सेन्ट्रल माईन प्लानिंग एण्ड डिजाइन इन्सटीच्यूट लिमिटेड
(कोल इण्डिया लिमिटेड की अनुषंगी कम्पनी / भारत सरकार का एक लोक उपक्रम)
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पत्रांक: रिन/ तवा-II (युजी)/२०१३/168 दिनांक: ०९/०५/२०१३

महाप्रबन्धक सचिवालय
GM's Secretariat Pathakhera Area
प्राप्ति क्र. (Received No.)...306
प्राप्ति तिथि (In Dated)...11/5/13
निर्गत तिथि (Out Dated)...11/5/13...

सेवा में,

महाप्रबंधक,
वेस्टर्न कोलफील्डस लिमिटेड,
पाथाखेड़ा क्षेत्र

विषय: तवा-II भूमिगत खदान का भूधसान पूर्वानुमान अध्ययन रिपोर्ट

महोदय,

तवा-II भूमिगत खदान का भूधसान पूर्वानुमान अध्ययन रिपोर्ट की एक प्रति इस पत्र के साथ आपके अवलोकनार्थ संलग्न है।

सधन्यवाद,

भवदीय

9/5

क्षेत्रीय निदेशक

संलग्न: यथोपरि

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REPORT ON

SUBSIDENCE PREDICTION AND MANAGEMENT FOR TAWA- II UNDERGROUND MINES

WESTERN COALFIELDS LIMITED

DECEMBER 2012

REPORT ON

SUBSIDENCE PREDICTION AND MANAGEMENT

FOR

TAWA-II UNDERGROUND MINES

WESTERN COALFIELDS LIMITED

DECEMBER 2012

MINING LABORATORY (UMD)
CENTRAL MINE PLANNING & DESIGN INSTITUTE LTD.
GONDWANA PLACE, KANKE ROAD
RANCHI – 834 008

Report on subsidence prediction and management for Tawa-II Underground Mine, WCL.

Job No. : **4101506**

Customer: WCL, Through Regional Director, RI-IV, CMPDI

Reference: Letter no. RI-IV/Environment/2012/962 dated 12/13.07.2012.

Month of submission of report : December 2012

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1.0 INTRODUCTION :

A project report for Tawa-II Underground Mine, Pathakhera Area, WCL has been prepared by CMPDI, Regional Institute-IV, for a targeted production of 0.36MTY. As per project report, in the proposed mining area three coal seams, viz. Lower workable seam, Bagdona seam and seam IA, in descending order will be extracted by bord and pillar method with caving, using LHDs as mechanisation. The coal seams will be extracted in descending order. Considering the extractable reserves of 7.055 MT, the total life of the mine has been assessed as 21 years. The mining area is covered by M.P. Govt. forest land, M.P. Govt. reserve forest land, Govt. Revenue land, Tenancy land and roads. Considering these aspects subsidence prediction has been done for this mine.

As required by Regional Director, RI-IV, CMPDI vide letter no. RI-IV/Environment/2012/962 dated 12/13.07.2012, Mining Laboratory (UMD) of CMPDI (HQ) has carried out subsidence prediction study at the end of 10^{th}, 15^{th} and 21^{st} (i.e. end of mine life) year of depillaring and likely impact of subsidence on surface topography, surface features and forest. The subsidence prediction study is intended to constitute a part of EMP report. The results of the study and subsidence management are presented in the following sections.

2.0 DETAILS OF THE MINE:

2.1	Mine	:	Tawa II Underground Mine
2.2	Area	:	Pathakhera Area
2.3	Company	:	Western Coalfields Limited
2.4	Mining area	:	2.10 sq.km
2.5	Mineable reserves	:	11.899 MT
2.6	Extractable reserves as on 01/04/2009	:	7.055 MT

2.7 Details of the coal seams to be worked (in descending order):

	Seam	Thickness	Depth	Extraction thickness
a)	Lower Workable Seam	1.49m to 2.83m	90m to 320 m	1.5m to full seam thickness
	Parting	42.04 m to 63.59 m		
b)	Bagdona Seam	1.05m to 2.90m	150m to 380m	1.5m to full seam thickness
	Parting	28.85 m to 50.45 m		
c)	IA Seam	0.60m to 2.63m	185m to 370m	1.5m to full seam thickness

2.8 Proposed method of extraction: Bord and pillar method with caving using LHDs.

2.9 Anticipated percentage of extraction: 80%

2.10 Overlying rock mass: Medium to coarse grained sandstone and shale

2.11 Size of the panels: Some are critical and some are sub- critical

2.12 Balance life of the mine: 21 years

2.13 Topography: The eastern part of the mining area is hilly and rugged with thick forest cover and northern and north western regions are comparatively flat. The general elevation varies from 520m to 485m above MSL.

2.14 Surface properties and their protection: M.P.Govt. forest land, M.P.Govt. reserve forest land, Govt. revenue land, Private(Tenancy) land and road exist over the mining area.

3.0 TOPOGRAPHY, DRAINAGE AND LAND USE:

The eastern part of the mining area is hilly and rugged with thick forest cover and northern and north western regions are comparatively flat. The general elevation of the mining area varies from 520m to 485m above MSL

i.e. a difference of elevation of 65m. Tawa river controls the drainage pattern of the area. M.P.Govt.forest land, M.P.Govt Reserve forest land, Govt. revenue land, Private (Tenancy land) and roads exist over the mining area. The area is devoid of any inhabitation and does not support any village/ settlement. The total area of Tawa-II UG mine is 2.10 sq.km.

4.0 GEOLOGY:

The proposed Tawa-II mine has been envisaged in the northern part of Tawa Extension geological block beyond the northern mine boundary of tawa-II UG mine. The borehole drilled in the mining area indicate that the coal bearing strata consists of medium to coarse grained sandstone, alternate shale and sandstone, shale, shaly coal and coal seams. There are five coal seams occurring in the mining area, out of which three coal seams, viz. Lower Workable Seam , Bagdona Seam and IA seam are considered workable. The uppermost workable seam is Lower Workable Seam which occurs at a depth range of 90m to 320m. The thickness of this seam varies from 1.49m to 2.83m. The workable thickness is considered from 1.5m to full seam thickness. The middle workable seam is Bagdona seam which occurs at a depth range of 150m to 380m. Thickness of the seam varies from 1.05m to 2.90m. The workable thickness is considered from 1.5m to full seam thickness. The lower most workable seam is IA seam which occurs at a depth range of 185 to 375m. Its thickness varies from 0.60m to 2.63 m. The workable thickness is considered to be 1.5m to full seam thickness. Gradient of the coal seams is 1 in 7.5 to 1 in 10.i.e. 5.5^0 to 7.5^0 dip.

5.0 METHOD OF MINING:

Tawa-II UG mine is proposed to be developed on Bord and Pillar method. The extraction of pillars (depillaring) is proposed to be done by caving method. LHD is to be used for mechanisation. The minimum and maximum thickness of extraction have been considered 1.5m to full seam thickness.

Proposed layouts of all the three workable seams (i.e. Lower Workable Seam, Bagdona Seam and IA Seam) are shown in different colours in Plate 1. Proposed layouts of the panels in Lower Workable Seam, Bagdona seam and IA Seam with their sequence of depillaring at the end of 10, 15 and 21 years are shown in Plates 2, 3 and 4 respectively. The layout of the panels and their sequence of depillaring have been taken from mine projection plan of each seam as provided by CMPDI, RI-IV.

6.0 SUBSIDENCE PREDICTION:

The subsidence prediction numerical model based on Influence Function method, developed in CMPDI, has been used for estimation of likely subsidence over the mining area. Subsidence prediction has been done for the panels proposed to be extracted by caving method in the mine plans of Lower workable seam and Bagdona seam. As per project report, the minimum and maximum thickness of extraction have been considered to be 1.5m to full thickness of the seams respectively. Input data used for subsidence prediction, such as mining parameters, geology, panel dimension, sequence of extraction of the panels and surface features have been collected from project reports and mine plans sent by CMPDI, RI-IV.

Details of mine layout, surface contours, surface features, forest and other relevant features have been digitised from mine projection plan of Lower workable seam and Bagdona seam. Surface contours have been drawn by considering the RLs of bore holes drilled in the area, as surface contours of the area is not available. The digitised data have been used as input parameters for subsidence prediction model.

For subsidence prediction, subsidence parameters such as values of subsidence factor and angle of draw for single and multiple seam extraction have been taken considering the rock mass factor, geo-mining conditions and subsidence data observed in Satpura mine no.2 and Shobhapur mine. At Satpura mine no.2, the subsidence factor and angle of draw observed are 0.49 and 27° respectively. At Shobhapur mine, after extraction of both upper and lower workable seams, the subsidence factor and maximum angle of

draw observed by CMPDI were 0.55 and 35° respectively. The parameters taken for subsidence prediction are as follows :

i)	Subsidence factor:	0.49 for single seam extraction (i.e. Lower Workable Seam) and 0.55 for multiple seam extraction.
ii)	Angle of draw:	30^0 for single seam extraction and 35^0 multiple seam extraction
iii)	Anticipated percentage: of extraction in panels	80% within the panel
iv)	Depth:	Average depth for each panel.
v)	Thickness of extraction:	Average thickness of the seam for each panel.

Before subsidence prediction, the prediction model has been calibrated according to the above mentioned subsidence parameters. For subsidence calculation, underground extraction area has been divided into 20m x 20m grid blocks as individual elements. The numerical procedure followed for prediction involves estimation of subsidence at the grid points of each element and subsequent integration to arrive at resultant values and the final area influenced by ground movement. Subsidence has been calculated over 13,740 points.

Subsidence prediction has been done for three stages of depillaring, i.e. at the end of 10, 15 and 21 years of mining (at the end of mine life). Stages of depillaring in Lower Workable Seam, Bagdona Seam and IA Seam at 10, 15 and 21 years of mining are shown in different colours in plates 2, 3 and 4 respectively.

7.0 SUBSIDENCE PREDICTION RESULTS:

7.1 Maximum Subsidence, Subsidence contours and Subsidence profiles:

The anticipated maximum possible subsidence likely to occur over the mining area due to extraction of Lower workable seam, Bagdona seam and IA seam are 1.20m over panel R5, 1.00m over panel QMD 1 & 2 and 0.85m

over panel PMD1 respectively. The anticipated maximum possible subsidence likely to occur over the mining area after 10 and 15 years of mining are 1.20m and 1.37m respectively. The estimated maximum possible subsidence likely to occur at the end of mine life is 2.70m, which is likely to take place over the panels R4 of Lower workable seam, Q4 of Bagdona seam and P4 of IA seam. In the forest area, the maximum possible subsidence likely to occur is 2.70m, which is likely to take place over same panels. From the estimated subsidence at each grid point, subsidence contours are drawn at the end of 10, 15 and 21 years (i.e. at the end of mine life) of mining and shown in plates 6, 8 and 10 respectively. In the plates, subsidence contours are shown alternately in violet and red colours at 0.4m intervals. Final subsidence profiles along line AA' and BB' have also been drawn and shown in plates 15 and 16 respectively. Both the lines are intersecting at the maximum subsidence point over the mining area.

7.2 Effect of subsidence on surface topography and surface features along with mitigative measures :

Topography before mining, at the end of 10^{th} and 15^{th} year of mining and at the end of mine life are shown in Plates 5, 7, 9 and 11 respectively. Change in topography due to subsidence can be seen by comparing the above mentioned plates. For a comparative assessment of ground condition before and after mining, 3D views of surface before and after mining, (i.e. after extraction of lower workable seam, Bagdona seam and IA seam) are shown in Plates 12 and 13 respectively. By comparing the above two views, it is observed that there is negligible change in surface topography. Surface profiles before mining and after final subsidence (i.e. after extraction of all the three workable seams) have also been drawn along lines AA' and BB' and shown in Plates 15 and 16 respectively.

The topography of the mining area is hilly and rugged with thick forest cover in the eastern part and the northern and north western part regions are comparatively flat. The general elevation varies from 520m to 485m above MSL. i.e. a difference of elevation of 65m. For such terrain, the maximum anticipated subsidence of 2.70m is unlikely to affect the drainage pattern in

the area. However, subsidence may result in the formation of depressions over the centre of the panels and cracks at the zones of high tensile strain such as along the boundary and barriers. Pools of water are likely to be formed in these depressions during rains, which may be retained wherever possible for the benefit of vegetation in the forest land or filled up/drained out by cutting drains depending on safety of underground workings. The surface cracks, developed due to subsidence, need to be filled up properly and regularly with clay and stone chips to achieve the original drainage pattern of the area and to prevent ingress of air and water into the goaf. This will minimise the chances of underground inundation and spontaneous heating.

For estimating the effects of subsidence on surface features, panel wise anticipated maximum possible subsidence, slope and tensile strain have been calculated due to extraction of Lower workable seam, Bagdona seam and IA seam individually and cumulatively, which are shown in Tables 1, 2 3 and 4 respectively. Strain developed due to subsidence is the prime cause of damage to the surface features. Thus, values of strain likely to occur near important surface features have been estimated to envisage the extent of damages to the surface features. The impacts of subsidence on different surface features are outlined below.

Impact of subsidence on roads:

Roads passing over the mining area are likely to be affected by a maximum amount of 0.98m subsidence and 8.75mm/m slope over panel R3 of Lower Workable Seam and Q3 of Bagdona Seam. Such amount of subsidence and slope will cause depressions with gentle slope and road can be used after necessary repairs. However, to protect the roads completely from subsidence, it is suggested to leave coal pillars unextracted vertically below and within 30^0 angle of draw for single seam extraction and 35^0 angle of draw for multiple seam extraction from these roads.

Impact of subsidence on Inclines mouth:

Incline mouths are not likely to be affected by subsidence because sufficient panels are proposed to be left unextracted vertically below and within 35^0 angle of draw from these incline mouths.

Impact of subsidence on Tenancy Land:

Tenancy Land over the mining area are likely to be affected by a maximum amount of 2.66m subsidence, 18.93mm/m slope and 9.47mm/m tensile strain over panel R4 of Lower Workable Seam, Q4 of Bagdona Seam and P4 of IA seam. Such amount of subsidence and tensile strain will result in reduction in yield and water retention capacity of sub-soil and the surface will get distorted. Therefore crop compensation has to be paid to the owners in the year when depillaring commences below such land.

Impact of subsidence on Govt. Revenue Land:

Govt. revenue Land over the mining area are likely to be affected by a maximum amount of 2.09m subsidence, 16.59mm/m slope and 8.29mm/m tensile strain over the panels strain over panel R3 of Lower Workable Seam, Q3 of Bagdona Seam and P3 of IA seam. Such amount of subsidence and tensile strain will result in very severe distortion in the surface.

7.3 Effect of subsidence on forest with mitigative measures :

All the panels except R6, R7, RMD6 and RMD7 of Lower workable , Q6, Q7, QMD6 and QMD7 of Bagdona seam of the three workable seams including IA seam are below the forest land. For estimating the effect of subsidence on forest, panel wise anticipated maximum possible subsidence, slope and tensile strain have been calculated due to extraction of Lower Workable seam and Bagdona seam and IA seam individually and cumulatively, which are shown in Tables 1, 2, 3 and 4 respectively. In the tables panels and schedule of extraction of the panels are proposed in the mine projection plan of each seam. Table 4 shows the estimated maximum possible subsidence, slope and tensile strain due to extraction of all the three seams. Panels below forest land are marked with * sign in the tables.

It is evident from the data in the above tables that due to extraction of all the three workable seams, the values of tensile strain likely to occur over the forest area exceed the limit as prescribed by MOEF for the purpose of Net Present Value, i.e. values of strain in the forest area are more than 10 mm/m. Due to extraction of Lower workable seam only, the maximum value of subsidence and tensile strain likely to occur in the forest area are 1.20m over panel R5 and 8.37 mm/m over panel RMD1 respectively. Due to extraction of Bagdona seam only, the maximum value of subsidence and

tensile strain likely to occur in the forest area are 1.00m and 5.56 mm/m respectively over the panel QMD1and 2. Due to extraction of IA seam only, the maximum value of subsidence and tensile strain likely to occur in the forest area are 0.85m and 4.50mm/m respectively over the panel PMD1. Due to extraction of all the three workable seams, the cumulative maximum subsidence and tensile strain likely to occur over the forest area are 2.70m (over panels R4 of Lower Workable Seam, Q4 of Bagdona Seam and P4 of IA Seam) and 14.18 mm/m(over the panels RMD1 of Lower Workable Seam, QMD1 and 2 of Bagdona Seam and PMD1 of IA Seam) respectively.

Thus, the area experiences a maximum strain of 14.18mm/m. Such amount of tensile strain is likely to develop surface cracks more than 150mm wide. The anticipated maximum possible slope likely to occur in the forest area is 28.36mm/m, i.e. a tilt of 1.63^0 , which is unlikely to cause falling of trees in the forest area.

Thus, it is anticipated that the forest may not be considerably affected by subsidence. Only a limited number of trees falling on the edges of subsidence trough and surface cracks may get tilted or dislodged. However, provision has to be made for compensatory afforestation and strengthening of forest cover to take care of losses, if any. Surface cracks likely to develop in the forest area should be filled up with clay and stone chips and thereafter with about 0.3m high clay heap over the cracks.

As per recommendation of MOEF, the area in the forest having more than 10 mm/m strain would be considered as subsidence affected area due to underground mining and accordingly NPV is to be paid. Thus considering the above, the area likely to be affected by 10 mm/m or more strain due to extraction of all the three workable seams (Lower Workable seam, Bagdona seam and IA seam) is shown in Plate 14.

8.0 SUBSIDENCE MANAGEMENT:

Considering the impact of subsidence on surface topography, forest and surface features, as explained in earlier chapters, the following subsidence management aspects are required to be undertaken to overcome or to minimise adverse effects.

i) Due to subsidence, surface cracks likely to develop over the mining area need to be filled up properly and regularly by clay and stone chips and thereafter with about 0.3m high clay heap over the cracks. It will help in achieving the original drainage pattern over the mining area, improving the water retention capacity of the soil, minimising the top soil erosion and avoiding chances of underground inundation and spontaneous heating.

ii) It is suggested that a team is formed by the mine management which will be responsible for the proper and regular filling of surface cracks developed due to subsidence. The team will also maintain record of the development and filling of surface cracks. Adequate supply of filling materials should be arranged by mine management at the site.

iii) It is suggested that a time lag of about 5 years should be maintained before extracting the panels of lower seam immediately below the extracted panels of upper seam. This will allow the super incumbent strata to consolidate and settle before the extraction of lower seam. With this time lag in multiple seam extraction, depressions on the surface will take place in steps and after long intervals of time, and as a result reduced amount of slope and strain will occur on the surface. Hence, it is not expected to have adverse impact on the forest. Only a limited number of trees located on the edges of subsidence trough and surface cracks may get tilted or dislodged. Therefore, it is recommended that the depillaring of the panels is scheduled in such a manner that at least a gap of 5 years is maintained between extractions of successive panels in superimposition.

iv) Provision has to be made for compensatory afforestation and strengthening of forest cover to take care of losses, if any.

v) Subsidence may result in depressions on the surface with accumulation of water during the rains. Such accumulation of water may be beneficial for vegetation in the forest. These water bodies may be retained wherever possible or filled up/drained out by cutting drains depending on safety of the underground workings.

vi) Surface drains should be made outside of the subsidence influence area to prevent the surface water of adjoining area from coming into active subsidence area.

vii) Coal pillars are to be left un-extracted vertically below and within subsidence influence area from the surface features which need to be protected from subsidence damages, if any.

viii) Considering the make of water in small seasonal streamlets existing over the mining area, due care has to be undertaken while extraction is made below these streamlets such as avoiding extraction during monsoon and filling up cracks developed in the bed of the streamlets, when dry. However, if it is required to keep these streamlets totally out of subsidence influence area, coal pillars should be left un-extracted vertically below and within angle of draw from the streamlet, i.e. within 30^0 angle of draw for single seam extraction and 35^0 angle of draw for multiple seam extraction.

The impact of subsidence on different surface features and forest land along with the degree of damage are provided in Annexure I for reference, i.e. the "Subsidence Impact Matrix". The Subsidence Impact Matrix (SIM) shown therein was developed under a Ministry of Coal funded S&T project.

9.0 CONCLUSION:

i) Due to extraction of Lower Workable seam only, the anticipated maximum possible subsidence likely to occur over the mining area is 1.20m, which is likely to take place over the panel R5. The estimated maximum possible slope and tensile strain likely to occur are 16.74 mm/m and 8.37 mm/m respectively over the panel RMD1.

ii) Due to extraction of Bagdona seam only, the anticipated maximum possible subsidence likely to occur over the mining area is 1.00m, which is likely to take place over the panel QMD1&2. The estimated maximum possible slope and tensile strain likely to occur are 11.11 mm/m and 5.56 mm/m respectively over the panel QMD1&2.

iii) Due to extraction of IA seam only, the anticipated maximum possible subsidence likely to occur over the mining area is 0.85m, which is likely to take place over the panel PMD1. The estimated maximum possible slope and tensile strain likely to occur are 8.99 mm/m and 4.50 mm/m respectively over the panel PMD1.

iv) After extraction of all the three workable seams, i.e. after extraction of Lower Workable seam, Bagdona seam and IA seam, the anticipated maximum possible subsidence likely to occur over the mining area is 2.70m, which is likely to take place over the panels R4 of Lower Workable seam, Q4 of Bagdona seam and P4 of IA seam. The estimated maximum possible slope and tensile strain likely to occur are 28.36 mm/m and 14.18 mm/m respectively over the panels RMD1 of Lower Workable seam, QMD1&2 of Bagdona seam and PMD1 of IA seam.

v) All the panels except R6, R7, RMD6 and RMD7 of Lower workable , Q6, Q7, QMD6 and QMD7 of Bagdona seam of the three workable seams including IA seam are below the forest land, therefore the values of subsidence, slope and tensile strain which are likely to occur over the mining area as stated above remains the same in the forest area. After extraction of all the three workable coal seams (Lower Workable seam, Bagdona seam and IA seam), the maximum possible subsidence likely to

occur in the forest area is 2.70m. The estimated maximum possible slope and tensile strain likely to occur are 28.36 mm/m and 14.18 mm/m respectively. Such amount of tensile strain is likely to develop surface cracks more than 150 mm wide. The maximum value of 28.36 mm/m slope, i.e. a tilt of 1.63^0 is not likely to cause falling of trees in the forest. To minimise the slope and tensile strain in the forest area, it is recommended to maintain at least a gap of 5 years between extractions of successive panels in superimposition. This will allow the strata to settle before the extraction of lower seam as well as tilt will take place in steps (after extraction of each seam) and after an interval of 5 year time. Thus, it is anticipated that the forest may not be considerably affected by subsidence. Only a limited number of trees falling on the edges of subsidence trough and surface cracks may get tilted or dislodged.

vi) Provision has to be made for compensatory afforestation and strengthening of forest cover to take care of losses, if any.

vii) For the purpose of Net Present Value (NPV), Central Government has made a recommendation for subsidence affected area in the forest due to underground mining, which depicts that the area in the forest having more than 10 mm/m strain would be considered as affected area and accordingly NPV is to be paid. Considering the above, the surface over the mining area likely to be affected by 10 mm/m or more strain (due to extraction both the workable seams) is drawn and shown in Plate 14. For the affected area of forest, as shown in Plate 14, NPV has to be paid.

viii) Though the small seasonal streamlets have not been shown on surface plan but if such streamlets exist over the mining area to control the surface drainage are likely to be affected by subsidence. Considering the make of water in these streamlets, due care has to be taken while extraction is made below it, such as avoiding extraction during monsoon and filling up cracks developed in the bed of streamlets, when dry to avoid inrush of water belowground in the rainy season. However, if it is necessary to bring the streamlets out of subsidence influence area, coal

pillars should be left un-extracted vertically below and within subsidence influence area from it.

ix) Roads passing over the mining area are likely to be affected by a maximum amount of 0.98m subsidence and 8.75mm/m slope over panel R3 of Lower Workable Seam and Q3 of Bagdona Seam. Such amount of subsidence and slope will cause depressions with gentle slope and road can be used after necessary repairs. However, to protect the road completely from subsidence, it is suggested to leave coal pillars unextracted vertically below and within 30^0 angle of draw for single seam extraction and 35^0 angle of draw for multiple seam extraction from these roads.

x) Incline mouths are not likely to be affected by subsidence because sufficient panels are proposed to be left unextracted vertically below and within 35^0 angle of draw from these incline mouths.

xi) Tenancy lands over the mining area are likely to be affected by subsidence. Therefore, crop compensation has to be paid to the owners in the year when depillaring commences below such land.

xii) Govt. revenue Land over the mining area are likely to be affected by a maximum amount of 2.09m subsidence, 16.59mm/m slope and 8.29mm/m tensile strain. Such amount of subsidence and tensile strain will result in very severe distortion in the surface.

xiii) The topography of the mining area is hilly and rugged with thick forest cover in the eastern part and the northern and north western part regions are comparatively flat. The general elevation varies from 520m to 485m above MSL. i.e. a difference of elevation of 65m. For such terrain, the maximum anticipated subsidence of 2.70m is unlikely to affect the drainage pattern in the area. However, subsidence may result in the formation of depressions over the centre of the panels where water may accumulate during rains. The accumulation of water may be beneficial for

vegetation in the forest. Thus, the desirable water bodies may be retained after extraction of both the workable seams. In case the safety of underground workings is impinged by it, the depressions should be filled up or water from them should be drained out by cutting drains.

xiv) Surface cracks formed due to subsidence will need to be filled up with clay and stone chips and thereafter with about 0.3m high clay heap over the cracks. It will help in achieving the original drainage pattern in the mining area, improving water retention capacity of the soil, minimising the top soil erosion and avoiding chances of underground inundation and spontaneous heating.

xv) It is suggested that the mine management forms a team that will be responsible for the proper and regular filling of surface cracks developed due to subsidence. The team will also maintain a record of the development and filling of surface cracks. Adequate supply of filling materials should be arranged by the mine management at the site.

xvi) Surface drains should be made outside of the subsidence influence area to prevent the surface water of adjoining area from coming into active subsidence area.

xvii) For the safety of underground workings it will be necessary to prevent the formation of water bodies on the surface while extracting panels in the lower seam. It is also suggested that dewatering of the goaves of upper seam should be continued as long as the lower seam is worked to prevent the formation of large water bodies over the working area.

xviii) It is recommended that while carrying out extraction in the Lower Workable seam, close subsidence monitoring required to be done over some initial panels. On the basis of observed data, necessary correction in subsidence estimation may be done, if required.

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Table 1: Anticipated maximum subsidence, slope and tensile strain at surface after extraction of panels of Lower workable seam only.

Panel No.	Av. Width	Av. Depth	Extraction Thickness	Max. Subsidence	Max. Slope	Max. Tensile Strain
	(m)	(m)	(m)	(mm)	(mm/m)	(mm/m)
R5*	270	219	2.8	1200	10.96	5.48
R6	270	248	2.7	940	7.58	3.79
R1*	108	117	2	230	3.93	1.97
R2*	270	118	1.5	730	12.37	6.19
R3*	270	159	2.4	1180	14.84	7.42
R4*	270	176	2.2	1060	12.05	6.02
R7	228	315	2.3	240	1.52	0.76
R8*	180	315	2.3	350	2.22	1.11
RMD7	180	297	2.5	200	1.35	0.67
RMD6	180	242	2.5	570	4.71	2.36
RMD5*	180	242	2.5	620	5.12	2.56
RMD4*	180	163	1.5	620	7.61	3.80
RMD1*	180	129	2.4	1080	16.74	8.37

Table 2: Anticipated maximum subsidence, slope and tensile strain at surface after extraction of panels of Bagdona seam only.

Panel No.	Av. Width	Av. Depth	Extraction Thickness	Max. Subsidence	Max. Slope	Max. Tensile Strain
	(m)	(m)	(m)	(mm)	(mm/m)	(mm/m)
Q7	228	333	1.9	230	1.38	0.69
Q6	270	306	1.6	440	2.88	1.44
Q8*	180	333	1.9	270	1.62	0.81
Q5*	270	295	1.9	660	4.47	2.24
Q4*	270	229	1.7	830	7.25	3.62
Q3*	228	224	1.7	700	6.25	3.13
Q2*	48	192	1.5	0	0.00	0.00
Q1*	90	186	2.2	20	0.22	0.11
QMD7	180	361	1.9	90	0.50	0.25
QMD6	228	323	1.9	330	2.04	1.02
QMD5*	228	284	1.9	560	3.94	1.97
QMD4*	228	233	1.8	710	6.09	3.05
QMD1&2*	228	180	2	1000	11.11	5.56

Table 3: Anticipated maximum subsidence, slope and tensile strain at surface after extraction of panels of IA Seam only.

Panel No.	Av. Width	Av. Depth	Extraction Thickness	Max. Subsidence	Max. Slope	Max. Tensile Strain
	(m)	(m)	(m)	(mm)	(mm/m)	(mm/m)
P1*	90	199	2.5	200	2.01	1.01
P2*	270	229	2	760	6.64	3.32
P3*	228	252	1.5	370	- 2.94	1.47
P4*	270	281	2	830	5.91	2.95
P5*	180	308	2	490	3.18	1.59
P8*	180	356	2	130	0.73	0.37
PMD4*	228	293	2	600	4.10	2.05
PMD1*	138	189	2.5	850	8.99	4.50

Table 4: Anticipated maximum possible subsidence, slope and tensile strain at surface after extraction of Lower Workable seam, Bagdona seam and IA Seam.

Panel No.	Av. Depth	Max. Subsidence	Max. Slope	Max. Tensile Strain	Likely width of cracks
	(m)	(mm)	(mm/m)	(mm/m)	(mm)
R1, Q1, P1 (*)	199	450	4.52	2.26	FINE CRACKS
R2, P2 (*)	229	1480	12.93	6.46	<50
R3, Q3, P3 (*)	252	2200	17.46	8.73	<100
R4, Q4, P4 (*)	281	2700	19.22	9.61	<100
R5, Q5, P5 (*)	308	2270	14.74	7.37	<50
R6, Q6,	306	1370	8.95	4.48	FINE CRACKS
R7, Q7	333	470	2.82	1.41	NIL
R8, Q8, P8 (*)	356	730	4.10	2.05	FINE CRACKS
RMD1, QMD1&2, PMD1 (*)	189	2680	28.36	14.18	<150
RMD4, QMD4, PMD4 (*)	293	1890	12.90	6.45	<50
RMD5, QMD5 (*)	284	1190	8.38	4.19	FINE CRACKS
RMD6, QMD6	323	890	5.51	2.76	FINE CRACKS
RMD7, QMD7	361	290	1.61	0.80	NIL

Note: (*) Panels below forest land

SUBSIDENCE IMPACTS

The Subsidence Impact Matrix given below shows the degrees of damage for various surface features, including forest land, vis-a-vis subsidence, slope and strain values was developed as part of a Ministry of Coal funded S&T project and is extracted from the S&T Report titled "Subsidence in Mining Areas" by CMRI.

Sl. No.	Impact	Subsidence	Slope	Strain
		mm	mm/m	mm/m
1	2	3	4	5
	SURFACE TOPOGRAPHY			
1.	Practically no impact	<500	<3	<3
2.	Some fine cracks or one or two 50mm wide cracks with visible depression	<500 500-1000	3-5 5-10	3-5 3-5
3.	A large number of fine cracks or a few 100mm wide cracks with marked depression	500-2000	10-20	5-10
4.	A large number of 50-100mm wide cracks or a few 200mm wide cracks with stepping. Marked distortion in surface topography	500-2000	>20	10-20
5.	500mm wide cracks with stepping and prominent distortion in surface topography	>1000	>50	20-50
6.	Many 500mm wide cracks some upto 1000mm width, large stepping. Severe distortion in surface topography	>2000	>100	50-100
7.	Very severe distortion in surface topography. Stepped subsidence with very wide cracks.	>2000	>100	>100

1	2	3	4	5
		mm	mm/m	mm/m
	SURFACE WATER BODIES (Ponds, Rivers, Nallahs, Jores, HFL)			
1.	Practically no impact. No loss of water	<500	<3	<3
2.	Marginal impact in some cases only. Some loss of water and water logging	<1000	<5	<5
3.	Severe impacts. Major loss of water. Severe water logging	>1000	>5	>5
	SUB-SURFACE WATER TABLE			
1.	Marginal depletion in water retaining capacity	<500	<3	<3
2.	Severe depletion in water retaining capacity	-	-	>5
	AQUIFERS			
1.	Depletion in water retaining capacity	-	-	>3
	WATERLOGGING ON SURFACE			
1.	**Very little waterlogging**	**<500**	-	-
2.	**Some (300-500mm deep depending on surface topography)**	**500-1000**	-	-
3.	Marked waterlogging	>1000	-	-
	ROADS			
1.	Practically no impact	<500	<5	-
2.	Depressions with gentle slope	-	5-10	-
3.	Steeper slopes (speed restriction may be necessary)	-	20-50	-
4.	Marginal repairs necessary	-	20-50	>10
5.	Major repairs necessary	-	>50	>10

1	2	3	4	5
		mm	mm/m	mm/m
	RAILWAY LINES - JOINTED CONSTRUCTION			
1.	Practically no impact	-	<10	<3
2.	Minor to severe impacts, repairs necessary due to bending twisting and breaking of rails and steeper gradients	-	>10	>3
	RAILWAY LINES - WELDED CONSTRUCTION			
1.	No subsidence permitted. Even very small strain can cause twisting and breaking of rails,			
	RAILWAY SIDINGS (Jointed Construction)			
1.	Practically no impacts	-	<10	<3
2.	Minor to severe impacts, repairs necessary	-	>10	>3
	SINGLE STORY HUTMENTS (Kuccha)			
1.	Practically no impact. A few fine cracks in plastered walls	-	<5	<3
2.	Minor repairable impacts. Fine cracks. A few 10mm wide cracks.	-	<10	3-5
3.	Major/severe impacts. Wide cracks, stepping, tilting	-	>10	>5
	SINGLE STORY BUILDINGS			
1.	Very little impact. A few fine cracks or one/two 5-10mm wide crack in plaster	-	<5	<3
2.	Minor impacts, repairable. 5-10mm wide cracks, doors and windows getting slight jamming, slight tilting.	-	5-10	3-5
3.	Severe impacts, major repairs necessary. Wider cracks, stepping, crushing and marked tilting.	-	>10	>5

1	2	3	4	5
		mm	mm/m	mm/m
	DOUBLE STORY BUILDINGS			
1.	Very little impact. A few fine cracks or one/two 5-10mm wide cracks	-	<5	<3
2.	Little repairable impact, 5-10mm wide cracks, slight displacement of walls against roof, doors and windows getting slightly jammed.	-	5-10	3-5
3.	Severe impacts, major repair necessary. Wider cracks, stepping, crushing and tilting. Gaps between walls and roof.	-	>10	>5
	MULTI-STORY BUILDINGS			
1.	Little impacts, repairable 5-10mm wide cracks, doors and windows getting slight jamming, displacement of walls against roof.	-	<5	<3
2.	Severe impacts. Winder cracks, crushing, tilting, and stepping.	-	>5	>3
	LARGE BUILDINGS, MONUMENTS, HISTORICAL BUILDINGS, ETC.			
1.	Very little impact. A few fine cracks or one/two 5-10mm wide cracks	-	<3	<1.5
2.	Little impact, 5-10mm wide cracks, Damage to decorations; slight displacements; doors and windows getting jammed.	-	3-5	1.5-3
3.	Severe impacts. Wider cracks, tilting, crushing, etc. Major repairs necessary.	-	>5	>3
	AERIAL ROPEWAYS			
1.	Practically no impact	-	<5	<3
2.	Little repairable impacts	-	5-10	3-5
3.	Severe impacts. Ropes may leave pullies due to change in alignment. Tilting of pylons. Buckling of structure.	-	>10	>5
	HIGH TENSION PYLONS			
1.	Practically no impact	-	<5	<3
2.	Severe impacts. Tilting, buckling and may be collapse of pylons	-	>5	>3

1	2	3	4	5
		mm	mm/m	mm/m
	UNDERGROUND CABLES			
1.	Practically no impact	-	-	<3
2.	Severe impacts (cables may break due to tension).	-	-	>3
	UNDERGROUND PIPELINES			
1.	Practically no impact	-	-	<1.5
2.	Severe impacts. Breaking of pipes	-	-	>1.5
	OVERLYING VIRGIN SEAMS			
1.	Practically no impact. No visible signs of subsidence when the seams are developed.	-	**<5**	<3
2.	A little impact. A little crushing of coal, roof and floor rock. Fire risk when development is done in upper seam.	-	**5-10**	3-5
3.	Severe impacts. Crushing of coal, roof and floor rock. Stepping in tensile strain zone. Fire risk. Heaving, supports necessary during development.	-	**10-20**	5-10
4.	Very severe impacts. Severe crushing, large stepping, entry into subsided area rather difficult. High fire risk. Arching necessary.	-	**>20**	>10
	OVERLYING WORKINGS (Standing on developed pillars)			
1.	Practically no impact on galleries and pillars. Some spalling.	-	**<5**	<3
2.	Visible floor lifting, side spalling and roof falls. Supports required. Fire risk.	-	-	3-5
3.	Marked floor lifting, side spalling and roof falls. High fire risks. Workings unsafe.	-	-	5-10
4.	Severe floor lifting, large roof falls, wide spread side spalling, stepping, very high fire risk, workings unsafe.	-	-	>10
	OVERLYING WORKINGS (Standing on reduced pillars)			
1.	Practically no impact.	-	<3	<1.5

1	2	3	4	5
		mm	mm/m	mm/m
2.	Marginal impact on stability of stooks. The stooks with marginal factor of safety may collapse increasing loading on adjoining stooks.	-	<5	<5
3.	Failure of a few stooks may lead to chain of failures causing partial or total collapse of area. Thus causing additional subsidence on overlying horizons.	-	>5	>3
	OVERLYING WORKINGS (Packed or stowed)			
1.	Practically no impact on stowed workings. Some loss of water.	-	-	<5
2.	Complete loss of water from stowed areas and also from adjoining rise side areas.	-	-	>5
	WATERLOGGED OVERLYING WORKINGS (Standing on developed pillars)			
1.	Practically no impact on pillars, galleries and water retaining capacity of the workings.	-	-	<3
2.	Marginal loss of water through fine cracks in strata around. Dewatered areas may have risk of fires, roof falls, side spalling, floor lifting.	-	-	<5
3.	Major loss of water. High fire risk in dewatered areas with roof falls, side spalling, floor lifting, etc.	-	-	5-10
4.	Total loss of water. Very high fire risk with severe floor lifting, roof falls and spalling.	-	-	>10
	WATERLOGGED OVERLYING WORKINGS (Standing on reduced pillars/stooks)			
1.	Stooks may collapse causing additional subsidence on surface.	-	-	<3
2.	Partial loss of water. Collapse of stooks. Additional surface subsidence. Fire risk.	-	-	3-5
3.	Total loss of water. Collapse of workings. Additional surface subsidence; fire risk.	-	-	>5

1	2	3	4	5
		mm	mm/m	mm/m
	IN CURRENT WORKINGS FROM SUBSIDENCE AT THE LEVEL OF SURFACE			
1.	Practically no impact.	-	-	<5
2.	Leakage of air. Fire in goaves at shallow depth.	-	-	>5
	IN CURRENET WORKINGS FROM SUBSIDENCE AT THE LEVEL OF OVERLYING TATER BODIES			
1.	Practically no impact	-	-	<3
2.	Marginal increase in make of water.	-	-	3-5
3.	Appreciable increase in make of water.	-	-	5-10
4.	Heavy increase in make of water, which may lead to inundation.	-	-	>10
	SURFACE ATMOSPHERE			
1.	Practically no impact.	-	-	<5
2.	Some air from underground workings at shallow depth may leak to surface.	-	-	5-10
3.	Air leakage from shallow depth workings. If the workings have fire, surface atmosphere is likely to be polluted by gases coming from the fire.	-	-	>10
	SUB-SOIL			
1.	Practically no impact.	-	-	<3
2.	Very little impact in the form of reduction of water retaining capacity.	-	-	3-5
3.	Temporary loss in water retaining capacity. Cracks filling may improve water retaining capacity.	-	-	5-10
4.	Long term loss of water retaining capacity. Suitable protective measures necessary.	-	-	>10
	AGRICULTURE			
1.	Practically no impact.	-	-	<5
2.	Marginal impact, i.e. reduction in yield due to loss in water retaining capacity of sub-soil.	-	-	5-10
3.	Major impact, i.e. sizeable reduction in yield.	-	-	>10

1	2	3	4	5
		mm	mm/m	mm/m
	FOREST AND PLANTATION			
1.	Practically no impact.	-	<10	<5
2.	Temporary loss in water retaining capacity of top-soil may affect undergrowth slightly. Slight tilting of plants/trees.	-	10-20	5-10
3.	Short term impact on trees in zones having cracks. The cracks may get filled in due course. Tilting of trees.	-	20-50	10-20
4.	Wide cracks may severely affect undergrowth but may not have much impact on large trees except those in the tensile strain zone where wide cracks develop; high tilting may cause some trees to fall in the high slope zone.	-	>50	>20