SUBSIDENCE PREDICTION REPORT

(THROUGH 3-D NUMERICAL MODEL)

TILABONI UG MINE

BANKOLA AREA

EASTERN COALFIELDS LIMITED

WEST BENGAL (INDIA)

DEPARTMENT OF MINING ENGINEERING
INDIAN INSTITUTE OF TECHNOLOGY
(BANARAS HINDU UNIVERSITY)
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Date: 09/03/2020

CERTIFICATE

This is to certify that work for **"Numerical modeling in 3- dimension for subsidence prediction of Tilaboni UGP in ECL"** has been carried out by Centre of Advanced Studies, Department of Mining Engineering, Indian Institute of Technology (Banaras Hindu University) under the supervision of undersigned.

(Prof B K Shrivastva)

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1.0 INTRODUCTION

Tilaboni mine is located in the north eastern side of Raniganj Coalfield. It is situated in Bankola Area, Eastern Coalfields Limited, Burdwan district of West Bengal. It lies between latitude 23^0 37' 48" and 23^0 40' 14" N and Longitude 87^0 16' 05" and 87^0 18' 25" E. The total area of Combined Tilaboni and Tilaboni Extension geological blocks is 10.83 sq. km.

Boundary of Tilaboni UG project is as under:

North West : Kumardih A Colliery

North East : Jhanjra Block

South East : Tilaboni Extension Block/Fault F9-F9 (throw-15 to 95m)

South West : Shyamsundarpur Colliery/Fault F1-F1 (throw- 65m)

1.1 COMMUNICATION

The mine is well connected by both road and rail. The Andal-Madhaiganj road which joins the G.T Road at Andal traverses through the northern part of the block. The distance to G.T. Road from the southern boundary of block is about 14 km. Ukhra Railway Station on the Andal-Sainthia branch line of the Eastern Railway is situated about 3 km away from the block.

The Durgapur Industrial Complex situated to the South-East of the block is about 28 km by road from the block. The Raniganj township, is about 30 km by road.

The nearest airport is at Dumdum (Kolkata), about 200 km from the project.

The nearest railway station is Ukhra on Andal-Sainthia branch line of Eastern Railways.

1.2 CLIMATE AND RAINFALL

Humid tropical climate prevails over the area. During the summer months lasting from March to May, the temperature generally varies from 30^0C to 40^0C. In winter November to February) it drops down to about 10^0C during the night. The relative humidity varies from 45% to 98%. The average annual rainfall is about 1400 mm, the major part of which precipitates during the period from June to October. The area is often subjected to a cyclonic storm locally known as “Kal Baisakhi” during the month of April to June.

1.3 PHYSIOGRAPHY AND DRAINAGE

The area forms an alluvial plain with very gently undulating topography. The elevation varies from 80m to 106m above M.S.L. The area is drained by two small nalas which originate within the block. They join the Tumni nala beyond the confines of the block, which finally drain into the river Ajoy which is the main drainage channel of the coalfield.

1.4 LAND USE PATTERN

Most of the land overlying the project area is tenancy land and used for agricultural purpose. Paddy is the main crop of the area which is harvested during late November and early December. There is about 65.8 ha of forest land within the block, which includes 21.1 ha of plantation. About 72.6 ha land has been acquired for construction of mine infrastructure and residential buildings.

2.0 GEOLOGY

Raniganj formation occupies the Tilaboni Combined Block. The general statigraphic sequence of Raniganj Coalfield (after Geological Survey of India) is as follows :

General Stratigraphic Sequence of Tilaboni Combined Block

Stratigraphic Units	**Formation**	**L i t h o l o g y**
Recent		Alluvium/soil
Sub-recent & Quaternary		Laterite, lateritic gravel, clays, running sand etc.
--- Unconformity --------------------------------------		
	Intrusives (Dykes & Sills)	Dolerite, mica peridotite and lamprophyre
	Supra Panchet	Coarse grained quartzose sandstone with bands of dark red silty shale
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-- Unconformity -----------------------------------		
Early Triassic	Panchet Formation	Coarse grained greenish grey sandstone bands of red silty shale
Damuda Group	Raniganj Formation	Fine to coarse grained micaceous sandstone, shale, carbonaceous shale and coal seams
	Barren Measures	Black laminated fissile shales with clays and ironstone bands
	Barakar Formation	Coarse grained feldspathic sandstone, shale and coal seams
--- Unconformity -----------------------------------		
Archaeans		Gneiss, granites &

		schists, shales and coal seams

The entire block is covered either by soil or laterite. The stratigraphic sequence, thickness of different formations and occurrence of different seams have been deciphered on the basis of sub-surface data obtained from exploratory drilling.

The sequence of coal seam with their thickness, parting, depth and reserves in the proposed project area have been shown in the following table:

Seam	Thickness Range (m)	Depth (m)	Total Geological Reserves (Mt)	Nos. of BH intersection
R-X A	0.84-2.22	65.69-90.72	0.6325	5
Parting	26.76-32.95			
R-IX Top	0.98-2.73	23.70-125.30	3.0631	16
Parting	1.63-21.81			
R-IX Bot	0.36-2.23	18.0-128.28	4.6733	22
Parting with R-VIII T1	28.35-80.85			
Parting with R-VIII Top	99.63-100.59			
R-VIII Top	1.07-1.32	77.09-154.18	-	4
R-VIII T1	0.10-1.01	37.73-190.67	-	53
Parting	14.30-31.88			
R-VIII T2	0.50-2.01	20.35-222.91	12.5810	69
Parting with R-VIII B1 (Top)	6.00-27.73			
Parting with R-VIII B1 (Comb)	23.76-27.50			
R-VIII B1 (Top)	0.30-1.47	82.22-231.04	7.5236	54
Parting	1.12-8.95			
R-VIII B1 (Bot)	0.90-2.59	84.85-237.30	13.0029	52
R-VIII B1	3.10-4.82	19.10-104.05	20.5636	22
Parting	8.20-21.77			
R-VIII B2	0.30-1.45	29.56-251.15	4.8036	68
R-VIII Bot	1.65-1.84	135.64-159.33		2
Parting with R-VII Top	27.14-42.45			
Parting with R-VII Comb	26.84-53.35			
R-VII Top	0.70-2.26	153.10-279.05	3.7302	17

Parting	1.14-14.09			
R-VII Bot	1.95-2.95	156.50-294.16	8.6470	17
R-VII	1.95-6.18	75.93-211.98	41.9954	50
Parting with R-VII A	23.85-48.74			
Parting with R-VII A/B Comb	39.00-54.55			
R-VII A	1.37-3.33	110.52-243.20	20.1713	34
Parting	3.85-27.20			
R-VII B	0.21-3.40	126.80-260.50	21.0555	35
R-VII A/B Comb	3.23-5.18	201.93-335.55	16.0614	21
Parting	12.96-27.50			
R-VII C	0.12-2.20	149.40-355.03	19.8299	48
Parting	18.13-51.08			
R-VI	1.98-6.58	187.75-391.15	63.8800	46
Parting	19.70-63.17			
R-V	1.20-6.30	216.75-341.25	61.9739	32
Parting	0.92-49.24			
R-IV	1.52-11.45	242.60-366.24	111.3215	34
Parting	24.12-35.34			
R-III	2.05-3.59	270.78-401.00	37.1007	32
Parting	9.42-45.52			
R-II	0.45-2.32	283.25-440.64	21.9464	28
Total			**494.5568**	

3.0 METHOD OF WORK

It is proposed to extract the coal by underground Bord and Pillar method of mining with Continuous Miner technology along with SDL. The Maximum extraction thickness will be 4.8m.

4.0 PERIOD OF PREDICTION

The detailed time period, for the prediction of subsidence required, is 25 years, at an interval of 5 years.

Stage – I 5 years

Stage – II 10 years

Stage – III 15 years

Stage – IV 20 years

Stage – V 25 years (End of mining)

4.1 SIMULATION FOR PREDICTION

The natural mining has to be simulated before it can lend itself to the numerical modelling. As the first step, Fig. 1 is a simulated grid map of the proposed mining area of the Tilaboni UG Mine in terms of contours of the surface profile. Fig. 2, Fig.3, Fig. 4 and Fig. 5 are the simulated grid maps of the workings of the seam R-VIIIT2, R-VIIIB1, R-VII and R-VIIA. The simulated mine plan has a scale of 1:5000, same as that provided by the mining company. Various types of hatchings of the panels in these maps portray the sequence of mining operations in the 5 years time block.

The prediction of subsidence and the resulting surface is, therefore, confined to 5, 10, 15, 20 and 25 years of mining. Table 4 gives the coordinates of few boreholes on the simulated grid maps, which can be used for the studying, and the analyzing of all the maps provided by us.

FIG. 2 SIMULATED GRID MAP OF R-VIIIT2 SEAM <TILABONI UG MINE>

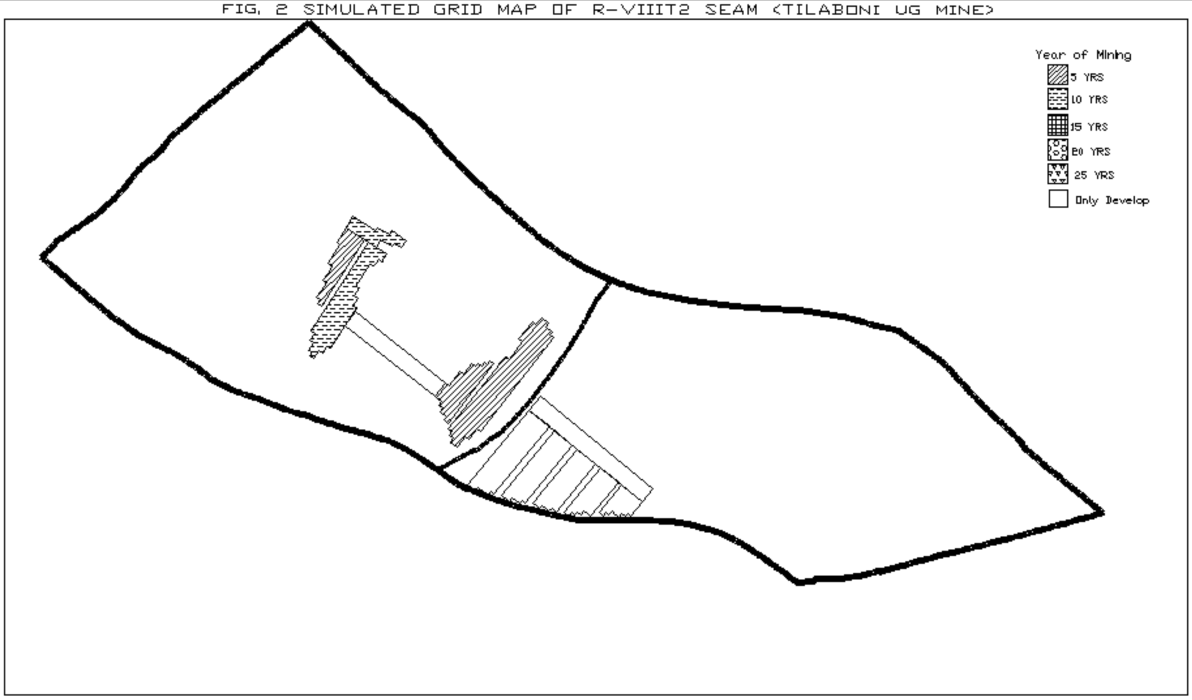


FIG. 3 SIMULATED GRID MAP OF R-VIIIB1&R-VIIIB1(BOT.) SEAM (TILABONI UG MINE)

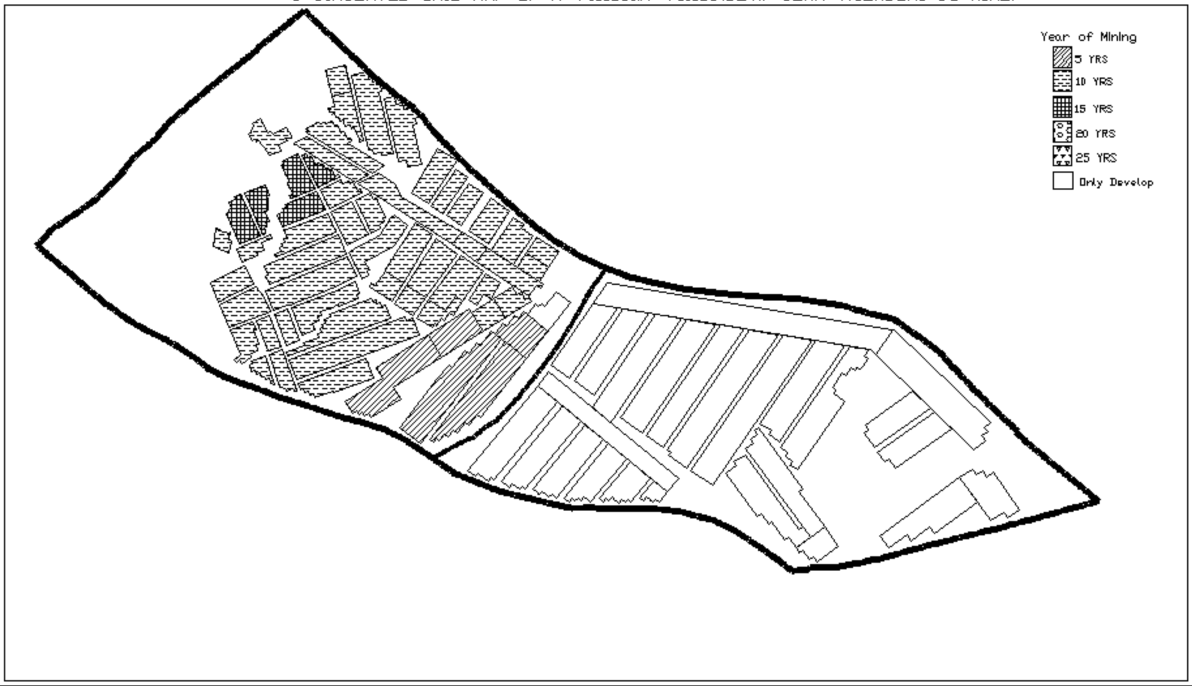


FIG. 4 SIMULATED GRID MAP OF R-VII&R-VII(BOT.) SEAM (TILABONI UG MINE)

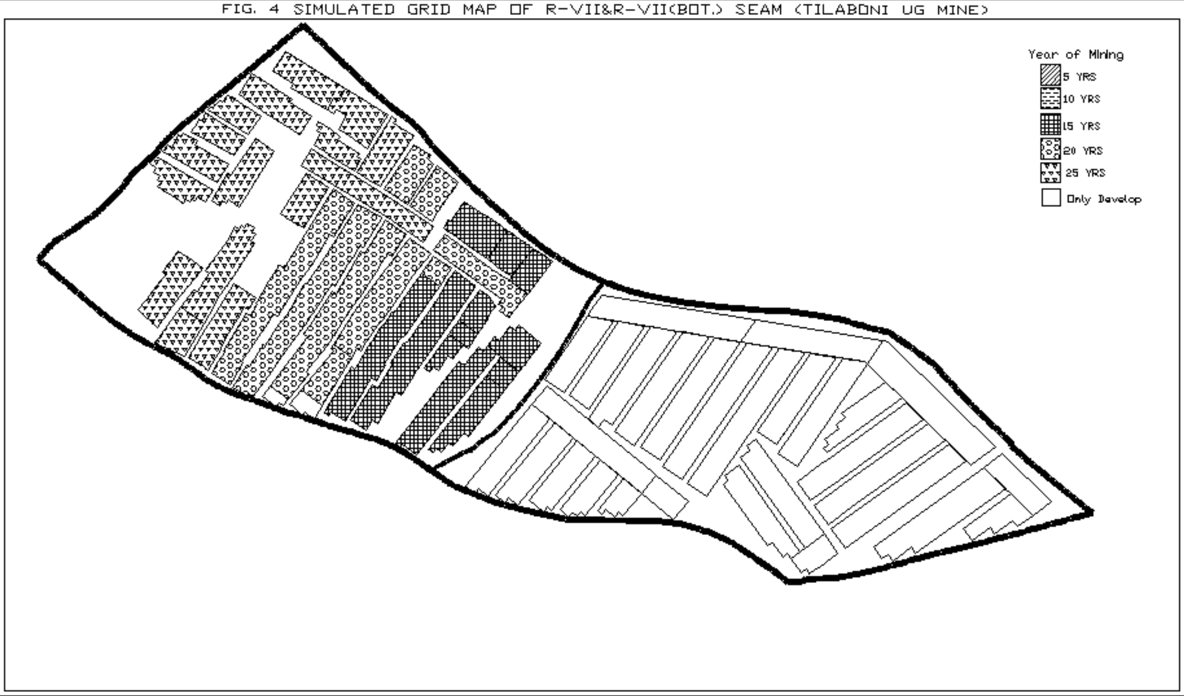


FIG. 5 SIMULATED GRID MAP OF R-VIIA&R-VIIA&B(COM) SEAM (TILABONI UG MINE)

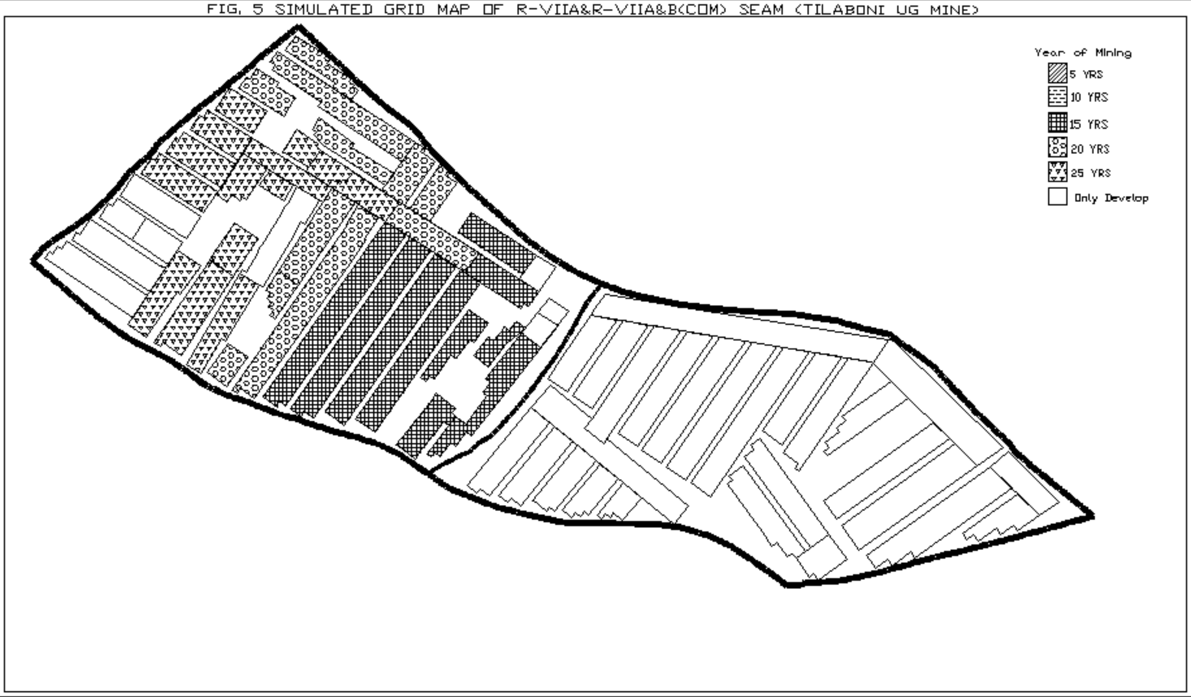


Table 4 : Coordinates of boreholes on the simulated grip map

Sl. No.	Borehole No.	X-Coordinate	Y-Coordinate
1.	TLB-5	1168	2313
2.	TLB-10	1784	2820
3	TLB-18	2869	2370
4.	NCRJ-3	2748	1766
5.	CMRT-11	2304	2420
6.	CMRT-1	1860	3479

4.2 **REQUISITE GEOTECHNICAL PARAMETERS FOR THE PREDICTION**

The numerical prediction of subsidence requires following basic data:

1) Geotechnical parameters of the seam and surrounding rock mass upto the surface,
2) Mathematical model and computer programs (software)
3) Major structural features of the strata,
4) Details of the mine excavation
5) Sequence of extraction and size of panels, and
6) Important features on the surface.

The information on the above mentioned parameters were provided by the company. The company also provided the data for the physico-mechanical properties used in the simulation. The above properties were taken for various panels as per their proximity to the above boreholes in the block. The boreholes nearest to the panels were considered to be representative one and hence selected for the simulation.

4.3 PREDICTION TECHNIQUE

The computer-simulated model was developed for the prediction of subsidence and alterations in the resulting profile of the surface, keeping in mind the total area, the mining sequence and geo-technical properties and above all, depth of each mining panel, which varies significantly from panel to panel and seam to seam. The grid map for simulation is based on 25 m grid on the surface having about 45241 points for calculation process using finite element method (FEM) – a numerical simulation technique. The computation for prediction of subsidence of the area is based on the grid pattern. The 3-D mathematical model, thus simulated was subjected to the finite element analysis. The model also takes care of the non-linear behaviour of the rock mass (if any), bed separation and its recontact.

5.0 RESULT

5.1 PREDICTED SUBSIDENCE CONTOURS

Fig. 6 shows the subsidence contours after 5 years of mining. Similarly, Fig. 7, Fig. 8, Fig. 9 and Fig. 10 give the subsidence contours at the end of 10 year, 15 year, 20 year and 25 years of mining respectively. The maximum values of the subsidence predicted at the end of each time blocks are given in Table 5.

Table 5: Maximum values of predicted subsidence at the various time blocks

Sl. No.	Year	Subsidence values, m
1.	5	-2.871
2.	10	-2.930
3.	15	-4.543
4.	20	-5.651
5.	25	-5.717

To illustrate an overall picture, a few subsidence values along with coordinates on the simulated grid maps for various time blocks of mining have also been summarized in the Appendix in the Table I.

5.2 THREE DIMENSIONAL PROJECTIONS OF SUBSIDENCE

To give a 3-dimensional impact of the subsidence, the predicted subsidence has been projected on the surface for each of the mining periods based on x and y coordinate defining the horizontal plane and ‘Z’ coordinate, the depth of the surface. It may be noted that the ‘Z’ coordinate has been exaggerated (25 times) to have a better visual appreciation of the impact of subsidence.

Figs. 6 through 10 give prediction of the subsidence at the end of 5, 10, 15, 20 years and 25 years of mining respectively, considering the surface to be horizontal, before mining. These figures give a real feel of the impact of subsidence as a result of the multi seam mining and the progression of mining with time. Two sets of subsidence figures are provided for each stage. These are having opposite viewing directions, *i.e.* 45^{o} and 225^{o}. It may be pointed out at this stage that the 3-dimensional projections shown in the figures 11 through 15 should not be used to pin point the maximum subsidence area because all the points may not be visible on the map. However, these drawings provide fairly accurate idea about ground behavior after mining.

It is worth noting that the troughs shown in the figures should be viewed in the proper perspective as the scale in 'Z' direction has been enlarged to 20 times to have appreciable viewing impact.

5.3 SURFACE PROFILE

The surface profiles of the mining block after each stage of mining have been predicted. These profiles have been obtained by superimposing subsidence with pre-mining surface profile after each mining sequence for different time blocks. Fig. 1 gives the surface profile of the mining block before mining. The contour maps which would finally emerge as a result of mining after 5, 10, 15, 20 and 25 years of mining have been predicted and is shown in Figs. 16 through 20.

Fig. 21 shows the 3-dimensional prediction of subsidence before mining for the Tilaboni UG Mine. Figs. 21 through 26 gives the 3-dimensional prediction of surface at the end of each mining sequence (the 'Z' axis has been exaggerated to 10 times for having better visual appearance of the impact of subsidence). A set of figures showing surface subsidence and surface profile at the end of 5, 10, 15 20 and 25 years of mining is also being provided in larger sizes at a scale of 1: 5000. The surface contours along with the panels of the (seam-R-VIII T2, R-VIII B1, R-VII and R-VIIA) are also being provided in larger sizes *i.e.,* at a scale of 1:5000.

6.0 Tensile Strain and Crack Width

6.1 *Maximum Tensile Strain*

Maximum predicted tensile strain for Tilaboni UG Mine at various time blocks has been given in the table 6.

Table 6. Predicted value for the maximum tensile strain in forest area for Tilaboni UG Mine at various time block

Sl. No.	Time Block	Tensile Strain mm/m
1.	5	27.19
2.	10	61.93
3.	15	63.44

4.	20	67.75
5.	25	91.77

The predicted maximum tensile strain at the end of 5 years of mining is 27.19 mm/m and it sharply increases at the end of 10 year of mining (61.93 mm/.) It further slightly increases to 63.44 mm/m at end of 15 years of mining and 67.75 mm/m at the end of 20 years of mining. It further increases sharply to 91.77 mm/m at the end of 25 years of mining.

6.2 Crack Width

It is well known from the field experience that the cracks may occur under the condition of high tension and weak rocks. The prediction of crack width is associated with high degree of uncertainty. Zones of possible cracks will lie in the vicinity of weak rocks and near fault planes under large tensile strain. To have accurate predictions, the strain maps should be superimposed over the detailed geological plan and geotechnical data. Cracks of significant width are likely to be formed at the end of mining.

Cracks width of approximately 300 mm/m is likely to occur at the end of 5 year of mining. It will increase sharply to more than 600 mm/m at the end of 10, 15, and 20 years of mining. Approximately 900 mm/m wide cracks are likely to be formed at the end of 25 year of mining.

7.0 DISCUSSION

Mining of underground panels results into subsidence at the surface. The prediction of subsidence have been carried out at 5 years time interval. Therefore, the prediction have made for different time blocks i.e. at end of 5 years of mining, 10 years of mining, 15years of mining, 20 years of mining and 25 years of mining. Resulting horizontal tensile strain and crack width due to mining subsidence has also become very important for subsidence management plan.

Table 5 summarises the predicted peak subsidence at the surface at various time blocks. It shows that the predicted peak subsidence at end of 5 year of mining is 2.871 m, 2.930 m at end of 10 years of mining, 4.543 m at the end of 15 years of mining, 5.651 m at end of 20 years of mining and 5.717 m at end of 25 years of mining. The subsidence manifests itself in cracks and high horizontal tensile strain on the surface (major reason of damage to surface structure).

Table 6 summarises the predicted peak horizontal tensile strain on the surface. It shows that the peak horizontal tensile strain at the surface in 27.19 mm/m at the end of 5 years of mining. It sharply increases to 61.93 mm/m at the end of 10 years of mining, 63.44 mm/m at the end of 15 years of mining, 67.75 mm/m at the end of 20 years of mining and 91.77 mm/m at the end of 25 years of mining.

Wide cracks are also likely to occur in the surface.

There are many surface features located over the surface of Tilaboni mine. The major surface features are forest, road, ponds (water bodies), villages, mining colony, nalas etc. The surface features have been superimposed with horizontal tensile strain areas for various time blocks. Fig. 27 to Fig. 31 shows the peak high horizontal tensile strain superimposed with surface at end of 5 years, 10 years, 15 years, 20 years, and 25 years of mining. The various hatching colours are depicting the zone of high horizontal tensile strain. The high horizontal tensile strain have been depicted in the range of 20 mm/m, 21 mm/m to 30 mm/m, 31 mm/m to 40 mm/m, 41 mm/m to 50 mm/m, 51 mm/m to 60 mm/m and more than 60 mm/m.

FIG. 27 HORIZONTAL TENSILE STRAIN AT THE SURFACE OF 5 YEAR OF MINING (TILABONI UG MINE)

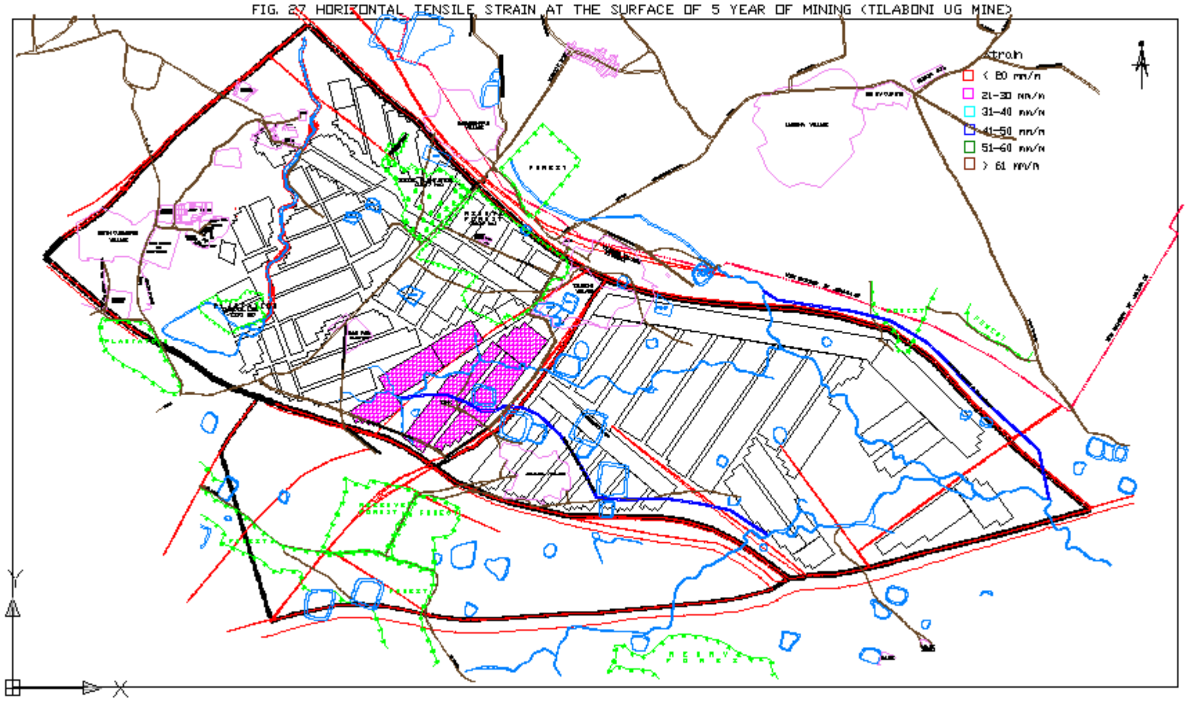


FIG. 28 HORIZONTAL TENSILE STRAIN AT THE SURFACE OF 10 YEAR OF MINING (TILABONI UG MINE)

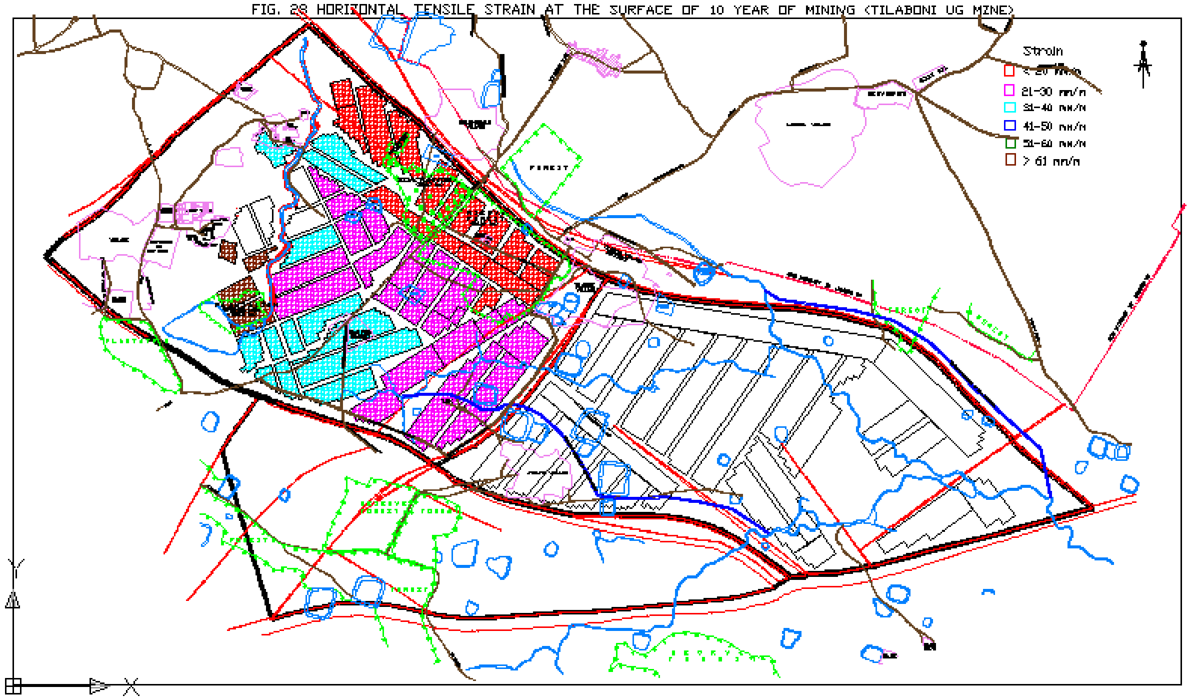


FIG. 29 HORIZONTAL TENSILE STRAIN AT THE SURFACE OF 15 YEAR OF MINING (TILABONI UG MINE)

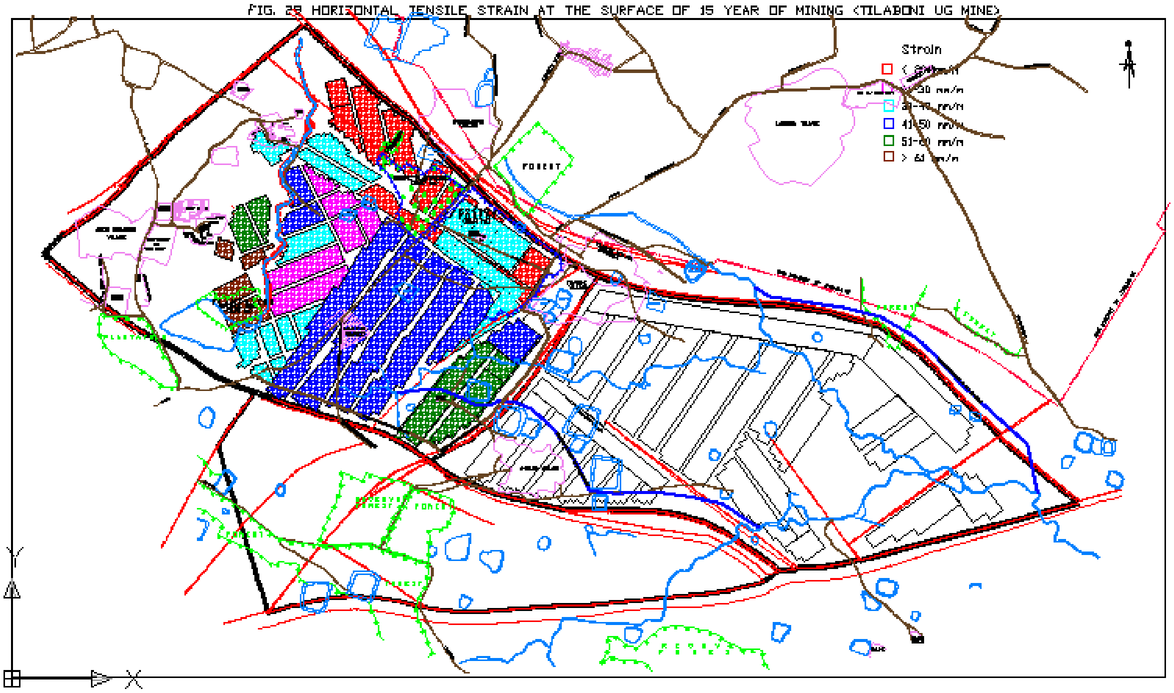


FIG. 30 HORIZONTAL TENSILE STRAIN AT THE SURFACE OF 20 YEAR OF MINING (TILABONI UG MINE)

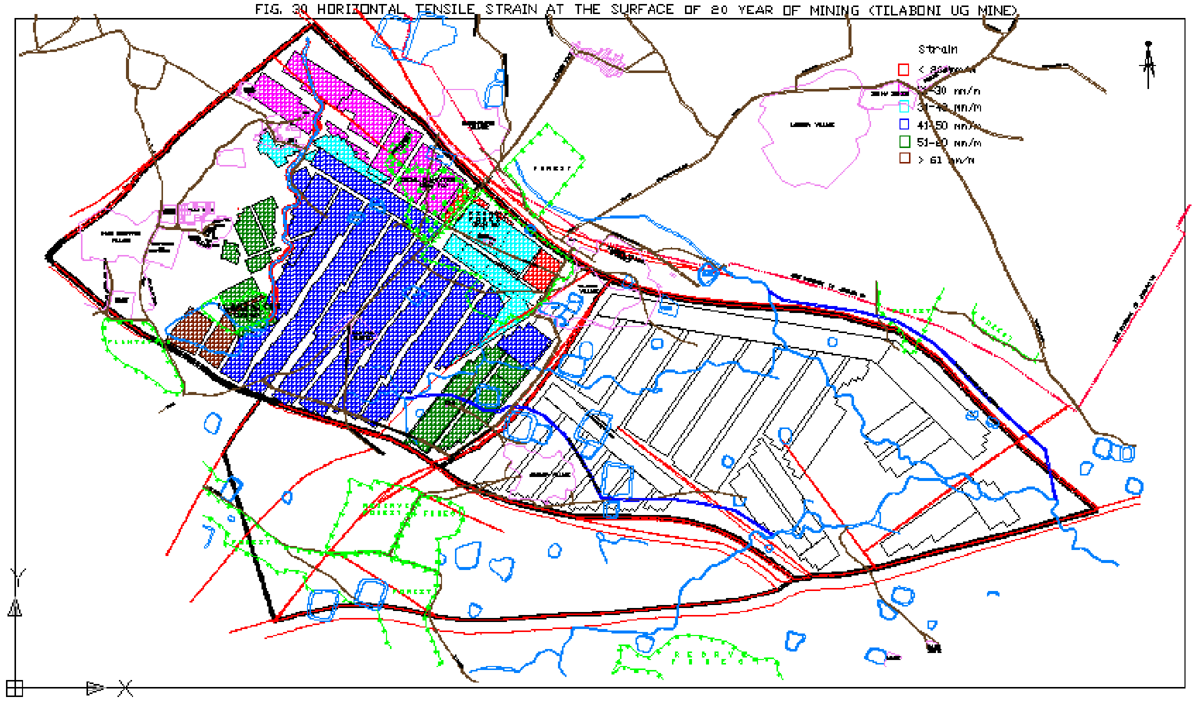
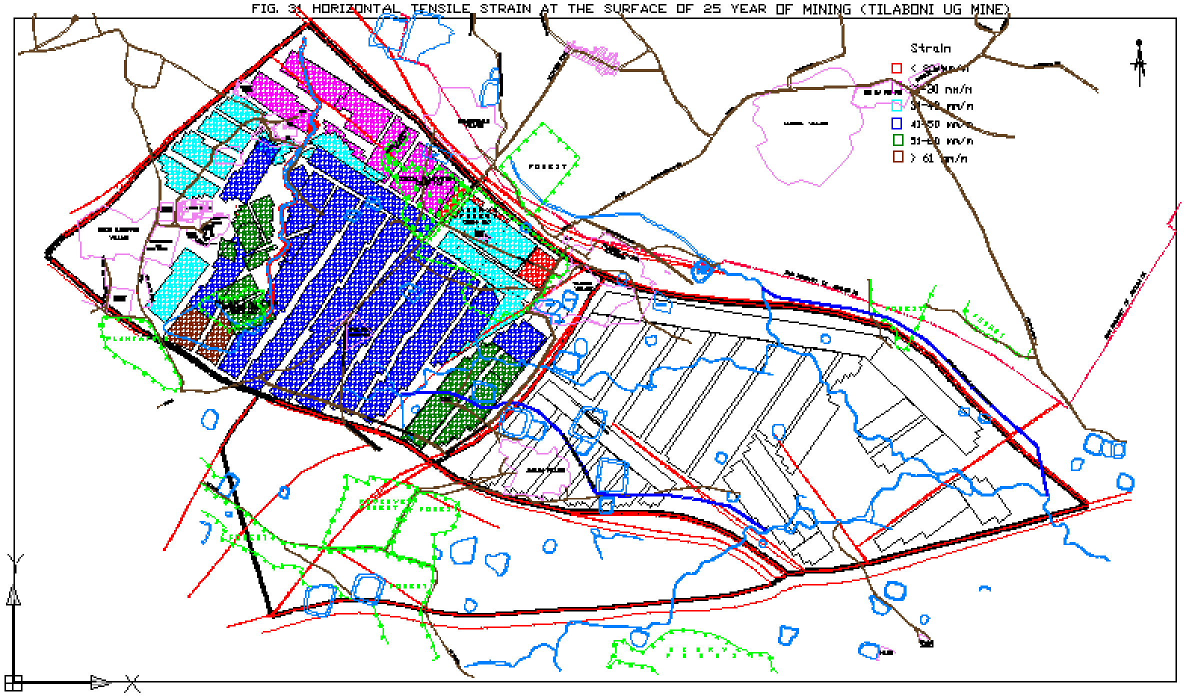


FIG. 31 HORIZONTAL TENSILE STRAIN AT THE SURFACE OF 25 YEAR OF MINING (TILABONI UG MINE)



The impact of subsidence on surface structures over the Tilaboni mine are discussed below.

1. **Forest area:** A forest area of approximately 40 hectares termed as reserve forest is within the mining block. Another forest area is adjacent to mining block (outside the mining block).

It is clear from the Fig. 27 through 31 that the forest block outside the mine boundary will not get affected by the mine subsidence. However, the reserve forest will get affected by the subsidence resulting from underground mining.

The reserve forest area will not have any impact of subsidence at the end of 5 years of mining as no panel is being worked below it (Fig. 27). The reserve forest area will get affected by mining subsidence after 5 years of mining. However, it will have horizontal Tensile Strain less than 20 mm/m and almost all forest area will get affected by subsidence (Fig. 28).

The reserve forest will experience horizontal tensile strain more than 30 mm/m (30-40 mm/m) at the end of 15 years of mining (Fig. 29). We may conclude that the forest cover will be damaged at end of 15 years of mining

2. Social Plantation: A small patch of land adjacent to reserve forest has social plantation i.e. plantation done by mining company.

The social plantation will not have any impact of subsidence at the end of 5 years of mining as no panel is being worked below these (Fig. 27).

The social plantation area will experience horizontal tensile strain less than 20 mm/m at the end of 15 years of mining (Fig. 29).

Fig 30 and 31 shows that these social plantation will have horizontal tensile strain more than 30 mm/m at the end 20 years of mining and 25 years of mining.

3. **Road** : A road is passing through mine boundary (Ukhara-Landoha DB Road). This road will not experience any horizontal tensile strain up to 5 years of mining (Fig. 27). However, this road will experience upto 50 mm/m of horizontal tensile strain at end of 10 years of mining resulting in wide cracks and damage to the road.

Mine officials are planning to divert the road and taking it outside the mine boundary.

4. **Pond:** There are some ponds on the surface of mine boundary. They will not experience any horizontal tensile strain at the end of 5 years of mining. These ponds will experience high horizontal tensile strain at the end of 10 years of mining (Fig. 28). It will get damaged. *It is suggested that these ponds must be relocated after 5 years of mining*.

5. **Village:** There are several villages on the surface within mining boundary or adjacent to it.

Nabaghanapur, Tilaboni, Jhanjra and Shyam Sunderpur villages are adjacent to mine boundary, where as Maji Para Basti is within the mine boundary. Fig 27 to Fig. 31 shows that the adjacent villages (Nabaghanapur, Tilaboni, Jhanjra and Shyam Sunderpur) will not get affected by mine subsidence. However, Maji Para Basti will not be affected by mine subsidence only upto 5 years of mining. The structures in Maji Para Basti will experience horizontal tensile strain up to 30-40 mm/m after 5 years of mining. The structures will get damaged.

Mine officials are planning to shift Maji Para Basti.

6.. **Staff Quarter :** The staff quarter built over mine surface will not get damaged by subsidence (Fig. 27 to Fig. 31).

7. **Nala :** There are many seasonal Nalas flowing on the surface. These are likely to get affected by mine subsidence and wide cracks are likes to occur.

It is suggested that these should be diverted before depillaring.

OPTION-I

Discussion was held with mine officials regarding this matter. They requested to suggest the measures so that the reserve forest could be protected. The following suggestions are being made.

(a) Barrier pillars to be left in all panels that are passing through forest area. It will results in having sub panel completely within the forest area.

(b) No depillaring operations should be carried out in panels and sub panels lying within reserve forest area. Partial extraction of these panels may be carried out such that all surface and underground strictures are stable.

Based on above discussion a set of strategy was carried out option-I Fig. 32, Fig. 33, Fig. 34 and Fig. 35 are simulated grid maps of the working of seam R-VIIIT2, R-VIIIB1, R-VII and R-VIIA. Subsidence was predicted as shown at the end of 5 years, 10 years, 15 years, 20 years and 25 years we shown in Fig. 36, Fig. 37, Fig. 38, Fig. 39 and Fig. 40. It shown that there will not be any subsidence in reserve forest area.

Fig. 41 through Fig. 45 shown the peak horizontal tensile strain areas.

It clearly shows that reserve forest area will have horizontal tensile strain less than 5 mm/m. One can safely conclude that following the suggestion of option-I, there will not be any impact of subsidence reserve forest area.

FIG. 32 SIMULATED GRID MAP OF R-VIIIT2 SEAM <TILABONI UG MINE>

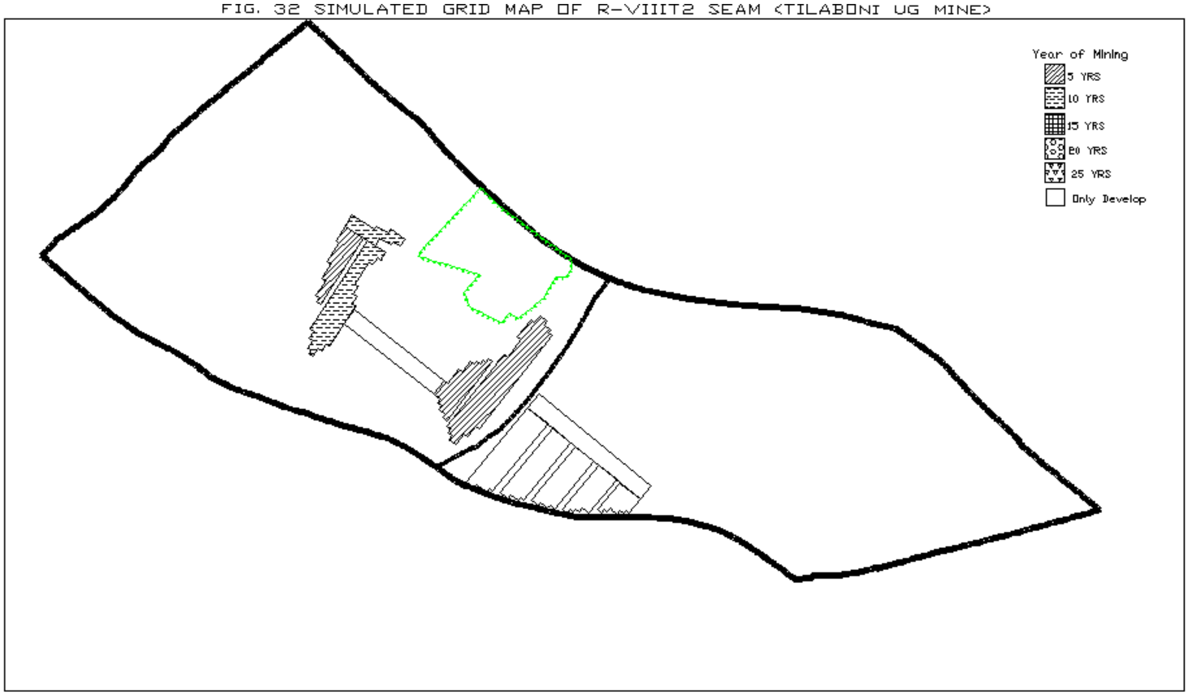


FIG. 33 SIMULATED GRID MAP OF R-VIIIB1&R-VIIIB1(BOT.) SEAM (TILABONI UG MINE)

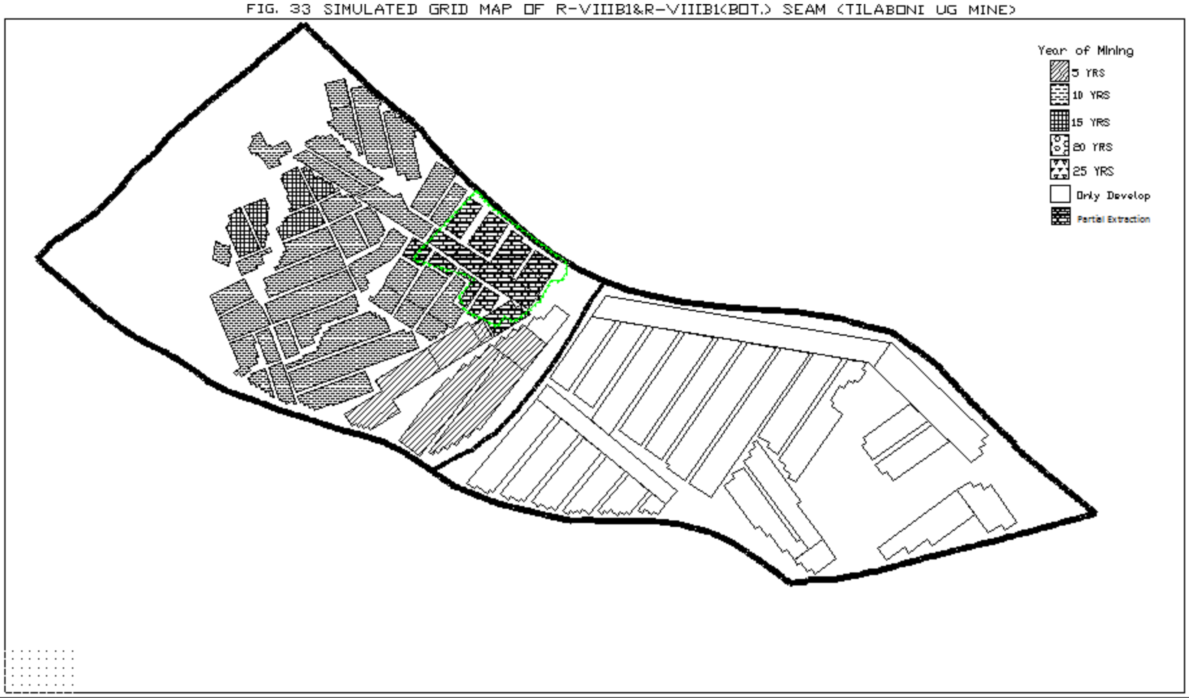


FIG. 34 SIMULATED GRID MAP OF R~VII&R-VII(BOT.) SEAM (TILABONI UG MINE)

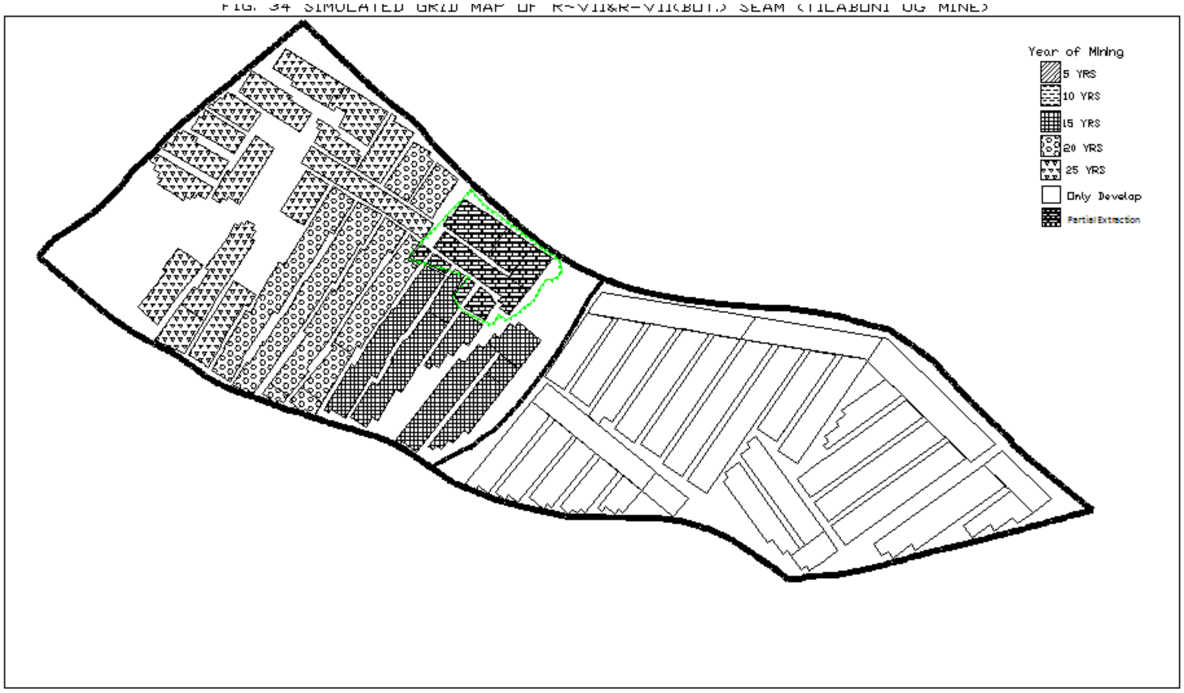


FIG. 35 SIMULATED GRID MAP OF R~VIIA&R-VIIA&B(COM) SEAM (TILABONI UG MINE)

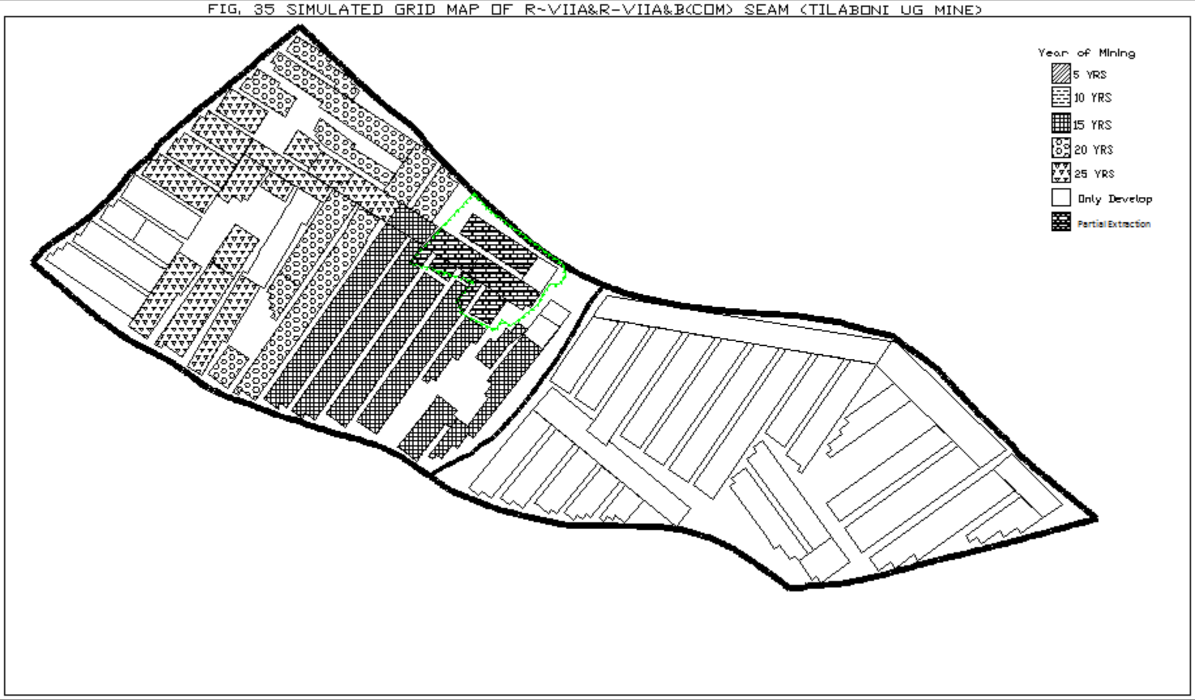


FIG. 41 HORIZONTAL TENSILE STRAIN AT THE SURFACE OF 5 YEAR OF MINING (TILABONI UG MINE)

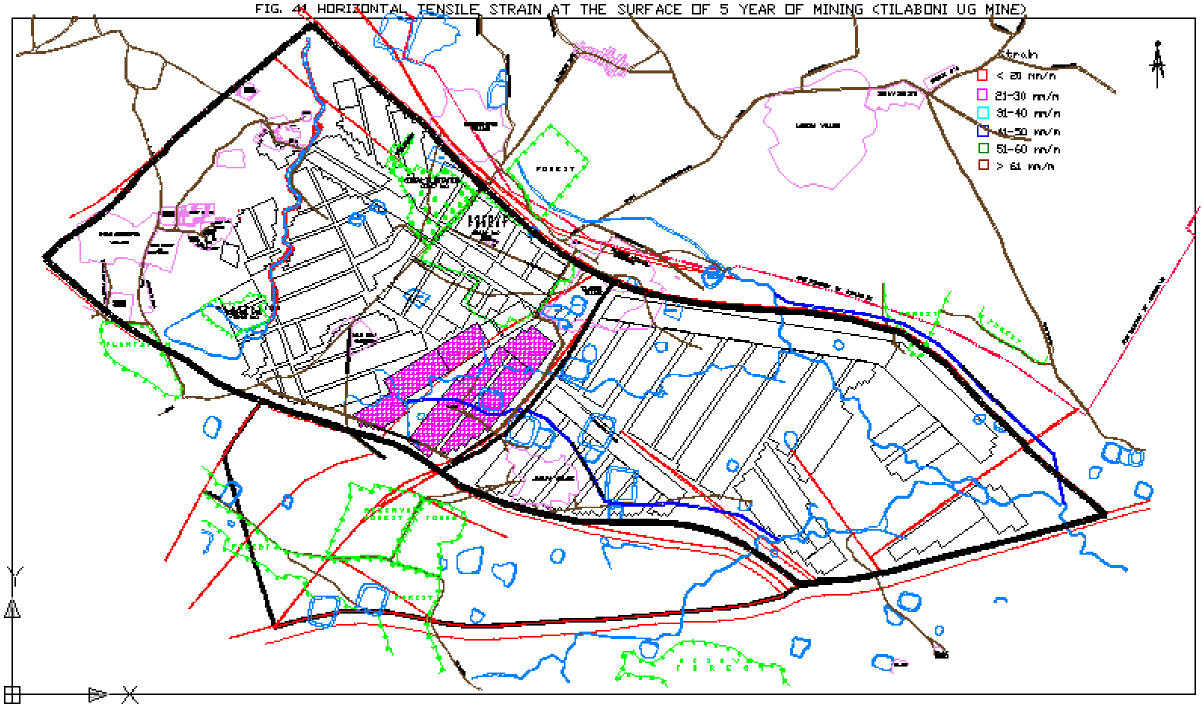


FIG. 42 HORIZONTAL TENSILE STRAIN AT THE SURFACE OF 10 YEAR OF MINING (TILABONI UG MINE)

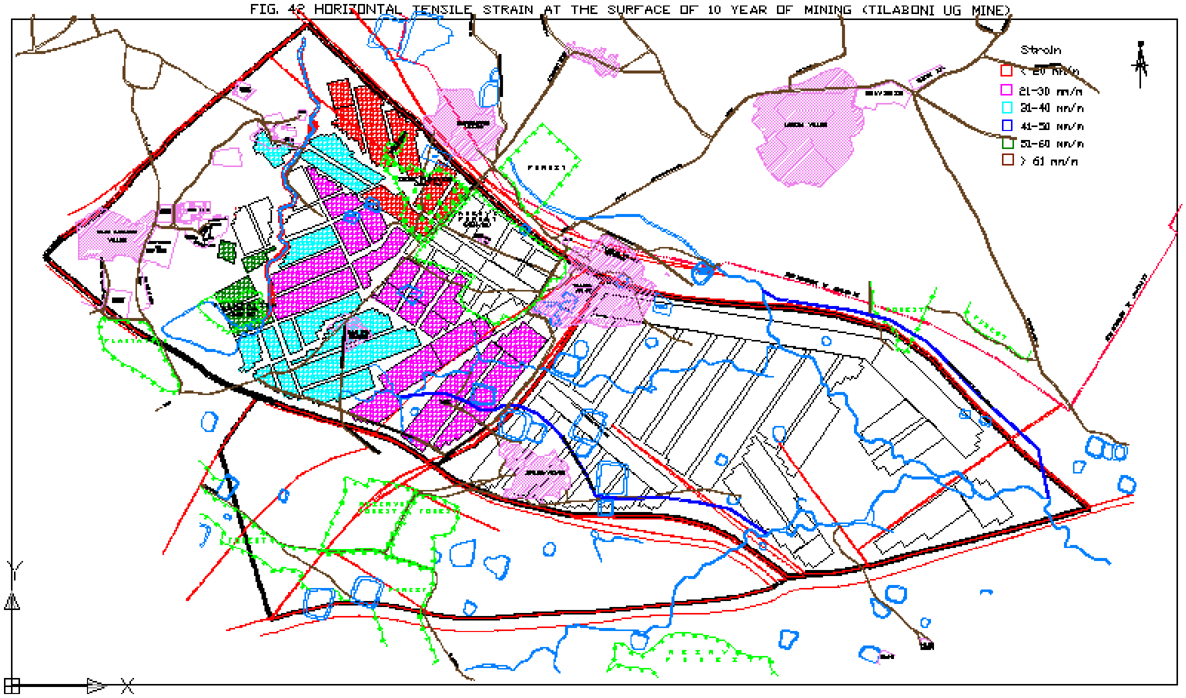


FIG. 43 HORIZONTAL TENSILE STRAIN AT THE SURFACE OF 15 YEAR OF MINING (TILABONI UG MINE)

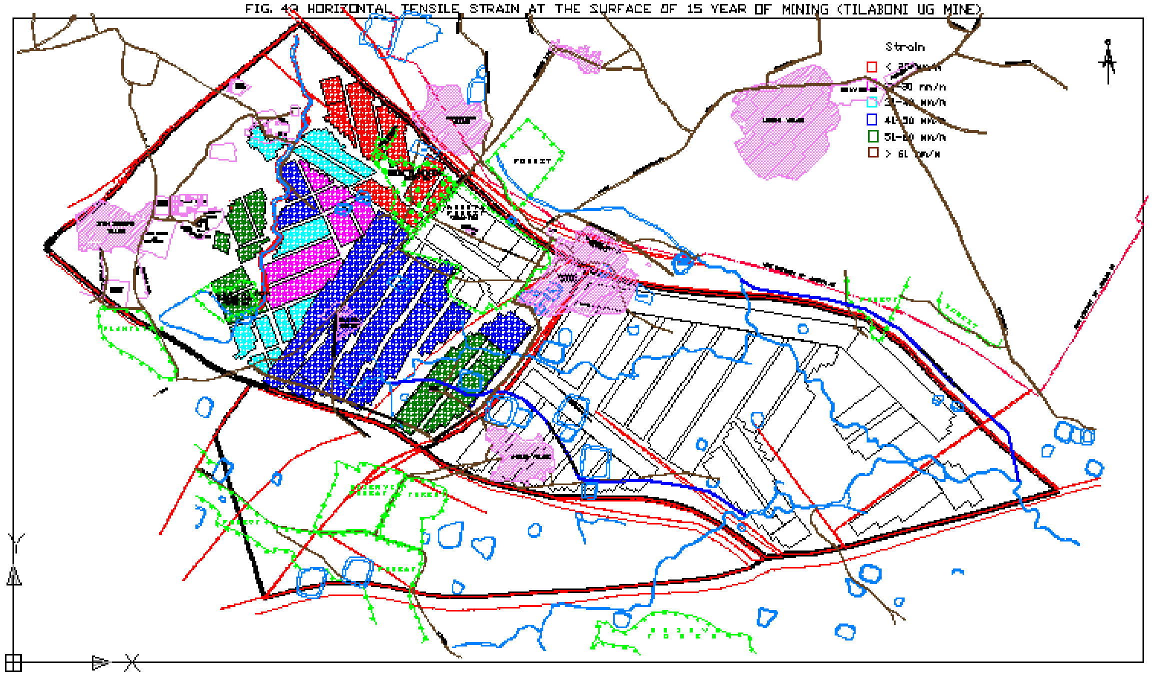


FIG. 44 HORIZONTAL TENSILE STRAIN AT THE SURFACE OF 20 YEAR OF MINING (TILABONI UG MINE)

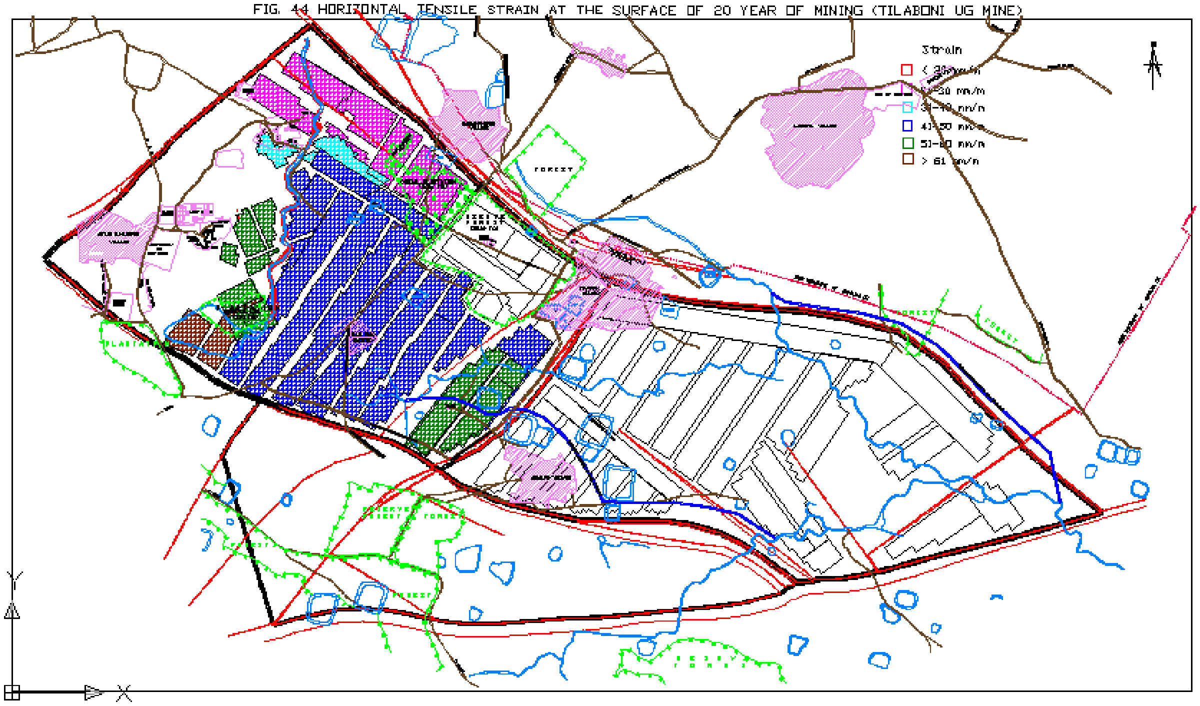
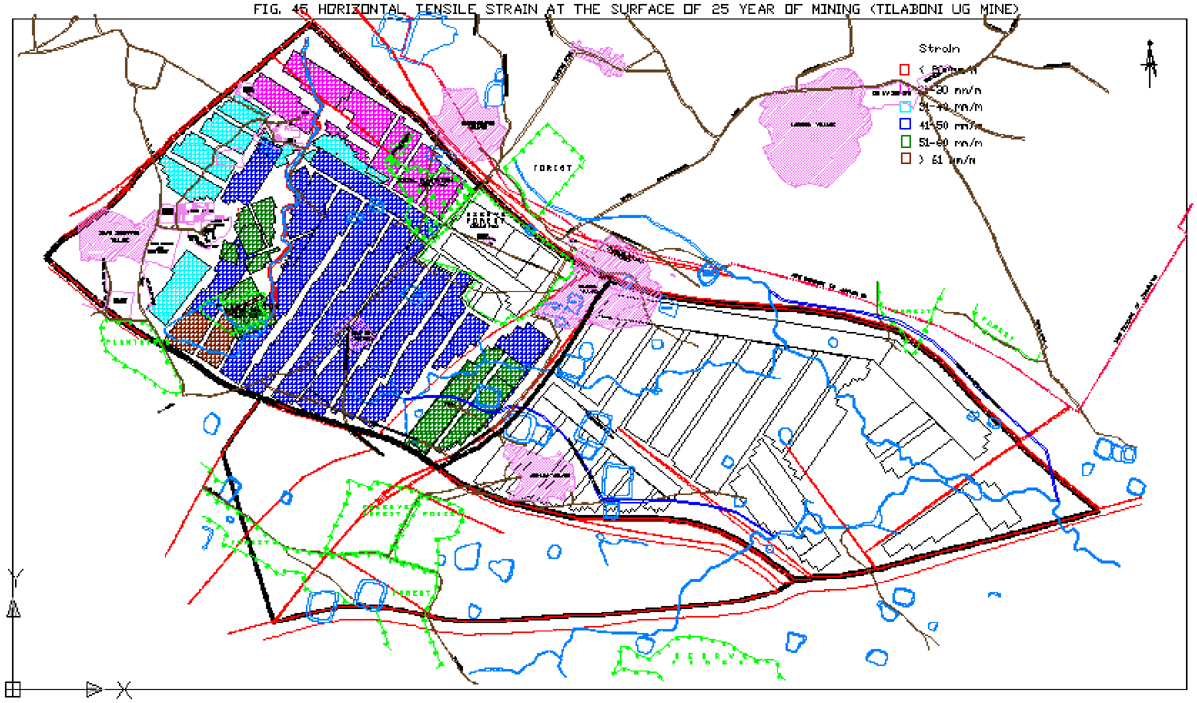


FIG. 45 HORIZONTAL TENSILE STRAIN AT THE SURFACE OF 25 YEAR OF MINING (TILABONI UG MINE)



8.0 SUBSIDENCE MANAGEMENT PLAN

Extraction of panels underground will lead to high horizontal tensile strain at the surface. It will affect forest cover, Maji Para Basti, Road, Ponds, Nalas and general surface in particular.

1. **Reserve Forest:** The extraction of panels will lead to high horizontal tensile strain in Reserve forest. However, by following option-I, there will not be any significant impact of subsidence on forest area.

2. **Social Plantation :** The extraction of panels will lead to high horizontal tensile strain in social plantation. Remedial measures should be taken.

3. **Maji Para Basti :** Maji para Basti will get affected by mine subsidence. Adjusted villages around main boundary will not get affected. Mine officials are planning to relocate Maji Para Basti.

4. **Road :** Road passing though mine boundary (Ukhara-Landoha DB Road) will get severely damaged due to mine subsidence. Mine official are planning to divert this road.

5. **Ponds :** Ponds located within mine boundary will get damaged due to mine subsidence. It is advised to relocate these ponds. Water should not be allowed to accumulate in these ponds.

6. **Staff quarter:** It is not likely to get affected by mine subsidence. Hence, management plan is not required.

7. **Nalas:** The nalas over surface within block boundary should be diverted before the depillaring operations.

8. **General Surface:** The general surface will experience high horizontal tensile strain. It has been predicted that wide cracks (upto 900 mm wide cracks) are likely to be formed on the surface. These cracks may endanger the underground workings. Underground workings may breathe air through these cracks leading to spontaneous heating and fire. Surface water also may enter through these cracks.

   It is suggested that Special effort should be made to fill the cracks on the surface as soon they are formed. The surface should be inspected daily above the active working zone. A record should also be maintained of the crack formation, its widening and subsequent filling.

9.0 CONCLUSION

Tilaboni mine is located in the north eastern side of Raniganj Coalfield. It is situated in Bankola Area, Eastern Coalfields Limited, Burdwan district of West Bengal. The surface area has forest cover of 65.8 Ha. Continuous miner operation will be carried along with LHDs and SDLs. The life of the mine is 25 years. Thickness of the seams is varying from 2.0m to 5.5m within the property. The maximum thickness of extraction is limited to 4.8m for this mine.

The predicted maximum subsidence is 2.871 m at the end of 5 years of mining. It increases to 2.930 m at the end of 10 years of mining and 4.543 m at the 15 years of mining. It further increases to 5.651 m at end of 20 years of mining and 5.171 m at end of 25 years of mining.

The peak horizontal tensile strain at surface is predicted as 27.19 mm/m at the end of 5 years of mining, 61.63 mm/m at the end of 10 years of mining, 63.44 mm/m at end of 15 years of mining, 67.75 mm/m at the end of 20 years of mining and 91.77 mm/m at the end of 25 years of mining.

Wide cracks upto 900 mm are likely to occur on the surface . The structure on the surface is like to get damaged by mine subsidence.

(a) The reserve forest is likely to get damaged as horizontal tensile strain up to 40 mm/m is likely to occur. However, following option-I there will not be any significant impact of subsidence on reserve forest **and no horizontal strain will be generated.**

(b) The extraction of panels will lead to high horizontal tensile strain in social plantation. Remedial measures should be taken.

(c) Maji Para Basti is also likely to be affected by mine subsidence. Mine officials plan to relocate it before depillaring operations.

(d) Ukhra-Laudoha D.B Road is also likely to get affected by mine subsidence. It will be damaged. However, mine officials are planning to divert it before depillaring operation.

(e) There are seasonal water bodies on the surface, such as ponds and seasonal nalas. These are likely to get damaged due to mine subsidence. It is suggested that water should not be allowed to accumulate in these ponds and the nalas should be diverted before depillaring operation.

(f) It has been predicted that wide cracks (upto 900 mm wide cracks) are likely to be formed on the surface. These cracks may endanger the underground workings. Underground workings may breathe air through these cracks leading to spontaneous heating and fire. Surface water also may enter through these cracks. It is suggested that Special effort should be made to fill the cracks on the surface as soon they are formed. The surface should be inspected daily above the active working zone. A record should also be maintained of the crack formation, its widening and subsequent filling.

Undertaking for 3-Dimensional Numerical Modelling for subsidence prediction of Tilaboni UGP, Bankola Area, ECL

I, on behalf of Eastern Coalfields Limited, Bankola Area, Dist. - Paschim Bardhaman, West Bengal, do hereby undertake that recommendations of IIT-(BHU) in the report "Numerical modeling in 3- dimension for subsidence prediction of Tilaboni UGP in ECL" shall be followed during mining in Tilaboni UGP.

21/03/2020

General Manager
Bankola Area

11/3/20.

Area Manager (PCD)
Bankola Area