Strata Control TARPs During Different Phases of Longwall Mining

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Abstract. Longwall technology is the mass production technology for underground coal mining. Stability of Gate roadways forming Longwall panels is essential to ensure the safety of Longwall mines. Gates and chain pillars between Longwall mining panels are subjected to a complex loading process throughout their service life. Primary and secondary supporting with available support hardware are the major measures for stabilising gates. Various factors affect instability in gates which can control by monitoring and suitable strata control techniques via Trigger Action Response Plan (TARP). Condition based, TARP's are handful tool for successful working of Longwall. This paper presents condition of gate roads during different phases of Longwall mining and control measures taken through TARPs are listed at Adriyala Longwall Project.

Keywords: Longwall mining · Gateroads · Roof convergence · Trigger Action Response Plan (TARP)

1 Introduction

The principal hazard management plans (PHMPs) are fundamental to manage the major hazards effectively in coal mines. Trigger values in TARPs are intended to be inherent non-emotional guides to mine operators. They are the key elements of the PHMPs aimed to initiate control actions at various levels of deviation from normality aimed at elimination or mitigation of hazards.

TARPs aim to provide assurance and guidance when the situation deviates from the original plan or there is a change IN conditions that could be hazardous. The trigger action response plans (TARPs) are inherent to managing the multiple hazards such as: strata control, high spontaneous combustion (SPONCOM) propensity, heat and ventilation and other engineering areas.

Fundamental principles that TARPs should conform to following elements: the TARP must be simple and robust; it must be adequately resourced both in terms of personnel and equipment; its focus should be on prevention and control through early detection; setting trigger values require detailed knowledge of what is normal, they need to be regularly reviewed and revised as necessary and experience dictates; there is no substitute for high quality mine strata monitoring systems; they should be set based on the best available

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Table 1. Details of Longwall panels worked at ALP

Description	LWP No. 1	LWP No. 2	LWP No. 3
Dimensions of panel	2312 m × 250 m	2232 m × 250 m	2494 m x 250 m
Depth range	362 m to 450 m	409 m to 506 m	443 m to 541 m
Reserves in the panel	3.36 MT	3.25 MT	3.6 MT
Gate road dimension (W x H)	5.2 m × 3.3 m	5.2 m × 3.3 m	5.5 m × 3.3 m
Total Reserves extracted	3.37 Mt	3.25 Mt	1.3 Mt

advice-both on site and off site, and If a TARP mandates an action, then that action must be carried out, properly and promptly [2–4].

Large scale coal production from underground coal mines at great depths can be possible with Longwall technology only. Longwall mining is worldwide proven technology for producing coal up to 10 Mt per annum from underground coal mines.

In low capacity long walls, the gate roadways were developed with conventional road header and the roof is supported with 1.8 m long cement grouted roof bolts by using electrical drills. The development rates were slow. The secondary support in the gate roadways was done by the conventional approach of rope stitching, girders and cogs etc. which are not stiff to arrest increase of rate of convergence and strata problems. In most of these Longwalls, the occurrence of cavities and strata problems were very common phenomenon in gate roadways and Longwall faces due to poor standards of bolting, instrumentation, monitoring and poor health and under rated powered roof supports in the Longwall face. Earlier, these Longwalls were introduced without complete geotechnical analysis of the strata which created unexpected strata problems while developing or retreating of Longwalls [9, 10].

High capacity Longwall technology is the only viable solution for extraction from deeper deposits of underground mines with high production rates, if properly planne and executed in view of strata control.

In Adriyala longwall project, 2.817 Mt capacity mechanised longwall was introduced in the year 2014. So far two panels have been successfully extracted and third panel is under extraction with the effective strata control methodology applied. Table 1 shows the details of Longwall panels worked at ALP [1]. In this paper attempt was made to review of existing Trigger Action Response Plans and updating the same for achieving effective strata control during various stages; such as longwall gate road development, longwall face equipment Installation chamber and retreat of longwall panel.

2 Strata Monitoring in Gate Roads During Development of Longwall Panels

Strata monitoring carried from right from the beginning of developemnt of gateraodways with strata monitoring instrumentation plan and auditing of gate road as per the advice of scientific bodies CIMFR, & Dr. Russell Frith, Geotech consulatnat, Australia [2,

3]. Accordingly zoning of gate roads were devedied based on the monitoring auditing schemes. The detaisl of the instrumentatin and auditing details are given below.

2.1 Monitoring of Vertical Roof Movement

Adriyala with 4 workable seams No. 1, 2, 3, 4 seams, present longwall panels are extracting in No. 1 Seam only. The bore hole section of No. 1 seam is shown in the Fig. 1.

The No. 1 seam is about 6.7 m thickness consisting of two clay band of 0.7 m and 0.3 m thickness located at 0.2 m and 2.9 m from roof of No. 1 seam. Longwall planned to work with a height of 3.5 m from floor of No. 1 seam.

Accordingly, development of gate roads planned to work with section from floor of No. 1 seam with a height of 3.3 m and width of 5.2 m. Three gate roads namely Tailgate-1 (TG1), Maingate-1 (MG-1) and Tailgate-2 (TG-2) are developed prior to retreat operation of the first Longwall panel.

Vertical roof movements are monitored with conventional convergence stations installed for every 50 m interval and two point telltales (Dual Height Telescopic Telltales) [6, 7] for every 200 m interval i.e., at junctions of cut through as shown in Fig. 2a&b. Data are collected on daily basis from each convergence station and telltales. During the development stage, about 170 convergence stations and 40 Tell Tales have been installed and monitored daily. Figure 3 shows the cumulative convergence in MG-1 and TG-2 along gate road length from setup room.

During the development of MG-1 excessive convergences are recorded due to roof of working section contains thin laminated layers, and clay bands it is very initial stages of development of gate roads under coal roof, it has taken some time to understand the things and later changed the working section with roof containing thick shaly coal band

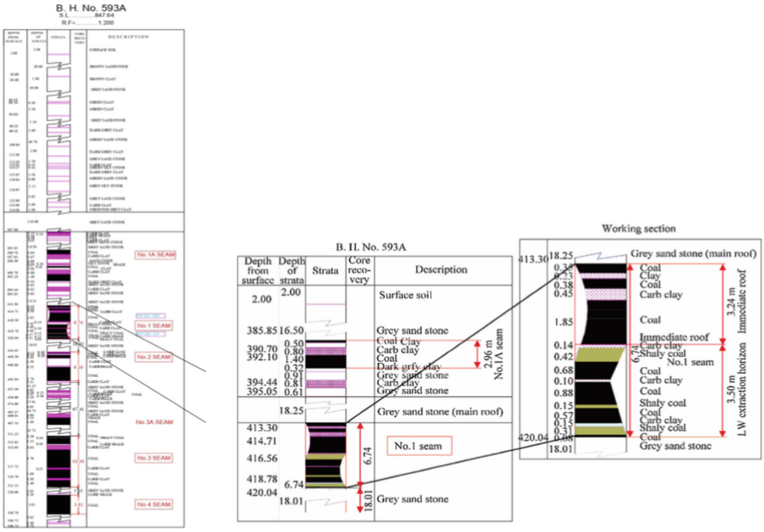

Fig. 1. Borehole section (BH 593A) and No. 1 seam working section of ALP mine

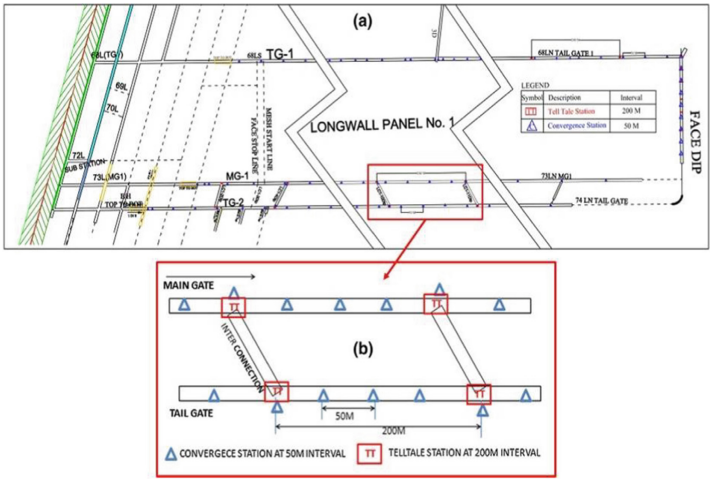

Fig. 2 a & b Strata monitoring plan for gate road development of Longwall panel No. 1

leaving the middle clay in to the roof, due to which it is required to cut the stone floor up to 0.8 m in the floor. Later with the advice of scientific bodies, mine management has developed a Trigger Action Response Plan (TARP) [8]. As part of developing roof control "triggers" or conditions for use by mine operators to assist with their management of roadway roof stability, it will be necessary to define acceptable and unacceptable levels of monitoring data; there it derives the Trigger Action Response Plan (TARP) [5, 12].

3 TARP During Gate Roads Development

3.1 LWP No. 1 and LWP No. 2 (Refer Table 2)

Throughout the development of LWP No. 1, TARP is implemented for strata management of gate roads, and regular strata audit is done for the presence and status of guttering, water seepage, slips, and load on supports were monitored, the geotechnical and geological mapping was carried out for gate roadways of TG-1, MG-1, TG-2 and face dip. The gateroad cumulative roof convergence along the length of gateroads MG-1, TG-2 is given in Fig. 3. The geological features like water seepage, guttering, slickensides, slips and joints convergence based zoning were mapped as shown in Fig. 4. It is found that, 80 to 85% gate roads fall under green zone, 10 to 20% under Yellow zone, and 0 to 5% under red zone category. This shows Most of the gate roadways are under green zone indicate optimum bolting system. Yellow zones are due to water seepage and geological disturbances are additionally supported. After additional supporting, the convergences were stabilized.

The TARP for LWP No. 1 development of gateroads is being followed for development of gateroads of LWP No. 2 also as the method of drivage of gateroads (by road headers) is same in both the panels. And TARP is similar in both the cases as the mining conditions are similar.

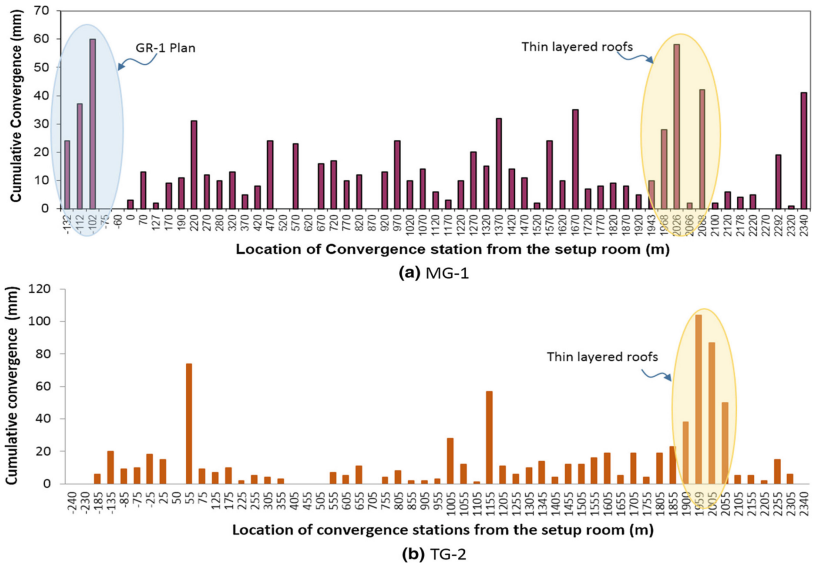

Fig. 3. Cumulative roof convergence measured at stations after 2 years of development.

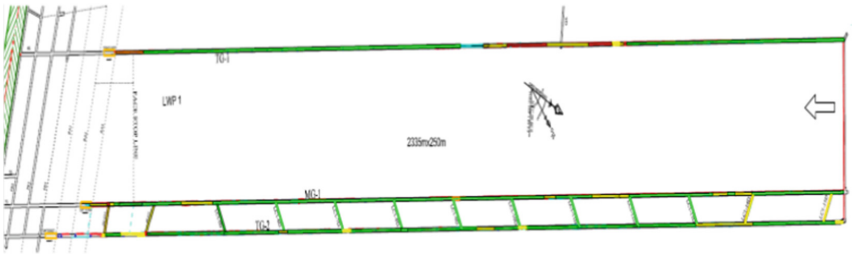

Fig. 4. Zoning of gate roads as per TARP of LWP No. 1

3.2 LWP No. 3

During development of LWP No. 3, existing TARPs were modified (refer Table 3) based on the experiences gained during Longwall panel No. 1 & No. 2, and TARP was updated.

Based on modified and Updated TARP, zoning of gateroads of LWP No. 3, w.r.t. geologial features, physical obervations, disturbances and convergence is as shown in Fig. 5.

3.3 LWP No. 4

Based on the experience of LWP No. 3 development with Bolter miner machinaery, TARP is reviewed further and updated one is proposed for LWP No. 4 development, where the cable bolts shall be installed during the development stage within 200 m from working face irrespective of cumulative convergence. TARP for LWP No. 4 development is given in Table 4 & 5.

Table 2. Trigger Action Response Plan (TARP) during Development of LWP No. 1 & 2 gate roads

Monitoring Triggers	Status Level		
	Level 1 (Green Zone)	Level 2 (Yellow Zone)	Level 3 (Red Zone)
Strata monitoring	Convergence stations/Tell tale movement in Gate roadways • Total convergence is below 30mm	Convergence Stations/ Tell tale movement in gate roadways • Total convergence is below 100mm	Convergecne stations/Tell tale movement in gate roadways • Total convergence is above 100mm
Strata condition	Strata as normal condition without much variation	If roadway encountered • Unexpected fault • Excessive water seepage • Any change in seam gradient • Deterioration of roof structure • Guttering or cracks • Excessive weighting in junctions or roof • Any major geological discontinuity.	• Conditions likely to cause roof or side to collapse or cause injury to men or machinery.
Support installation	• Supporting complying with S.S.R of the mine • Failure of support due to operator or person failure which can be replaced.	• Supports not taking prescribed anchorage strength. • Install rope stitching at 1m interval • Vertical props erected immediately 1m interval immediately	• Supports were failing due to lower anchorage strength. • Girder supports to be erected at 1m interval

4 Drivage of Longwall Face Equipment Installation Chamber, LWP No. 1

It was proposed to drive a gallery of 8.0m wide with coal roof, for installation of Longwall face equipment, it was planned to drive the 8.0m width gallery in two phases,

In the first phase, the installation chamber was formed with 5 m width and 3.2 m height. The length of installation chamber or Longwall face i.e., 250 m is completed.

Table 3. Trigger Action Repsonse Plan (TARP) during Development of LWP No. 3 gate roads

Trigger Level	Description	Support system
Green	Convergence less than 50mm and one side guttering along gallery	As per SSR 8 bolts /m, continue monitoring
Yellow	Convergence more than 50mm but less than 80mm and observes • One side guttering and water seepage • Tensile cracks in the roof	One cable bolt per 2m and continue monitoring
Red	Convergence more than 80mm . Both sides guttering with guttering height more than 1.0m.	AS per SSR 8 bolts/m + two cable bolts/2m and conintues

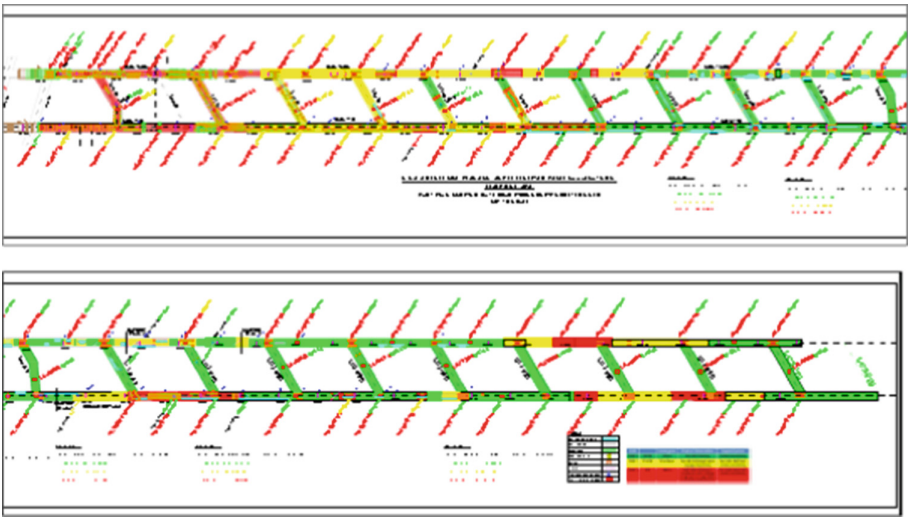

Fig. 5 Zoning of gate roads as per TARP of LWP No. 3

The support pattern followed in 5 m roof span is 6 nos. of roof bolts; 2.4 m resin bolts along with rigid wire mesh in a row and the row spacing is 0.5 m, so there are 12 bolts in 1m drivage. During this extraction the shear movement/fracture was noticed in some places along the Longwall face in southern side at the intersection of face and immediate roof.

Table 4: TARP for roadways where roof was not supported with cable bolts along with drivage during the development of LWP No. 4

Zone	Convergence	Physical observations	Action plan
5.5m to 6.0m width drivage with recommended support plan			
Green	0-30mm	Normal strata conditions	Continue monitoring shift wise
Yellow	31-50mm	• Water seepage less than 10ml/min • Both sides guttering with height of guttering is less than 0.5m. • Minor faults and disturbance in the roof	Install additional cable bolts
Red	More than 50mm	•Water seepage more than 10ml/min •Both sides guttering with height of guttering is more than 0.5m. •Tension cracks in the middle of the gallery. •Major faults and high disturbance in the roof.	Install one additional cable bolt than support in yellow zone and cement injection in to the roof strata or Girder support. Monitoring shall be done on shift basis till the convergence or roof got stabilized. Indicator props shall be installed for visual purpose. People passing through the zones shall be enlightened about the intended associated danger

In the second phase the installation chamber was widened up to 8 m by driving a 3 m cut with road header. The widening activity was stopped after 45 m because of significant and unexpected high convergence was recorded at 10 m TT, as shown in Fig. 6. This increased convergence was also recorded at 20 m TT though the magnitude was much lower compared to that of 10m TT. To tackle this situation additional two rows of 40T OC hydraulic props were installed in 3 m widen portion at an interval of 1m in the affected zone. To facilitate easy installation of the powered support with the help of free steered vehicles, the vertical OC props should be removed. To eliminate vertical supports, it was proposed to install two cable bolts in a row with spacing of 2 m between two rows as additional support along the installation chamber. After the installation of cable bolts the widening activity was completed successfully [11].

Table 5: TARP for already cable bolted roadways during the Development of LWP No. 4

Zone	Convergence	Physical observations	Action plan
5.5m to 6.0m width drivage with recommended support plan			
Green	0-50mm	Normal strata conditions	Continue monitoring on daily basis
Yellow	51-80mm	• Water seepage less than 10ml/min • Both sides guttering with height of guttering is less than 0.5m. • Minor faults and disturbance in the roof	install additional cable bolt
Red	More than 80mm	•Water seepage more than 10ml/min •Both sides guttering with height of guttering is more than 0.5m. •Tension cracks in the middle of the gallery. •Major faults and high disturbance in the roof.	Install one additional cable bolt than support in yellow zone and cement injection in to the roof strata or Girder support. Monitoring shall be done on shift basis till the convergence or roof got stabilized. Indicator props shall be installed for visual purpose. People passing through the zones shall be enlightened about the intended associated danger

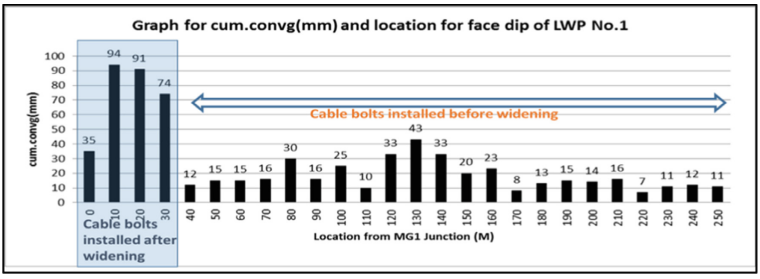

Fig. 6. Convergence in installation roadway with cable bolting

Table 6. TARP for Installation chamber

Trigger	Surge	Creep	Additional support
Level 1	<20 mm	<2 mm/week	no additional cable bolting
Level 2	<20 mm	>2 mm/week	no additional cable bolting
Level 3	>20 mm	<2 mm/week	no additional cable bolting
Level 4	>20 mm	>2 mm/week	install additonal one cable bolt
Level 5	>20 mm to 50 mm		install additonal one cable bolt

Table 7: Secondary support plan for LWP No. 1 retreat

Trigger	Convergence	Additional Support
Green Zone	<30mm	1 cable bolt/2m no need of cement injection
Yellow Zone	30mm to 100mm	1 cable bolt/2m with cement injection
Red Zone	>100mm	1 cable bolt/1m with cement injection where girder support exists

4.1 TARP for Installation Chamber Are

Widening Surge of 20 mm convergence (increase in convergence due to widening after development) and Creep (rate of convergence w.r.t. time) of 2mm/week. Surge is the increase in convergence after widening of the gallery to 8.0 m, if the convergence increased is below 20 mm [2, 3]. Table 6 shows TARP for Installation chamber (Table 7).

5 TARP During LWP No. 1 Retreat

Based on TARP during development of gateroad of LWP No. 1, secondary support paln for LWP No. 1 retreat was framed. Support pattern for LWP No. 1 retreat is:

Trigger Action Response Plan for Gateraods and Longwall face operations during retreat of Longwall are as given in Tables 8 & 9.

With the above TARPs Longwall panel No. 1 & No. 2 retreated succesfully and LWP No. 3 is extraction under succfulway.

Table 8: TRIGGER ACTION RESPONSE PLAN (TARP) for Gate roads during Longwall extraction

Triggers / Levels	Green – Normal Level 1	Yellow – Level 2	Red- Level 3
Convergence	• Rate of Convergence > 10mm/week or total convergence >50mm and < 20m outbye of face.	Rate of Convergence > 10mm/week or total convergence >50mm and 20m to 50m outbye of face.	• Rate of Convergence > 10mm/week or total convergence >50mm and > 50m outbye of face.
Guttering	• Guttering height in gate roads less than 0.5m.	• Guttering height in gate roads is more than 0.5m but less than 1.0m. • Both sides guttering with guttering height of 0.3m to 0.5m	• Guttering height in gate roads is more than 1.0m. • Both sides guttering with guttering height of more than 0.5m.
Rib spall	• Rib spall less than 0.3m at the top.	• Rib spall more than 0.3m and less than 0.5m.	• Rib spall more than 0.5m
Visual signs	• No visual signs of tensile cracks in the roof and no loading on the supports.	• Visual signs of roof deformation and tensile cracks in the roof and loading on the supports in gate roadways but not total failure of the supports or its accessories.	• Visual signs of more roof disturbances and tensile cracks of width more than 10mm and failure of roof bolts.
Action Plan	• Routine Inspection of gate roads and ensure cable bolting is being done atleast 200m from the face. • Record convergences in the gate roads. • Inspect for roof condition in gate roads for guttering status and rib spall status and confirm the TARP level. • Inspect gate roads for any tensile cracks in the roof and any change of state of roof condition and ensure TARP level. • Continue routine secondary support system with cable bolting. • Educate the crew regarding the TARP levels.	• Notify the Longwall Acceleration Position (LAP) and ensure TARP level. • *Increase the level of inspection especially in the identified zones and arrange for temporary support with props.* • Install any additional tell tales if required. • Install additional Props at strategic locations on guttering side. • Support the rib with additional one bolt / 1.2m. • Monitor for any load on supports or roof bolts, if found install additional roof bolts or supports. • Record the findings and reasons for change of TARP level and report to next supervisor and report for precautions to be taken.	• Notify and confirm the TARP level • Inform the TARP level to shift undermanager / Panel Incharge. • *Arrange for additional cable bolting i.e one cable bolt / 2m.* • Increase the frequency of inspection of the area. • Increase the monitoring frequency to shift wise within 100m from face. • Review of roof conditions from the face outbye to atleast 100m. • Install additional tell tales if required. • Rib supporting with mesh shall be done immediately i.e one bolt + mesh. • Cement injection shall be done if adverse guttering is noticed.

Table 9: TRIGGER ACTION RESPONSE PLAN (TARP) for Longwall face during Longwall extraction

	Green – Normal Level 1	Yellow – Level 2	Red Level 3
Trigger	• Tip to face dimension 530mm after shields advanced or cavity less than 300mm • Face line straight and correct horizon. • Face height is 3.5m. • Break line on rear of canopies	• Tip to face dimension is greater than 530mm and less than 750mm after shields advanced or cavity greater than 300mm and less than 500mm • Broken roof on top of canopies • Face line is not straight and extraction height is more than 3.5m but less than 3.7m.	• Tip to face distance is more than 750mm after shields advanced. • Cavities in front of shields greater than 500mm for more than 10 shields • Break line in front of shield canopies and large pieces of stone/coal falling onto AFC from roof. • Broken roof or cavities on top of canopies causing rear of canopy to set up into cavity • Face line not straight • Extraction height is more than 3.7m
Action Plan	• Continue routine monitoring of the Longwall face. • Longwall system pressure maintained to 300bar • Hi set pump is running and its pressure is maintained to 350bar • Check hi set increases set pressure to 350bar on shields • Ensure Positive set is activated on all shields • Inspect the condition of the Longwall supports and observe for any bleeding. • Ensure face is straight • Ensure extraction height is 3.5m	• Record TARP level on production report, pass onto next supervisor • Longwall system pressure maintained to 300bar • Hi set pump is running and its pressure is maintained to 350bar • Check hi set increases set pressure to 350bar on all shields • check positive set is activated on all shields • Observe for any face spalling if it is in weighting zone increase the rate of extraction. • Record areas of broken or poor roof on production report. Record TARP level on production report, pass onto next supervisor • Instruct shearer operators reduce speed of shearer to an adequate speed to ensure shields are maintained behind lead drum • Communicate with crew the need to turn off positive set in area of cavity and set information tag on shield • Ensure canopy is fully tight against the roof and there is no gap between roof and canopy. • Ensure canopy tip is touching the roof and tight against the roof. • Reduce of height of extraction to 3.5m if it is more than 3.5m and instruct the shearer operator to maintain the horizon. • Change the cutting sequence so that face is to be straight. • Ensure minimum height between top of spill trays and underside of canopies is 700mm, record height and location on production report • Reduce for any outside belt delays for ensuring faster extraction.	• Notify control and Shift Incharge and Panel Incharge of TARP level • Communicate and inspect cavities with crew. • Record areas of broken or poor roof on production report. Record TARP level on production report, pass onto next supervisor • Ensure shearer operators reduce speed of shearer to no greater than 4m/min in area of cavities. • All shields are to be advanced with single function adjacent electric control one behind leading drum • Ensure positive set is turned off in areas of cavities and not reinitiated without inspection • Record on production report any areas positive set is turned off and reason why • Try to maintain a minimum height between top of spill trays and underside of canopies of 700mm, record height and location on production report • minimise belt delays • Ensure canopy is tight against the roof and canopy tip is tight against the roof.

6 Conclusion

Trigger Action Response Plans are vital for the effective strata control on which the success of longwall technology greatly depends. With the advice of scientific bodies based on prevailing conditions, mine management has developed TARP during different stages of longwall mining. The given TARPs for various displacement levels is site specific and these values can be taken as references for defining TARPs for any given problem in similar nature. With the application of strata control TARPs at Adriyala longwall project, Longwall Panels were developed and extracted successfully. TARP should focus on prevention and control through early detection; setting trigger values require detailed knowledge of what is normal, they need to be regularly reviewed and revised as necessary and experience dictates. These TARPs are vital for successful running of longwall especially under greater depth.

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