

- Proposed Borehole Drilling Gallery
- Proposed Gas Transport Pipeline
- Group 3 Proposed Gas Drainage Borehole Path
- Proposed Gas Drainage Borehole Paths
- Seam C8 Roadways
- Fuhong Mining Lease Boundary
- Roads
- Topographic Contours (5 meter interval)

RAVEN RIDGE RESOURCES INCORPORATED
Exploration & Development Of Natural Resources
584 25 Road Grand Junction, Colorado 81505
(970) 245-4088 • FAX (970) 245-2514

US EPA and XISHUI FUHONG COAL MINE

FUHONG CMM RECOVERY PROJECT

Plate 4: Proposed CMM Planned Borehole Profile with Design Paths - Panel 8102

Dwg Name: Coal Model.dwg