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Coal Reserve Estimation and Selection of Mining Method in Khalashpir Coal Field, Rangpur, Bangladesh

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***Abstract*—Selection of mining method is often vacillating and a proper coal reserve estimation could be a solution to this, where the 'University of British Columbia (UBC) Method' and 'Present Situation of The Coal Basin' would be used as touchstones. This paper calculates the probable reserve with software and manually as well. The basin carries 8 coal seams with an average composite thickness of about 37.21 meters. There is nuance in between proved(3.75km² area with 184.19 million tons reserve) & probable (7.83 km² area with 385.53 million tons reserve) area results. In Khalashpir coal field each parameters are rated in UBC method and a final rating is summed up for each mining method and other technical aspect are also taken into consideration. On the basis of numerical approach, technical parameters and present situation of the coal basin, it has been assumed that Multislice longwall mining along with caved area fill, might be the most appropriate mining method for Khalashpir coal field.**

***Keywords*—Khalashpir coal field, UBC method, Technical parameters, rating, longwall mining.**

I. INTRODUCTION

Bangladesh is a small country where Gas has been the prime energy source. Due to the folded structures of the eastern part, there has been various gas fields discovered in that region, and thus a clear imbalance has been evident with the western part. The power generation, agricultures, industries and almost every sectors are greatly contingent upon gas supplies. So new gas field discovery has been the crying need at present. An awful prediction has been made that we might have the scarcity of gas by 2030. Hence, focusing on alternative energy resource has been a matter of concern now. And coal could be the adjunct to this as the western part has exhibited fault bound graben gondwana coal basins. Extraction of coal would not only pacify the energy need but also would help to make our country an energy rich and the western portion of the country would taste the development. So far six coal fields has been discovered and Khalishpir could take a position there with potentiality.

Though a conducive mining method hasn't been set yet for it. Here we are trying to postulate a one through this article.

The Khalashpir coalfield is situated at about 13 km west of the Pirgonj Upazila headquarters, 48 km south of the Rangpur District town and at a distance of about 290 km north of Dhaka.Agriculture is the prime livelihood medium and farmers grow amen and boro rice here in winter and dry seasons respectively. However, there are substantial areas of wheat and maize cultivation.Some people are also engaged in poultry farming. The prospective coal basin ~~is~~ lies in between latitudes 25º23'14" N to 25º30' 00" N and longitude from 89º09'12" E to 89º15'00" E respectively in the Survey of Bangladesh Topographic Sheet No. 78 G/3 \ (Fig. 1).

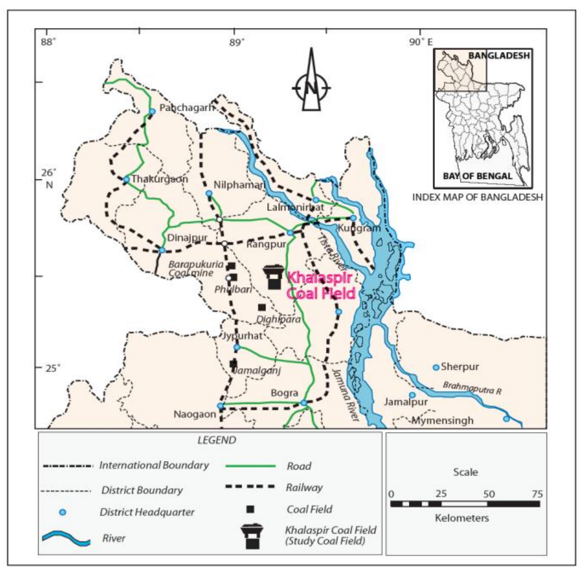

Figure-1: Map showing the location of the study area.

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The coal field was delineated by Geological Survey of Bangladesh (GSB) in 1989 on the basis of four borehole GDH-45, GDH-46, GDH-47, and GDH-48. Occurrence of the coal has been proved in an area almostof 2.52 sq.km. Later on, further area of 12.26 sq.km is estimated to have probable reserve (Islam et al 1992). A China Company consortium of Hosaf International Ltd. and Senwine Mining Group Co. Ltd. Carried out a feasibility study and drilled fourteen more drill holes which are GTB-1, GTB-2, GTB-3, GTB-4, GTB-6, GTB-8, GTB-9, GTB-10, GTB-12, GTB-16, GTB-18, GTB-19, GTB-20 and GTB-21 (2004-2006) to explore the extent, geology and other aspects of the basin at the Khalashpir Coalfield.

II. STRUCTURE AND TECTONICS OF THE KHALASHPIR BASIN

The Khalashpir basin is a more or less a NE-SW elongated basin (Islam *et al*, 1992). This basin is situated at the Rangpur Saddle of the Stable Shelf Zone in the northwestern part of the Bengal Basin. The geologic history of the basin probably started from the Precambrian age. Khalaspir basin is considered to be one of such discovered Gondwana basins in the area. Three prominent gravity highs, the Pirganj high (-22.2 milli gal), the Bhendabari high (-32.2 milli gal), and the Bhadhuria high (-30 milli gal) are found to encompass the basin in the northeast, north and south-southeast respectively (Fig-2). The gravity map shows that the basin is fault bounded in the northeast and northwest side. Drilling data reveal the existence of one prominent fault in the north-northeast side (near GDH-46) with NNW-SSE alignment (Islam *et al*., 1992). The basin is bounded by faults in the northeast and the western margin (Miah and Arifuzzaman, 1988).

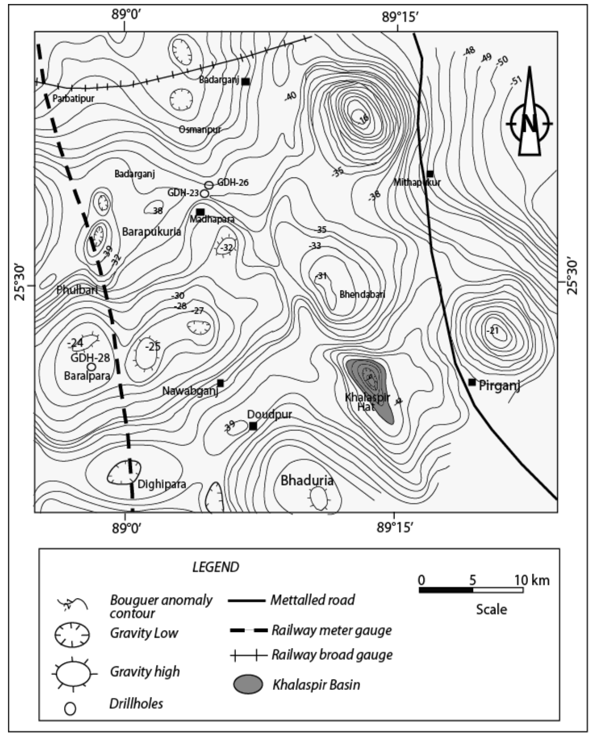

Figure-2: Bouguer anomaly contour map of Dinajpur and part of Rangpur District, Bangladesh showing Khalashpir basin (after Islam et al, 1992).

Objectives of the study

1. Estimation of the total proved and probable reserves within the basin.
2. Software based coal reserve calculation based on current data.
3. Selection of potential mineable coal seam with good quality and better position in the basin.
4. Selection of mining method for coal extraction from Khalashpir Coal Field.
5. Providing a mining method to extract maximum coal.
6. Selection of suitable filling materials.

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III. METHODOLOGY

Reserve Estimation

The thickness and continuity of the coal seams are determined from the drillholes data and seismic surveys. A majority of incline angle of section coal bed are bigger than >10° .Reserve can be estimated by different calculation. In this study, reserve is calculated using most common thickness area method. Formulation for reserve estimation is-

$$Reserve, \text{Q} = H \times A \times T \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Where,

H= Thickness of the coal seam

A= Area of proven reserve

T= Tonnage which is a conversion factor and depends on coal quality

In the study, 8 coal seams are considered to estimate the reserves. Among these 8 seams, I, II, and IV are stable and mineable coal seamscompared to the rest.In proved area of 3.75 km^2 (Table-I) having 14 drill holes, the totalreserve is thought to be almost 184.19million tons. While considering a probable area of 7.83 km^2 the total probable reserve is about385.53million tons.

TABLE-1
SEAM WISE TOTAL IN-SITU RESERVE OF KHALASHPIR COAL FIELD, RANGPUR, BANGLADESH

<table>
<tr><th rowspan="2">Seam No.</th><th rowspan="2">Average thickness of coal seam (m)</th><th colspan="2">Area (Sq. Km)</th><th colspan="2">Proved reserves (million tons)</th><th colspan="2">Probable Reserves (million tons)</th></tr>
<tr><th>Proved</th><th>Probable</th><th>Each seam</th><th>Total</th><th>Each seam</th><th>Total</th></tr>
<tr><td>I</td><td>8.303</td><td rowspan="7">3.75</td><td rowspan="7">7.83</td><td>41.10</td><td rowspan="8">184.19</td><td>85.82</td><td rowspan="8">385.53</td></tr>
<tr><td>II</td><td>9.778</td><td>48.40</td><td>101.06</td></tr>
<tr><td>III</td><td>2.00</td><td>9.90</td><td>20.67</td></tr>
<tr><td>IV</td><td>11.43</td><td>56.13</td><td>118.14</td></tr>
<tr><td>V</td><td>1.59</td><td>7.87</td><td>16.43</td></tr>
<tr><td>VI</td><td>1.93</td><td>9.55</td><td>19.95</td></tr>
<tr><td>VII</td><td>1.49</td><td>7.38</td><td>15.40</td></tr>
<tr><td>VIII</td><td>0.78</td><td></td><td></td><td>3.86</td><td>8.06</td></tr>
</table>

TABLE-II
AVERAGE THICKNESS AND DEPTH OF ALL COAL SEAM IN KHALASHPIR COAL

Parameters	Coal seam-I	Coal seam-II	Coal seam-III	Coal seam-IV	Coal seam-V	Coal seam-VI	Coal seam-VII	Coal seam-VIII
Average thickness (m)	8.303	9.778	2.00	11.43	1.59	1.93	1.49	0.78
Average depth (m)	261.26	283.89	308.28	325.01	358.84	370.18	382.56	394.02

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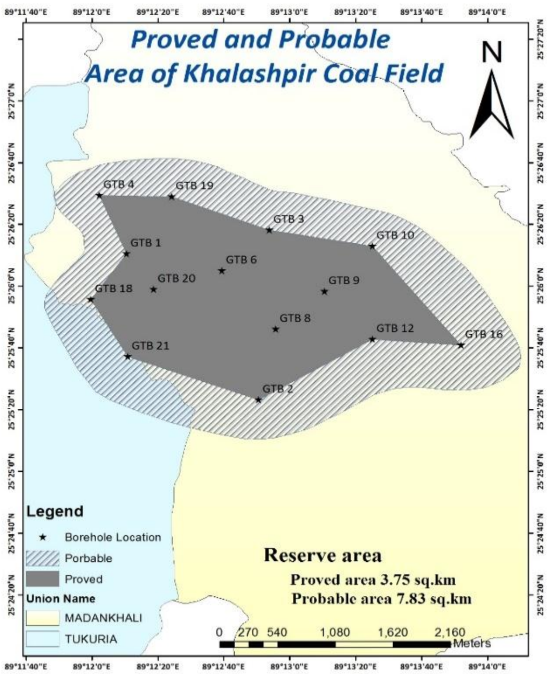

Figure-3: Proved and probable area of Khalashpir coal field, Rangpur, Bangladesh.

Software Based Reserve calculation

TABLE-III
RESERVE CALCULATION BY ROCKWARE SOFTWARE AT KHALASHPIR COAL FIELD.

Coal Seam no.	Volume (cu. m)	Apparent density	Reserve (million tons)
Coal seam 1	61600000	1.32	81.31
Coal seam 2	116400000	1.32	153.65
Coal seam 3	20000000	1.32	26.40
Coal seam 4	101800000	1.32	134.38
Coal seam 5	36800000	1.32	48.58
Coal seam 6	25400000	1.32	33.53
Coal seam 7	24000000	1.32	31.68
Coal seam 8	14600000	1.32	19.27
TOTAL =			**528.8**

IV. SELECTION OF MINING METHOD

The choice of method is largely dependent on the geology of coal deposit, in particular the depth of seam below the surface. Some controllable and uncontrollable parameters should be considered as well, and they should be determined after scientific and technical studies for each ore deposit.In simple word, our goal should be like, maximum yield, minimum cost and least danger. There are various methods for mining methods selection, such as, Nicholas Method, UBC Method, Mining Method selection based on technical parameter and fuzzy set theory. In this research work the following two methods were considered:

1. Selection of mining methods based on UBC method.
2. Selection of mining methods based on technical parameter.

A. Selection of Mining Methods Based on UBC Method

Input data for Khalashpir coal field used in UBC method

1. General ore Geometry and grade

General deposit shape: Tabular

Ore thickness: Average 11.43 m for Seam IV (table-ii)

Ore plunge: Plunge of the coal is (10°-20°)

Grade distribution: Uniform

Depth: Average 325.01 m for seam-IV (table-ii)

2. Rock Mass Rating (RMR) (after Bieniawski, 1973)

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TABLE-IV
RMR OF KHALASHPIR COAL FIELD

Classification parameter	Value	Rating
Coal		
Uniaxial Compressive Strength (MPa)	23.44	4
Rock Quality Designation	32%	7
Joint Spacing (m)	0.12	7
Joint Condition	Separation > 5 mm,	0
Groundwater	At dry condition	15
Total Rating		**33**
Hanging wall		
Uniaxial Compressive Strength (MPa)	50-100*	7
RQD	55%	12
Joint Spacing (m)	0.5	10
Joint Condition	Separation 1 - 5 mm,	10
Groundwater	At dry condition	15
Total Rating		**54**
Foot wall		
Uniaxial Compressive Strength (MPa)	50-100*	7
RQD	55%	12
Joint Spacing (m)	0.5	10
Joint Condition	Separation 1 – 5 mm,	10
Groundwater	At dry condition	15
Total Rating		**54**

3. *Rock Substance Strength (RSS)*

For coal **- 3.01**
For foot wall **- 8.05**
For hanging wall – **10.9**

Now this values were ranked through UBC method and we got

RANKING OF DIFFERENT PARAMETERS FOR KHALASHPIR COAL FIELD IN UBC METHOD

Parameters		Mining methods									
		OP	BC	SLS	SLC	LW	RP	SHS	C&F	TS	SSS
Ore geometry and grade											
General shape	Platy-tabular	2	2	4	4	4	4	4	4	2	1
Ore thickness	Intermediate	3	0	3	0	0	1	0	4	0	2
Ore plunge	Flat	3	3	2	1	4	4	-49	1	4	2
Grade distribution	Uniform	3	3	4	3	4	4	3	2	2	0
Depth	Intermediate	0	3	4	2	2	3	3	3	1	1
Rock Mass Rating (RMR)											
Ore zone	Weak	3	3	3	4	6	0	1	1	2	4
Hanging wall	Medium	4	3	3	3	4	3	2	4	2	1
Footwall	Medium	4	3	2	3	-	-	2	2	1	0
Rock Substance Rating (RSS)											
Ore zone	Very weak	4	4	0	2	6	0	0	0	3	4
Hanging wall	weak	3	3	1	3	5	0	1	5	2	2
Footwall	weak	3	3	1	2	-	-	2	3	2	2
Total		**32**	**30**	**27**	**27**	**35**	**19**	**-31**	**29**	**21**	**19**

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OP = Open pit, BC = Block caving, SLS = Sublevel stoping, SLC = Sublevel caving, LW = Longwall mining, RP = Room and pillar, SHS = Shrinkage stoping, C&F = Cut and fill, TS = Top slicing, SSS = Square set stoping sing UBC method the top four mining methods are Longwall mining-**35**, Open pit-**32**, Block caving- **30** and Cut & fill-**29**

B) Selection of Mining Methods based on Technical Parameter and Present Situation of the Basin

Various physical parameters, such as geologic and geotechnical properties of coal, foot wall, hanging wall, economic and environmental effects etc. have been considered in this case. While mining method selectionofKhalashpir coal fieldhas depended on the following points-

I) Geometric Shape of the Coal Deposit

The geometric shape of the coal seam-IVis platy, layered and stratified. As per the geometric shape, Longwall & Room and pillar mining methods are appropriate here.Usually, these methods are applied to the strati form ore deposits (Brady and Brown, 1985)

II) Thickness of the coal seam

The average thickness of coal seam-IV in Khalashpir coal basin is 11.43 m (Table-II), which is a thick seam. Based on this thickness the multi-slice longwall mining method is suitable for coal extraction. The longwall single slice mining methods are applied to the seam whose thickness ranges from 0.8-3.7 m. (Peng et al., 1984). So multi-slice longwall mining methods are the best and appropriate.

III) Inclination of seam

The seam inclination (dip) of coal seam-IV is about 10°-20°.It is a vital property for choosing an appropriate mining method. According to seam inclination, the Room and pillar as well as longwall methods are better.

IV) Depth of the coal seam

The depth of the coal seam-IV in Khalashpir coalfield is 325.01 m (Table-II) below the surfacewhich suggests for a longwall method, because Room and pillar method is used for shallow depth usually. The longwall mining method is applied in coal seam depth ranges from 46 to 762 m (Peng et al., 1984).

V) Strength of the Coal Seam

The strength of the bituminous coal in Khalashpir coalfield is low (Table-IV).

The Room and pillar mining are applied to strong and competent ore body (Brady and Brown, 1985). The size of the room and pillars depends on stability of the coal (for pillars). If the strength of coal is low thenstability also stands low.So the size of the pillar should be large to support the roof of the mine. Thusa huge volume of coal is left underground for supporting the roof. So Room and pillar methos is not accurate for Khalishpir coal field. The longwall mining is applied to any ore body but preferably the weak ore body with low strength and stability (Miller-Tait, et.al, 1995).

VI) Strength of the Hanging Wall

The room and pillar mining is applied to the strong hanging wall and the room and pillars size depends on the strength of the roof rock or hanging wall (Miller-Tait, et.al, 1995). If the hanging wall ~~is~~has low or moderate strength, then the pillar size ~~is~~ increases to protect hanging wall, and decreases the production rate of the mine. On the other hand the longwall mining is applied to the weak to moderate hanging wall or roof rock, must be break and cave; ideally in the thin bedded intermediate roof (Miller-Tait, et.al, 1995). The strength of the hanging wall of seam-IV is low to intermediate strength and roof is thin bedded (about 15 m). So the longwall mining method is preferable here.

VII) Subsidence effect

As subsidence is one of the major problems in the underground coal mining, it is emphasized to select the proper underground mining method. The coal seam-IV in Khalashpir coalfield is about 325.01 m below the surface. Above this, a huge thickness of sedimentary sequences of Gondwana Group, Dupi Tila Formation are present. When coal is extracted from the coal seam, due to low strength of hanging wall, the huge thickness of overburden sedimentary sequence will lose their equilibrium condition. Therefore, there would be a subsidence risk. On the basis of subsidence effect, the multi-slice longwall mining method with filling the caved area is recommended.

VIII) Hydrogeological conditions

There is a huge volume of Gondwana and Dupi Tila sediments presentabove the coal seam-IV in the Khalashpir coal basin. The Dupi Tila is a major aquifer system in Bangladesh. The unconsolidated and water bearing sandy layer is about 162 (average) meter thick (Dupitila Formation) overlying the coal deposit, and it is an active groundwater aquifer. The released enormous amount of water would be unmanageable and create several problems for an opencast mine.

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The presence of the loose sandy water bearing aquifer above coal deposit would not only create water management problem, but would also make open pit slope unstable and vulnerable to large scale landslides and these are great disturbance to mine operation.

IX) Settlement area

Area over the Khalishpir mine settlement possesses great fertile land and there are couple of villages there. If a new project of open pit mining is started then there would be disturbance to cultivation. And a large number of people would face residential problem as well. Moreover, surface subsidence is a common problem in case of underground mining. However,filling the caved area is preferable.

From the above discussion of UBC Method shows that the appropriate mining methods for coal extraction from the seam-IV is longwall mining atKhalashpir Coal Mine. After considering all the technical parameter of the coal seam, hanging wall, footwall and present situation of the basin, it is assumed the longwall multi-slice mining method with filling the caved area would be best fit for seam IV at Khalishpir coal field.

Multi-slice Longwall Mining Method Slice layout

By definition, a thick seam is one that can't be mined by one slice mining method. The highest 'one slice mining method' is presently applied about 4.5 m. Accordingly any coal seam above 4.5 m thick (above 3.5 m in some countries) is regarded as thick seam. In Khalashpir Coal Field, coal seam-IV has an average thickness of 11.43 m. It is therefore regarded as a thick coal seam.

For extraction, the coal seam-IV will be divided into 3 slices of inclined slice of 4 m, 4 m and 3.4 m of thickness (figure-4). Where each slice will be mined out using longwall shearer. The sequence of mining is in a descending order that is upper slice is mined prior to lower slice. If we allow the ascending order we can't control the thickness of caving we want. So a multi-slice longwall mining method would be adopted for the khalashpir Coal Field.

	Slice-1	3m	11.43 m
	Interslice layer	1m	
	Slice-2	3m	
	Interslice layer	1m	
	Slice-3	3.43m	

Figure-4: Proposed slices of Khalashpir coal mine.

V. Result And Discussion

The 8 coal seams encountered in khalashpir Coal basin has an average composite thickness of about 37.21 m. The proved reserve of coal in 3.75 km^2 is about 184.19 million tons and a probable reserve in an area of 7.83 km^2 is about 385.53 million tons. Software Based reserve calculation is about 528.8 million tons. Among the coal seams, seam-IV is the most potential because of having an average thickness of about 11.43 m and its 56.13 million tons of mineable reserve (about 31 % of total reserve), good quality and better position in the basin.

For the mining methods selection UBC (University of British Colombia) method and selection based on technical parameter and present situation of the basin are considered. At the end of the evaluations, the multi-slice longwall mining with filling the caved area considered as more suitable method for the Khalashpir Coal field.

But in the underground coal mine surface subsidence is a common problems. Due to surface subsidence the mine and mine area faces several problems in short term and even long term. If the non-filling method would be used in khalashpir coal field, then the possible problems that the mine and mine area face,are decrease of coal recovery & the mine service life and destroy the aquifer system, cultivation land, infrastructure of the mine area. The strata mechanics analysis shows that in the mining induce disturbed zone the main aquifer system of Bangladesh is dupitila aquifer system. So small or large fracture or crack would be developed due to subsidence and then the aquifer system would be imbalanced .Due to this problem the water inrush would occur and hamperthe production of the mine. At present time this situation is already being faced in the Barapukuria coal mine. If this land is destroyed due to mine subsidence, it would hamper the local and even gross food production of the country. So it is very much necessary to reduce the above stated problems in the Khalashpir Coal Field area and a backfilling technique could reduce this mentioned subsidence.Finally considering the ground condition of the basin, environment aspect, selection criteria and feasibility study, the multi-slice longwall with the filling the caved area would be best and appropriate choice for the extraction of coal from the Khalashpir coal field.

VI. Conclusion

Mono energy dependency can't support us for the rest of the century because number of new discoveries of natural gas shows a downward trend by the time we deplete our gas resources.

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Our recent natural gas can still support us best till 2035. And if we talk about alternative, then there is no optionwithout theextraction of our coal resources from the subsurface. Khalashpir is among the six (last Tilokpur, Naogaon, 2015) coal fields in pirganj upazila of Rangpur District in Bangladesh which was discovered in 1989 by GSB.

This Research shows that the calculated proved area and probable area is 3.75 sq.km and 7.83 sq.km respectively with reserve of 184.19 and 385.53 million tons accordingly. Reserve of each seam indicating that the seam-IV have the lion's share in the reserve (about 31% of the total reserve). So it will be very much professional to target the coal seam-IVfor underground mining.

In Khalashpir Coal Field, coal seam-IV has an average thickness of 11.43 m. It is therefore regarded as a thick coal seam. We usually can't extract such ultra-thick coal seam using ordinary longwall mining. So ultimately the mining method would be multi-slice longwall mining method.

Backfill in the caved area should be done to overcome subsidence and other technical ambiguities within the mine area. Mine backfilling study has been carried out in this research work and the Karatoya River has been proposed as fill materials for the backfilling. On the basis of economic aspect, availability of fills materials, environmental aspect and comparatively simplest method; it is therefore proposed that the partially cemented (very negligible amount) hydraulic backfilling method should take place at Khalashpir Coal Mine in order to control the subsidence. At the end of the evaluations, the mining method should bemulti-slice longwall with filling the caved area to get the desired outcome considering every aspects.

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