# Investigation report

## Report into a fatality at Goonyella Riverside Mine on 5 August 2017

Queensland Government

# Executive summary

An employee of Independent Mining Services (IMS), Mr Daniel Springer, was fatally injured on 5 August 2017 while he was performing maintenance on the outside of an excavator bucket at the Goonyella Riverside Mine. The work involved removing an external wear plate of the bucket by cutting it into smaller pieces. While performing a cut, part of the plate unexpectedly sprung up and struck Mr Springer in the head.

The Queensland Mines Inspectorate (QMI) within the Department of Natural Resources, Mines and Energy (DNRME) conducted an investigation over the ensuing nine months which included the commissioning of an independent metallurgical analysis, carried out by experts at the University of Queensland Materials Performance (UQMP) facility.

The investigation revealed that Goonyella Riverside mine commissioned ESCO Corporation, an engineering company, to undertake maintenance on a number of buckets in 2014 which involved modifications to the original equipment design. The original manufacturer was not consulted on these modifications. The external wear plate was originally made up of multiple small thin plates. During these modifications the multiple small plates were replaced with two large plates.

Analysis from UQMP showed that indentations in the external wear plate were the major reason for the build-up of stored tension which caused the plate to violently spring out during maintenance work. Indentations are caused from impact with hard objects during operation. It was also concluded that having two large wear plates would cause the spring-back to occur with much greater force compared to small thin plates and the spring-back distance is magnified by the length of the wear plate.

The velocity at which the plate moved at the time of the incident was such that a person would not have had time to move out of the way. The force of the impact was such that a person in the line of movement would likely receive fatal injury.

The mine did not undertake a formal risk assessment prior to making the modifications to the bucket. While it is possible that the magnitude of the risk may not have been identified by risk assessment alone, it would have given the best possibility of identifying the hazard.

There was a lack of understanding in the mining industry generally regarding the hazards associated with stored energy in steel plates, and how that energy could be introduced. There had not been similar widely-publicised incidents in the Queensland mining industry prior to this incident.

As a result of these factors, the mine was not aware of the full extent of the hazard and level of risk. As such Mr Daniel Springer, when conducting the maintenance work, was not aware that he was exposed to a potentially fatal hazard.

The QMI made a number of recommendations to the Queensland mine industry to ensure that this type of accident does not occur in the future:

- Smaller wear plates are to be used on excavator buckets as they are safer because the stored tension and spring-back is less than a design using larger plates. The large plates have inherently higher risk and the potential of being a fatal hazard.
- All mines to ensure that they have a procedure within their Safety and Health Management System (SHMS) that requires an effective risk management process to be carried out on any modification being made to plant and equipment prior to the modification being conducted.

- If a modification to plant and equipment is changing the original equipment manufacturer's design, the mine must consult with the manufacturer and / or an appropriate technical expert prior to the modification being conducted.
- The hazard of mechanical spring-back is not limited to excavator buckets. Since the incident, it has been identified that this hazard may also be present in other equipment types due to indentation. It is recommended that a risk assessment takes place before any indented plate sections are cut for removal from any equipment.

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# Purpose of the report

The Queensland Government believes that providing information relating to safety incidents on mine sites is an important part of continuous improvement of mine safety. This report is based on the findings of an investigation by the QMI and has two key purposes:

1) To provide family, friends and co-workers with an understanding of the events leading to the death of Mr Daniel Springer at the Goonyella Riverside Mine; and
2) To inform industry, government and the broader public of recommendations arising from the investigation with the goal of reducing the likelihood that such an event occur again.

# The investigation

The QMI's investigation included the following activities:

- Inspections of the incident scene
- Photography of the incident scene
- Collection and review of the mine's SHMS documentation, and this included:
    - Contractor management procedures
    - Training records
    - Supervision appointments
    - Work procedures / instructions
    - Maintenance records.
- Engaging an expert to conduct a metallurgical analysis of the wear plate
- Conducting lux (illumination) testing in the work area
- Interviewing witnesses and other relevant people
- Obtaining documentation from ESCO under search warrant.

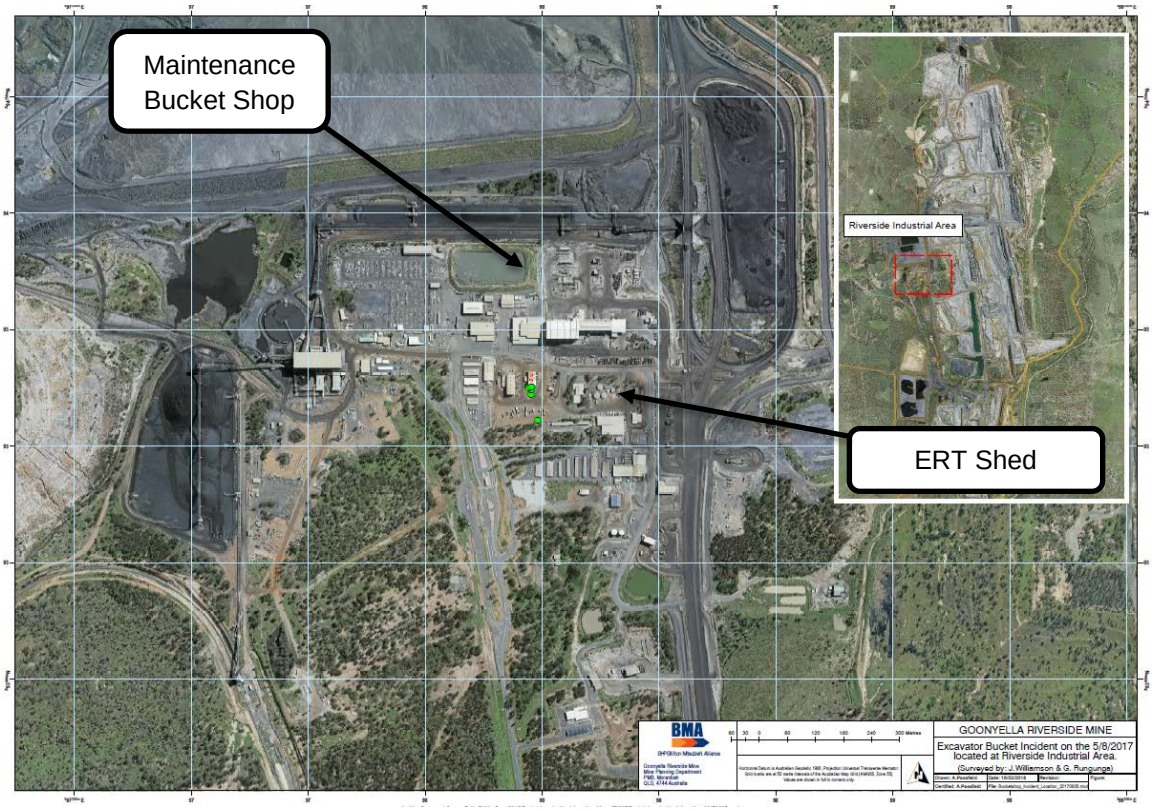
## Safety alert to industry

On 22 September 2017 Mines Safety Alert number 347 "Coal mine worker fatally injured performing maintenance work on a large excavator bucket" was published on the DNRME website and distributed to industry. The information release identified the importance of assessing the potential extent of stored energy hazard in carrying out similar tasks.

# Mine details

Goonyella Riverside Mine is an open cut coal mine, located 200 km southwest of Mackay. Mining operations commenced in 1971. It is one of the seven BHP Billiton Mitsubishi Alliance (BMA) Mines in central Queensland. Below is an overview of the mine layout showing the location of the maintenance bucket shop and the emergency response team (ERT) shed.

***Figure 1- An overview of the Goonyella Riverside MIA***




## Equipment involved

A Terex RH340 Excavator (refer to **Figure 2**) is a machine weighing approximately 550 tonnes that is powered by a diesel engine which in turn drives a complex hydraulic system that propels all of the machine's motions. These excavators are used for digging and loading overburden material and coal into dump trucks to transfer it to designated dump locations. The excavator also prepares and maintains the ground conditions on the bench that it works from within the mining pits.

An excavator's bucket is constantly working in hard and abrasive ground, and therefore requires periodic repair and maintenance. The bucket for a Terex RH340 Excavator is designed to hold approximately 34 cubic metres of ground material which weighs approximately 32 tonnes.

Maintenance of an excavator bucket usually includes the repair of cracks identified in the steel, and replacement of various sections of the steel wear plates that may be worn thin from abrasion. Minor excavator bucket repairs are usually performed at the mine site with the bucket still attached to the excavator and power sources isolated. This work normally consists of re-welding cracks identified in the bucket. However, for significant maintenance such as replacing a large portion of the wear plates on an excavator bucket, the bucket is commonly detached and transported to a workshop facility equipped with the required resources to perform the work.

***Figure 2 - Terex RH340 Excavator loading overburden material into a dump truck***


# Mr Daniel Springer

Mr Daniel Springer was a 30 year old boilermaker employed by Independent Mining Services (IMS). He started working at the mine's maintenance bucket shop a few days prior to the incident on 5 August 2017.

# The mine and the employer

BHP Billiton Mitsubishi Alliance owns and operates seven coal mines in the Bowen Basin including Goonyella Riverside mine.

IMS was established in 2008 and provides mining and engineering services to mines in the Bowen Basin, including Goonyella Riverside mine.

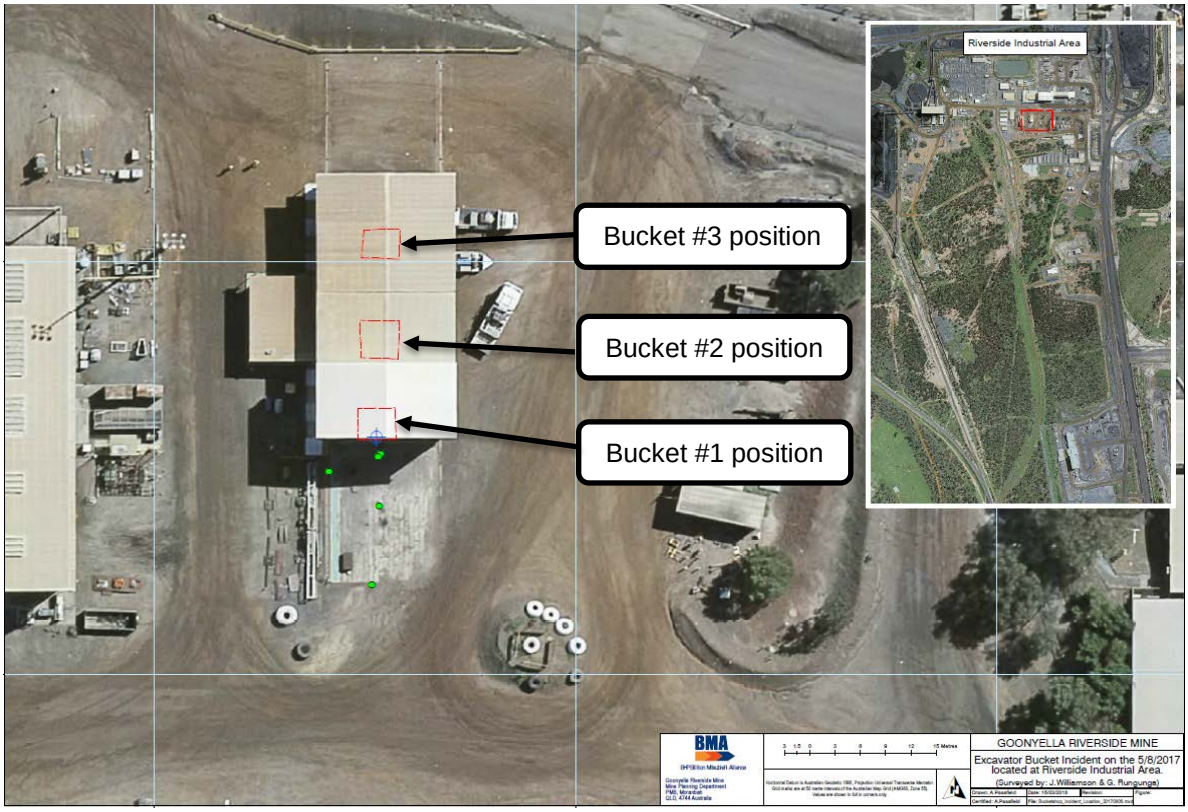
On 21 July 2017, IMS commenced work at Goonyella Riverside mine to carry out boilermaker work as part of maintenance activities.

# The incident

## Location of incident

The incident occurred in the maintenance bucket shop. Mr Daniel Springer was working on Bucket #1.

***Figure 3 - An overview of the maintenance bucket shop and bucket positions***




## Events leading up to the incident

During the period between October and December 2014, excavator bucket #1 (SN-9213-09) was rebuilt in Mackay by ESCO Corporation, an engineering company. The design of the external wear plates was changed from the original equipment manufacturer (OEM) design using multiple small plates to two large wear plates. The rebuilt bucket was returned to Goonyella Riverside mine in December 2014. The bucket was then used on a Terex RH340 Excavator in mining operations for an unknown period of time between December 2014 and July 2017.

On 20 July 2017, ALS Industrial (engineering consultants) provided Goonyella Riverside mine with a condition monitoring report on excavator bucket #1, which showed that non-destructive testing had identified cracking.

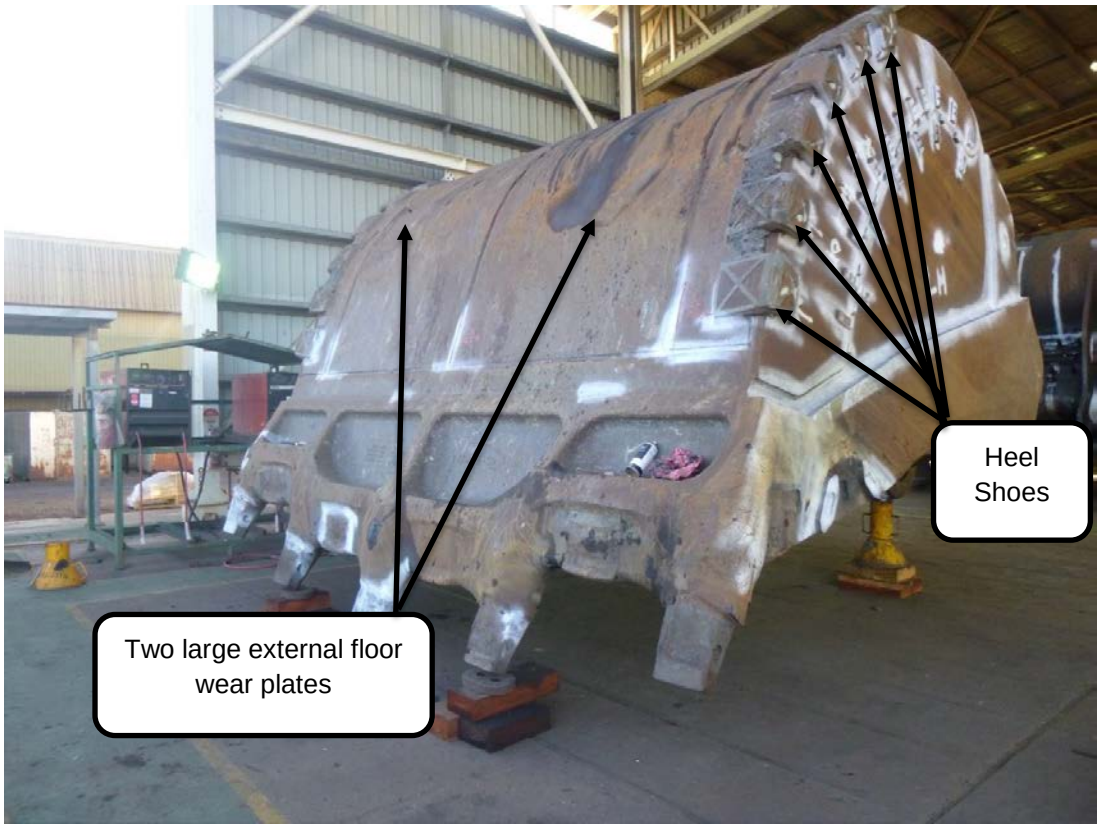
On 21 July 2017 IMS commenced work at Goonyella Riverside mine carrying out boilermaker work mostly in the mine's maintenance bucket shop. On 2 August 2017 Mr Springer and his co-worker commenced work with IMS at Goonyella Riverside mine. After completing an area familiarisation at the mine they commenced work in the maintenance bucket shop. They both worked day shift on 2 and 3 August 2017.

On 4 August 2017 Mr Springer and his co-worker arrived at Goonyella Riverside mine at approximately 05:50 pm to work night shift. They completed a shift handover with the out-going day shift IMS boilermakers. Around this time Mr Springer signed the Hot Works Permit and Job Safety Analysis (JSA) which had been compiled at the beginning of the day shift on this day. At approximately 06:15 pm, Mr Springer and his co-worker attended a shift pre-start meeting which was

held in a meeting room at the main maintenance workshop and then returned to the maintenance bucket shop to commence their boilermaker activities.

At the time there were three excavator buckets in the maintenance bucket shop, bucket #1, #2 and #3. Mr Springer and his co-worker undertook maintenance work on bucket #1. The co-worker was to gouge out identified cracks on the inside of the excavator bucket, and then re-weld these areas. Mr Springer's assigned work for the shift was to remove one remaining heel shoe from the outside of the excavator bucket #1, and then remove the two large external floor wear plates (refer **Figure 4**). Mr Springer completed his BMA Safe (BMA's risk management form to control identified hazards) at around 07:00 pm on the tasks that he had planned for this shift.

***Figure 4 - Excavator bucket #1 set up in the Maintenance Bucket Shop in July 2017 prior to the commencement of the maintenance rebuild.***




Mr Springer removed the one remaining heel shoe from the excavator bucket, and then commenced removing the large floor external wear plates. Using an air carbon arc gouger it appears that he firstly made a horizontal cut across the bottom of both large wear plates prior to a work platform being put in place. After placing a work platform adjacent to the bucket, Mr Springer removed two smaller sections from the left hand lower side of the left wear plate and placed them on the workshop floor. It is common for boilermakers to cut large plates into smaller sections when removing them, as this makes them easier to manually handle due to the lighter weight. Whilst these two smaller sections were being cut out the co-worker stated that he heard three or four popping noises signalling kickback (springing out) of the wear plate as it was being cut, and each time the co-worker heard one of these noises he would call out and ask Mr Springer if he was okay. On each occasion Mr Springer would answer stating that he was okay. At the time, the co-worker was working underneath and inside the

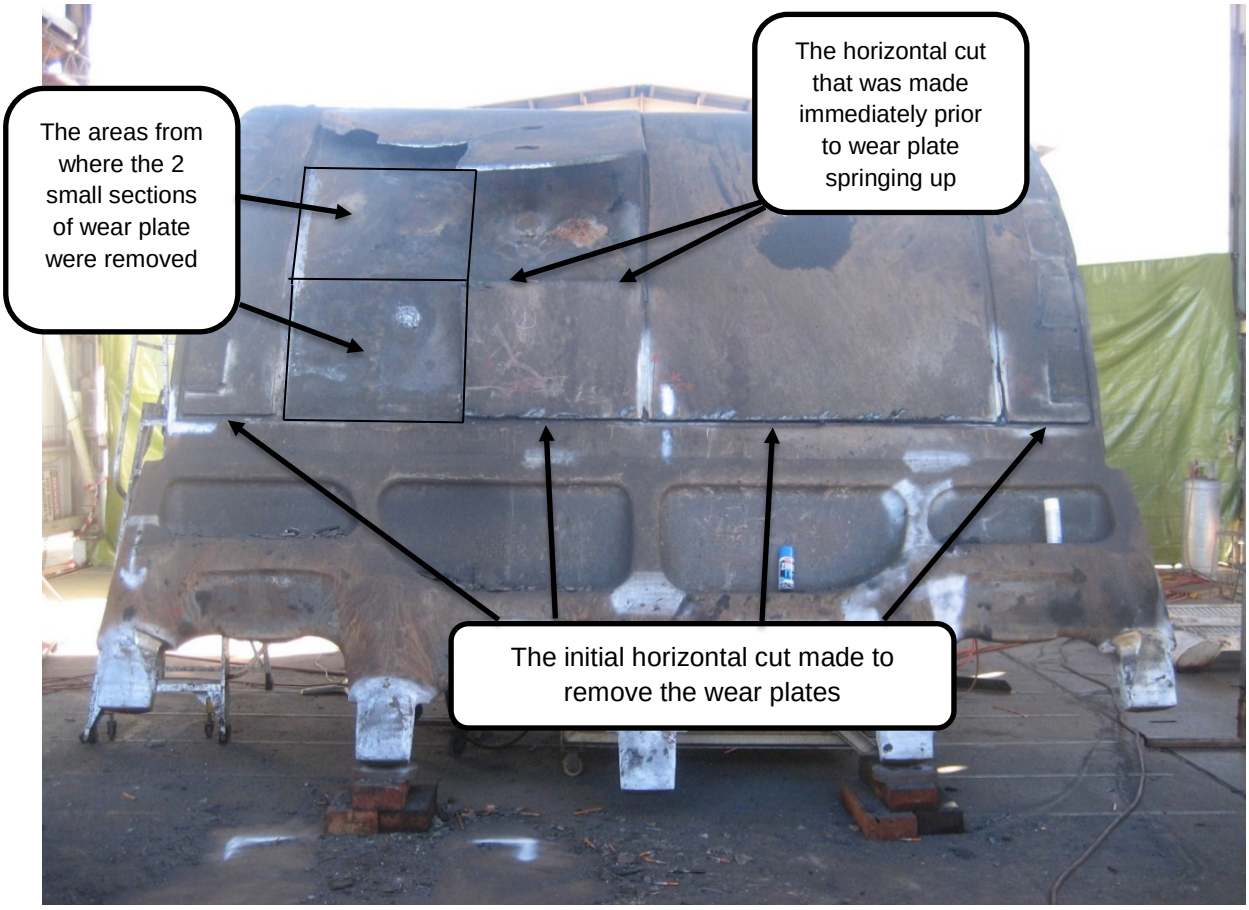
excavator bucket, and Mr Springer was working outside the bucket and up on a work platform, so they could not see each other but were able speak to each other.

There was evidence that Mr Springer then used an electric angle grinder to clean the cutting slag and weld away from the left side of where he had removed the two smaller sections of wear plate.

The co-worker stated that during the shift he and Mr Springer had discussed the potential of the wear plate springing out when cutting it, and Mr Springer had commented that he was aware of it and knew to keep out of the way when it was likely to happen. The co-worker stated that they had only expected the wear plate to spring out a short distance, and nothing like to the extent that the wear plate later sprang out.

Mr Springer then made a horizontal cut across the right hand side of the left wear plate as seen in **Figure 5** below, and this is when the plate has suddenly sprung up.

***Figure 5 - Excavator bucket #1 post incident occurring***




## Incident description

Incident occurred at approximately 12:56 am on 5 August 2017.

Mr Springer was struck in the upper forehead area by the steel wear plate. Evidence suggests that Mr Springer had just completed air carbon arc gouging the wear plate, and had lifted his welding face shield and hung the air carbon arc gouger handpiece over the adjacent handrail on the work platform that he was working upon. Given the position of the injury on his forehead it would appear that Mr

Springer was looking back at the steel wear plate when it suddenly released and sprang up 600 to 650 mm.

***Figure 6 - Photo of the maintenance bucket shop and bucket #1 post accident***

***Figure 7 - Photo of work platform Mr Springer was working on and bucket #1***

## Emergency response

At approximately 12:59 am 5 August 2017, the co-worker called an emergency over the two-way mine radio system. An emergency response team (ERT) member answered the call immediately and arrived at the incident scene at approximately 01:01 am 5 August 2017.

The ERT immediately commenced providing first aid to Mr Springer. They continued stabilising him until the Queensland Ambulance Service (QAS) from Moranbah arrived at 01:33 am 5 August 2017. QAS transported Mr Springer to Moranbah Hospital, from where he was airlifted to Mackay Base Hospital. Later that day he was flown to the Townsville Base Hospital where he underwent surgery.

The following day, 6 August 2017, doctors at the Townsville Base Hospital informed Mr Springer's family that he was clinically deceased. A decision was made to keep Mr Springer on a life support system so as to arrange for organ donation. Mr Springer was kept on a life support system until approximately 10:00 am on 7 August 2017.

# Safety observations

## Equipment modifications prior to incident

Documented records obtained by the QMI investigation team showed that in 2014 some person or persons at Goonyella Riverside mine made a decision to change the external floor wear plates on a number of excavator buckets used at the mine. The excavator bucket's OEM initially fabricated the buckets with multiple thin horizontal external wear strips on the underside of the bucket's floor. However, during maintenance rebuilds on a number of excavator buckets, they were replaced with two large external wear plates.

Goonyella Riverside mine could not provide documentation, records or evidence showing why this modification was requested. An ex-employee of ESCO Corporation, the engineering company that completed the works, indicated that it may have been performed to reduce maintenance downtime and cost associated with constant cracking of the smaller wear plates.

The mine's management structure at the time required the maintenance manager to ensure modifications were risk assessed prior to being carried out, and changes were to be implemented with regard to managing risk and with use of change management processes – including keeping records on the changes, designs, drawings and modifications made. It was apparent in the investigation that this did not happen.

### Management of change

At the time of the change, the mine's safety and health management system (SHMS) contained a GRM-HSE-PRO-0028 Change Management Procedure. This procedure stated that "this Management of Change Procedure shall be applied to all modifications or changes associated with Plant and Equipment – Introduction, replacement or modification of plant and equipment". The changes to the external floor wear plates conducted in 2014 should have been subjected to the six-step process for managing change as listed in the GRM-HSE-PRO-0028 Change Management Procedure, but this did not occur. In particular, a risk assessment was not conducted.

### Potential Hazard

The mine's failure to identify potential hazards associated with modifying the original design of the external floor wear plates is likely due to the following:

- The mine did not formally assess the risk associated with modifying the wear plates.
- The mine did not involve technical expertise in assessing the risk associated with modifying the wear plates.
- The mine had an insufficient knowledge or awareness of what could cause a build-up of tension in the large external floor wear plates on excavator buckets.
- **Across the coal industry as a whole there is also generally an insufficient knowledge or awareness of what can cause a build-up of tension in the large external wear plates on excavator buckets.**

## Training and inductions

Goonyella Riverside mine's STD-0016 Hot Work Standard procedure contained a requirement that all personnel who authorise or conduct hot work must be trained and assessed in the following competencies:

- GRM-SOP-290.01 Hot Work
- Permit to Work and Sub Permit Overview
- Hot Work Competency – Relevant Trade Certificate.

Mr Springer's training records provided by the mine showed that he had not been trained and assessed in the mine's GRM-SOP-290.01 Hot Work competency.

Mr Springer did possess the relevant trade certificate required, and had been trained and assessed in the Permit to Work and Sub Permit Review.

## Supervision

The IMS workforce consisted of two boilermakers on each shift working on a continuous four panel roster. The panel crews were individually named A crew, B crew, C crew and D crew.

The mine's maintenance manager and field maintenance superintendent, both stated that the field maintenance shift supervisors were assigned the responsibility of supervising the IMS workings in the maintenance bucket shop on each shift.

Up until IMS commenced work at Goonyella Riverside mine, preventative maintenance supervisors were responsible for supervising the workings in the maintenance bucket shop. This arrangement changed on 21 July 2017 when a preventative maintenance supervisor sent an email to the mine's four field maintenance shift supervisors informing them that they were to supervise the IMS workings in the maintenance bucket shop. The field maintenance shift supervisor for the A crew, was on leave at the time of the incident (he had been away from 18 July 2017). The step-up field maintenance shift supervisor for the A crew did not receive the email and subsequently was not aware that he was responsible for the supervision of work in the maintenance bucket shop. As a result, he did not inspect the maintenance bucket shop and was not aware of the Hot Work Sub Permit and JSA.

There was much confusion about who was supervising the IMS workings on each shift because both the field maintenance shift supervisors and the preventative maintenance supervisors were signing off

various Hot Work Permits and JSAs relating to the work IMS was carrying out in the maintenance bucket shop. In addition, Mr Springer and his co-worker did not attend all the Preventative Maintenance safe start meetings. This irregular attendance may have contributed to the confusion as to who was actually supervising Mr Springer and his co-worker.

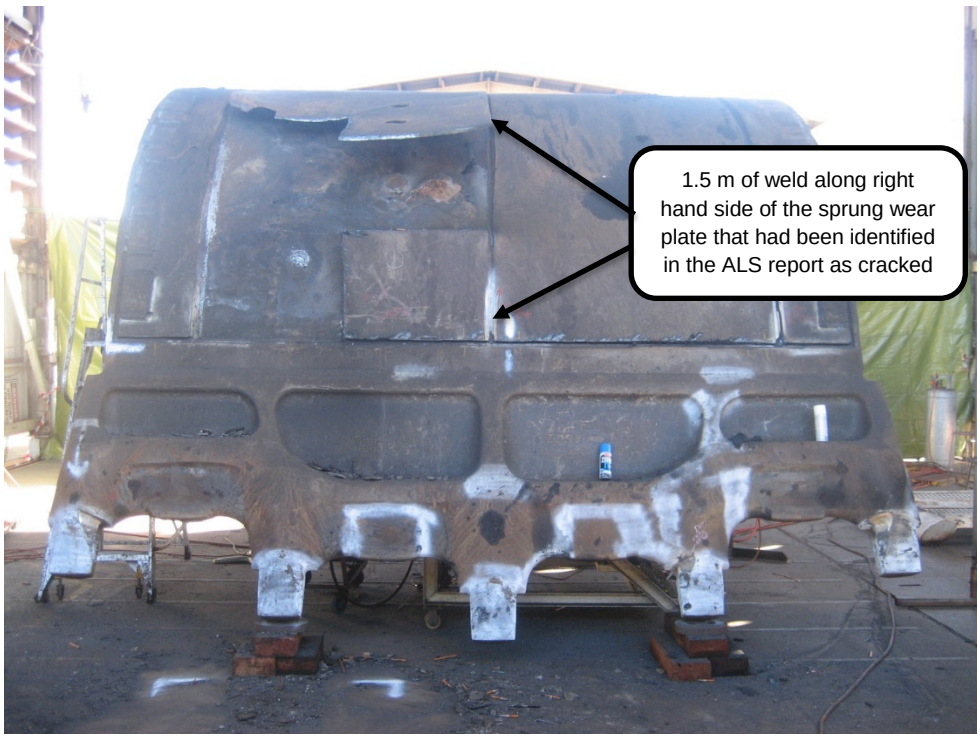
Goonyella Riverside mine was also unable to provide any documented record of the step-up field maintenance shift supervisor having ever been authorised and appointed as a supervisor by the mine's site senior executive (SSE) as required under sections 26 and 56 of the *Coal Mining Safety and Health Act 1999*. Therefore the step-up field maintenance shift supervisor was not authorised to be a supervisor at the mine.

## Planning

There was no documented plan on how the maintenance on bucket #1 was to be carried out. Instructions were given to remove the external heel shoes and external floor wear plates on the bucket, and numerous cracks identified in the bucket had to be gouged out and re-welded. However, it was left to the IMS boilermakers with their trade experience to determine how they sequenced this work.

There was no evidence of whether the bucket's ALS condition monitoring report had been considered when determining the method of removing the external floor wear plates. This report had identified that most of the weld along the right hand side of the left wear plate that Mr Springer was removing at the time of the accident (refer to **Figure 8** below) was cracked. If this had been considered prior to the work being undertaken, it may have meant the sequential method of dissecting the large wear plate into the smaller pieces would have been different.

***Figure 8 - Showing the pre-existing cracked weld on bucket #1***



## Risk assessment

In the hours prior to the accident the co-worker stated that he and Mr Springer had discussed the potential of the wear plate springing out when cutting it, and Mr Springer had commented that he was aware of this and knew to keep out of the way when it was likely to happen. The co-worker stated that they had only expected the wear plate to spring out a short distance of approximately 60 mm, and nothing like to the extent that the wear plate later sprang out (600 to 650 mm). This indicates that Mr Springer and his co-worker were not aware of the extent of the risk associated with the hazard.

Despite consideration having been given to potential kickback, and workers discussing the wear plate springing out, the JSA conducted on the task on 4 August 2017 did not identify the hazard associated with the wear plate springing out.

## Individual/team actions

The co-worker stated that he heard three or four popping noises signalling kickback (springing out) of the wear plates as they were being cut. On each occasion, he received verbal confirmation from Mr Springer that he was okay. Mr Springer continued working indicating that he may have not seen the cracked vertical welds and was not aware of the magnitude of the risk if the large plates sprung back.

## Task/environment conditions

### Proximity to wear plates

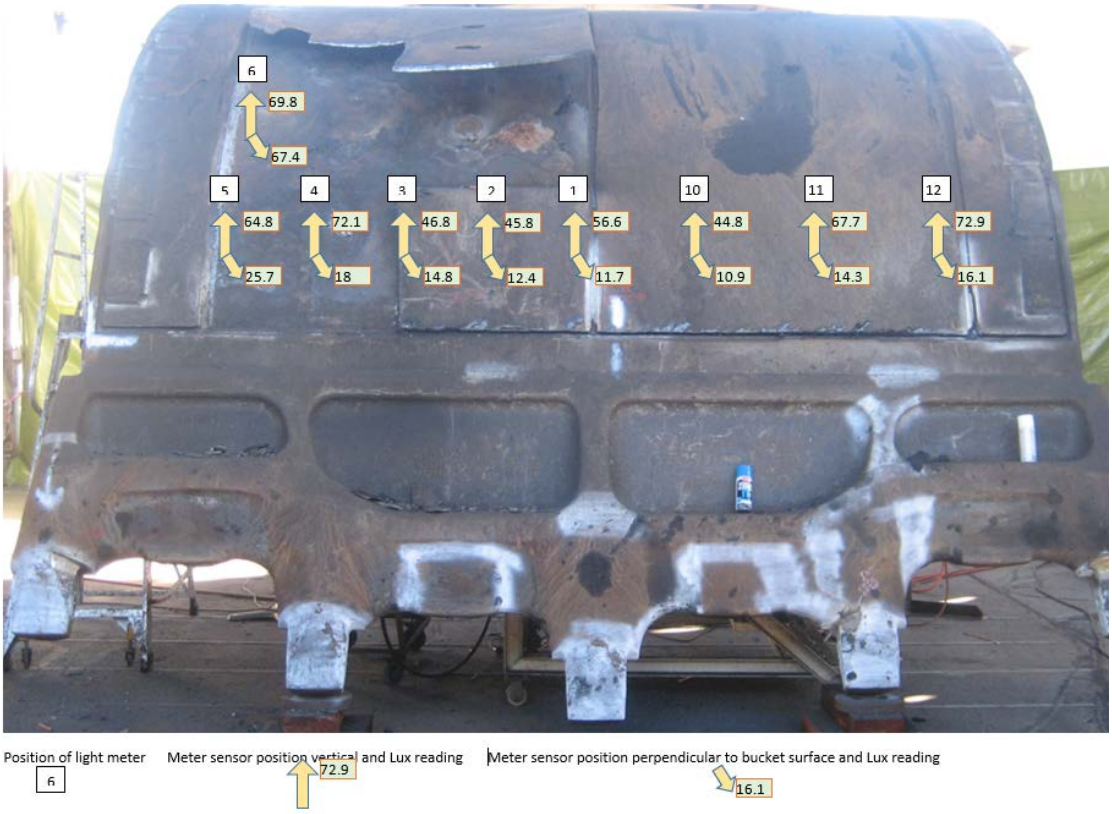
The task of gouging required the worker to be in close proximity to the wear plates. Further investigation identified that the velocity of the wear plates as they sprung back was such that the worker would not have had time to move out of the way.

### Illumination testing

Illumination testing was conducted as part of the investigation to establish if there were adequate lighting for the maintenance work activities. The results show that the levels of illumination in the area where Mr Springer was working on the night of the incident were between 7% and 46% of the minimal level required by AS/NZS 1680.2.4:2017. This may have contributed to Mr Springer not noticing the pre-existing crack in the weld running along the right hand side of the wear plate that he was removing at the time. It is reasonable to consider that Mr Springer may have thought this weld was intact at the time and holding the wear plate in position.

The level of illumination can be attributed to the fact that the bucket Mr Springer was working on was placed at the very southern end of the workshop as seen in **Figure 2** on page 4. This meant most of the permanently fixed lights in the workshop were to the north of the bucket, and none were shining directly onto the side of the bucket that Mr Springer was working on.

***Figure 9 - Positions and results of the lux / illumination testing***




# Safety and health management system

## Standard operating procedures

The mine's SHMS did not contain a standard operating procedure for modifying fixed and mobile plant as required by Section 68 of the Coal Mining Safety and Health Regulation 2017. This section states that a coal mine must have a standard operating procedure for modifying fixed and mobile plant, and also that the coal mine's safety and health management system must provide for the following:

(a) recording modifications made to the plant at the mine
(b) updating drawings of the plant held at the mine to include the modifications
(c) assessing and managing risk associated with the modifications.

The mine had a standard operating procedure (SOP) GRM-SOP-120.01 *Servicing Maintenance and Assembly of Vehicles Plant and Equipment* which referred to the above section 68 of the Coal Mining Safety and Health Regulation 2017. However, the SOP contained no reference to the three provisions listed above as required by the regulation. The SOP simply stated:

*"There is a need to identify critical situations where modification to equipment may affect the safety of persons and/or result in damage to the equipment. Refer to the GRM-HSE-PRO-0028* Change Management Procedure *for guidance on when and how to use change management".*

The GRM-HSE-PRO-0028 Change Management Procedure included a six-step process for managing change and stated that "The extent of the risk management process shall be appropriate to the nature of change as below:

(a) Minor change – BMA Safe
(b) Moderate Change – Job Safety Analysis
(c) Significant Change – Facilitated Risk Assessment".

There was no evidence that this procedure was followed or that any risk assessment was conducted prior to the modification to the external wear buckets.

In addition, the mine was unable to provide any evidence on how the above GRM-HSE-PRO-0028 *Change Management Procedure* was developed, or who was involved in the development of the procedure. There was also no evidence of any risk assessment having been used in the development of this procedure as required by legislation.

## Contractor management

The contract owner of the IMS contract with Goonyella Riverside mine (as listed on 21 July 2017), stated in an interview on 11 April 2018 that he did not believe he was the contract owner, and that a clerical error had been made with the documentation. Therefore there was confusion as to who the actual contract owner for IMS was.

The mine's Contractor Management Plan requires the contract owner to ensure that the contract partner completes and updates, as required, the Contractor Management System (CMS) Checklist to ensure the information is current. The CMS Checklist was completed on 21 July 2017, but was not updated as required. For example IMS had eight employees working at the mine by 4 August 2017, however the CMS Checklist only reflected the three IMS employees who were working at the mine on 21 July 2017.

## Site Senior Executive

The investigation revealed evidence to suggest that the appointed SSE at Goonyella Riverside mine was not the most senior officer employed who has responsibility for the coal mine as required by section 25 of the *Coal Mining Safety and Health Act 1999*. Evidence given by the maintenance manager showed that he did not report to the SSE but to the General Manager of Goonyella Riverside mine.

Since the SSE did not appear to manage the maintenance manager's routine individual development and performance review process, he could not ensure that he had the competencies required to carry out his responsibilities, and that he was effectively carrying his responsibilities as stated in the management structure.

This is contrary to section 55 of the *Coal Mining Safety and Health Act 1999*, which states that the SSE for a mine must develop, implement and maintain a management structure that helps ensure the safety and health of persons at the mine.

# Technical overview

This section provides a summary of the technical analysis that was conducted to determine the causation mechanisms for the spring-back of the wear plate. As part of the investigation, the Mines Inspectorate engaged University of Queensland Materials Performance (UQMP) to conduct a mechanical and metallurgical analysis of the wear plate to understand the incident further. UQMP's findings are included here.

The analysis focused on two conceivable types of causation mechanisms:

- metallurgical and weld cracking issues
- loading and residual stress issues.

Metallurgical testing identified that the material was a tough wear plate, suitable for the component. No hydrogen cracking or embrittlement was found.

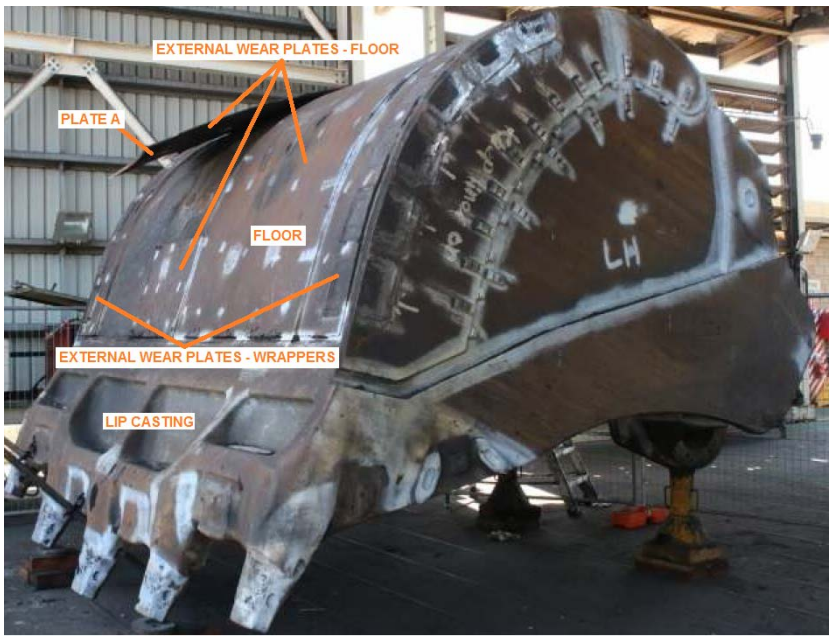
Mechanical analysis showed that the indentation of the wear plates caused during operation led to large residual stresses within the plate. This explains the full amplitude (distance) of spring-back observed in the incident. It also explains the final position and shape of the incident wear plate, including the observed transverse curvature.

## Excavator bucket

Goonyella Riverside Mine uses Terex RH340 excavators to load coal or overburden material onto rear dump trucks for transportation around the site.  The bucket is the part of the excavator that contains the material being loaded.

The bucket has three layers i.e. a structural steel shell with inner and outerwear liners. The external outer floor wear liner (plates) can be seen in **Figure 10**. Plate A is the one involved in the incident.

***Figure 10 - Excavator Bucket***



## Manufacturing

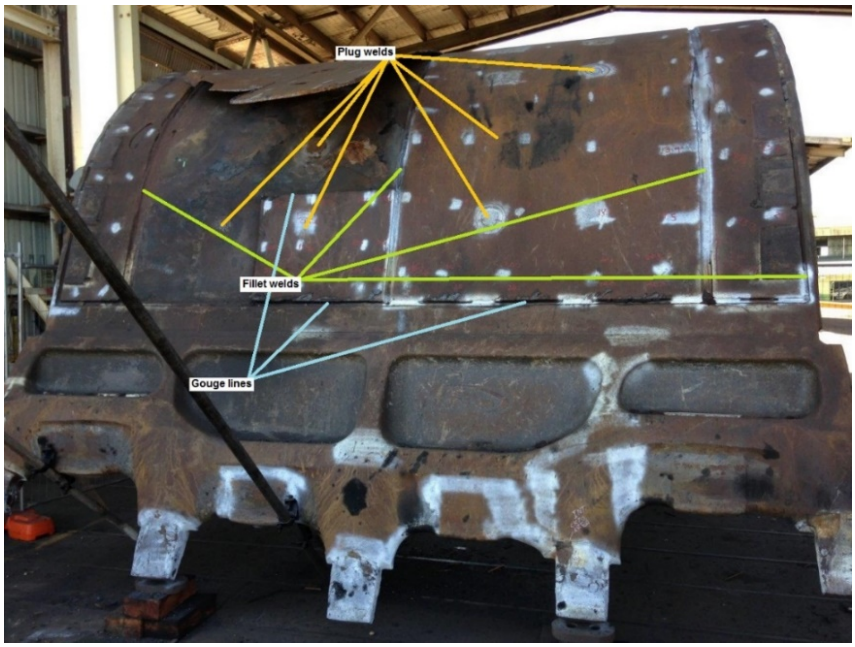
According to the material certificates provided by ESCO, the external wear plate was manufactured by Nippon Steel in Japan to NSSMC Standard 'Abrex 400'. The chemical and mechanical analysis performed by UQMP proved that Plate A conformed to this standard. It was of good quality and suitable for the application. Before assembly, Plate A was bent to fit the profile of the bucket floor.

## Welding

Each of the two external floor wear plates were welded to the basket structural plate in two ways:

- A fillet weld around the outer edges
- 8 x plug welds throughout the central areas (See **Figure 11**)

***Figure 11 - Welding and gouging***




For both the plug and edge welds, the ESCO welding procedure specification (WPS) prescribes that a flux-cored welding process be used with a minimum preheat temperature of 50 degrees Centigrade and an AWS A5.29 E81T1-N1 welding wire. This material is susceptible to hydrogen cracking and the risk is increased if hydrogen containing substances present during welding (either in welding consumables or in parent material) or preheat temperatures are inadequate.

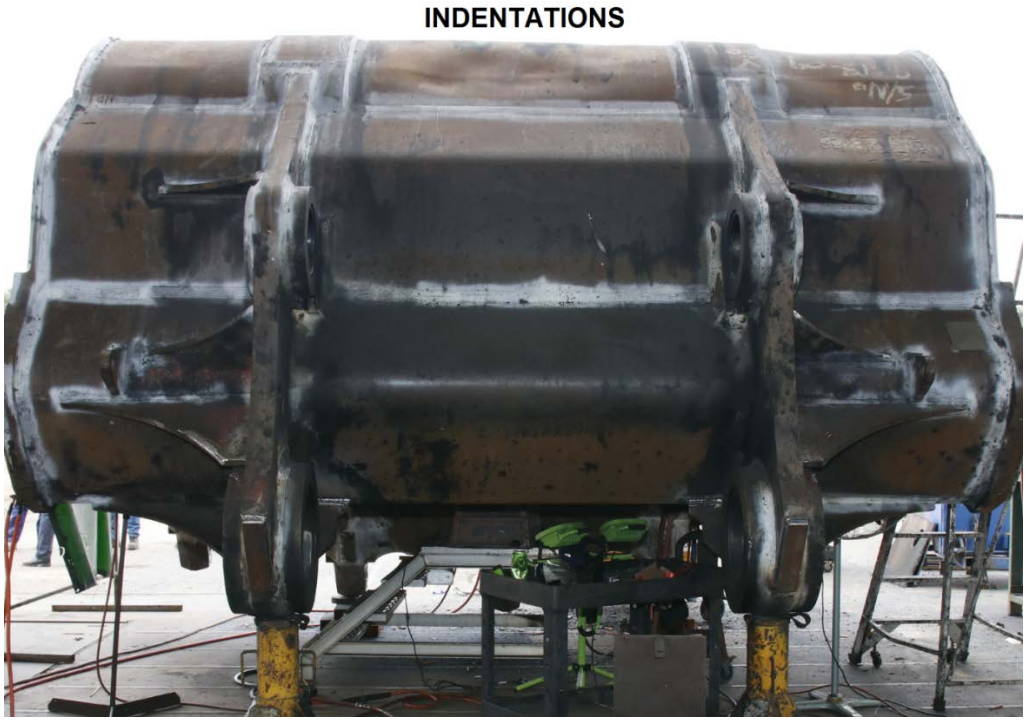
The metallurgical investigation found no hydrogen cracking or embrittlement, which implies that it is likely the essential parameters of the WPS had been followed during the installation of Plate A.

## Condition of Plate A prior to removal

Plate A was indented in at least six areas and was worn unevenly. A wide range of thickness of the wear plate was found from near new to totally worn away. The majority of the plug welds were cracked and were no longer holding the plate to the bucket structure. A large portion of the vertical part of the fillet edge welds were cracked as well. Horizontal welds only showed minor cracking.

Considering the condition and other maintenance work on the bucket, an order was placed with IMS to install a new liner.

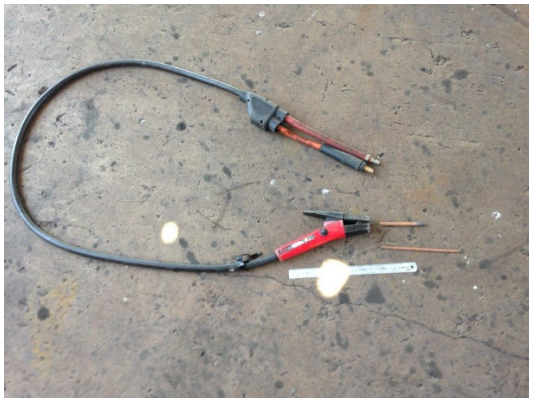
***Figure 12 - Indentation on back wall***



## Removal of Plate A

Before a new outer floor liner could be installed, the existing liner (Including Plate A) had to be removed. It was detached by air carbon arc gouging and removing the welds that were holding it to the basket structure (see **Figure 11).** It was then cut into smaller pieces that could be man-handled.

***Figure 13 - Gouging Plate A for this investigation [(a) Gouging rods, holder, air- and power supply (Scale: Steel ruler is 300mm long); (b) While gouging; (c) After gouging (d) Smaller***



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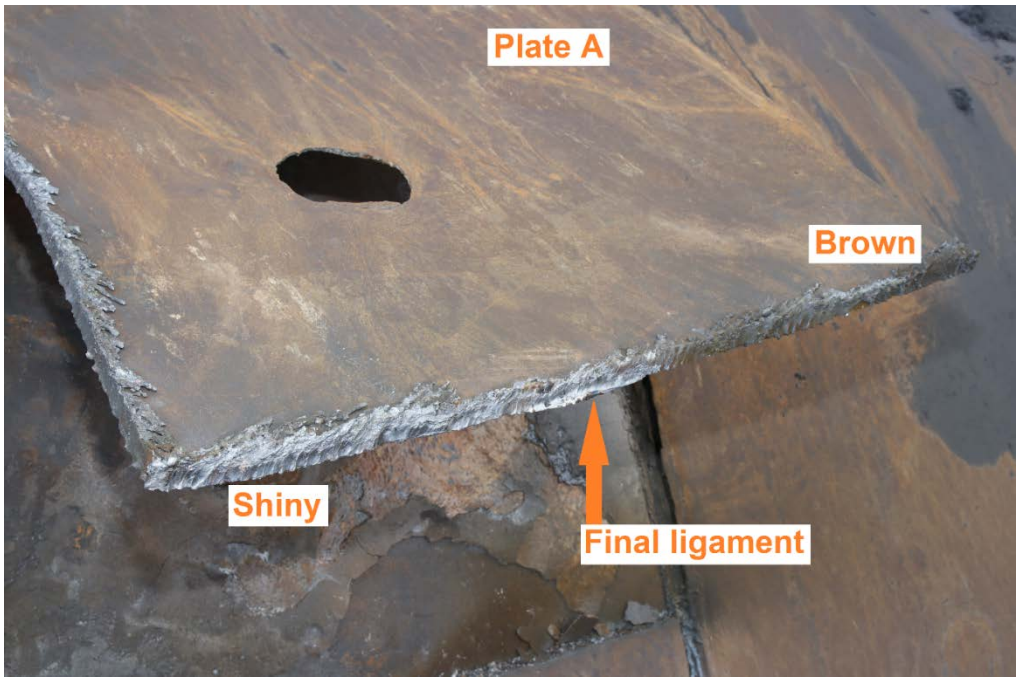
Mr Springer was gouging Plate A horizontally, approximately 1.7 m from the top when it rapidly released and he was struck. Approximately one half of this horizontal gouge line had a shiny, freshly gouged appearance (See **Figure 14**). The other half was brownish in colour and appeared to be coated with gouging fumes and debris. Near the convergence of the shiny and brown areas is a small ligament that hadn't been gouged, but appears to have failed in shear. It is postulated that this ligament was the last to fail before the plate was released.

***Figure 14 - Final horizontal gouge line***




## Cause of damage to Plate A

During operations, the excavator bucket performs various actions such as loosening, collecting and scooping material, which cause indentation in the wear plate. Wear plates are also subjected to abrasive erosion from sliding on the materials that they make contact with. For Plate A, certain areas were subjected to more wear than others.

A number of factors contributed to weld cracking:

- After welding, the heat-affected zone (HAZ) in the parent material, directly next to the weld usually has the lowest strength. The HAZ does not melt during welding, but usually experiences grain growth at elevated temperature, which lowers the tensile and impact strength. This is also the zone where cracking is the most likely. Most of the cracking on Plate A was found in the HAZ.
- Directly after welding, the molten metal solidifies and then contracts as it cools. This contracting weld material causes stress and strain both within the plate and welds. The amount of residual stress from welding was unlikely to be sufficient to cause either cracking or the amount of elastic spring-back that was encountered. It did however add to the overall stress prior to cracking.
- The stresses caused by indentation are by far the greatest cause of both plug and perimeter weld cracking (see discussion below about elastic spring-back from indentations).
- Before gouging, almost all vertical and plug welds on Plate A were cracked. However, the upper and lower horizontal perimeter welds were in better condition and sufficient to hold the plate in position, despite considerable residual stresses. Due to the curvature of the plate as well as the positioning of indentations, larger stresses were applied to the vertical welds and plug welds than the horizontal welds. This resulted in the vertical and plug welds failing earlier.

## Elastic spring-back

To determine the reason for the magnitude of elastic spring-back observed from plate A, a number of factors were considered and are detailed below.

### Misshape

The possibility of misshape was considered i.e. in preparation for fitting, Plate A was either flat or bent to a different profile than that of the basket structure. If this was the case, the plate would have been forced in position by a method such as dogging and wedging. Once in position, it would have been welded to the basket structure. After fitment and welding it would have remained in a strained condition.

It was concluded that misshape was not a major contributing factor to the elastic spring-back that caused this incident because:

- UQMP's investigation found that it was improbable that misshape was a major contributing factor.
- ESCO, the company that refurbished the bucket in 2014, sub-contracted the bending of floor wear plates. Any that were not formed to the required profile were not accepted, due to the additional effort required by ESCO for fitting, dogging and welding it in position.

### Spring-back due to wear

When the wear plate was bent to the profile of the bucket floor, the outer surface was stretched, and the inner surface compressed. The material was deformed, both elastically (returns to original position once released) and plastically (permanent). Once the elastic strain had been released, the residual stresses from the plastic deformation remained. These residual stresses maintained the shape of the plate.

During operations, the outer (stretched) surface of the plate was worn away. Consequently, if unconstrained, the plate radius would have increased during the initial phases of the plate wearing away. This means that the plate would have tended to straighten out. Finite element analysis (FEA) showed that beyond 7 mm of wear, this effect reverses, i.e. the plate returns to a bent profile.

The wear plate was however constrained by the plug and edge welds. Once the final horizontal gouge line released the plate, there was no more constraint. It resulted in a tendency for the plate to have some level of elastic spring-back.

This effect may have been a contributor, but is insufficient to explain the total amount of spring-back of approximately 600 to 650 mm. At most, spring-back of about 120 mm can be explained by this mechanism.

### Indentation

Operational impacts and indentations affected the strain and resulting stresses in Plate A in a number of ways:

- The indentations bent the plate in the opposite direction than the profile bending. Where the magnitude of indentation was sufficient, the material yielded in the opposite direction, effectively cancelling or reducing the residual stresses needed to maintain the plate profile. This contributed to elastic spring-back potential.

- Where the impact was severe enough to cause yielding, the plate permanently elongated (stretched) on the opposite side of where the impact had come from. The elongated material tended to lift up the plate and contribute to elastic spring-back.
- Multiple, overlapping indentations may have had a cumulative effect, depending on their relative positioning.

Indentation is the single largest contributor and can by itself explain the observed 600 to 650 mm of elastic spring-back.

### Dirt ingress

During operations, dirt entered the space between the structural plate and Plate A after some of the welds had cracked and after Plate A had worn through. The process of dirt entering was accelerated by the actions of the excavator. Note that the dirt did not contribute to the initial cracking of the plate.

Impact tests done in the laboratory showed that a substantial impact will indent a plate, whether it is back-supported by a soft material, a hard material or not supported at all. A soft backing will cause more indentation than a hard backing for the same impact.

Similarly, once dirt entered the space between the plates (soft backing), Plate A indented more than when it was directly backed by the structural plate (hard). The increased level of indentation increased the level of elastic spring-back potential.

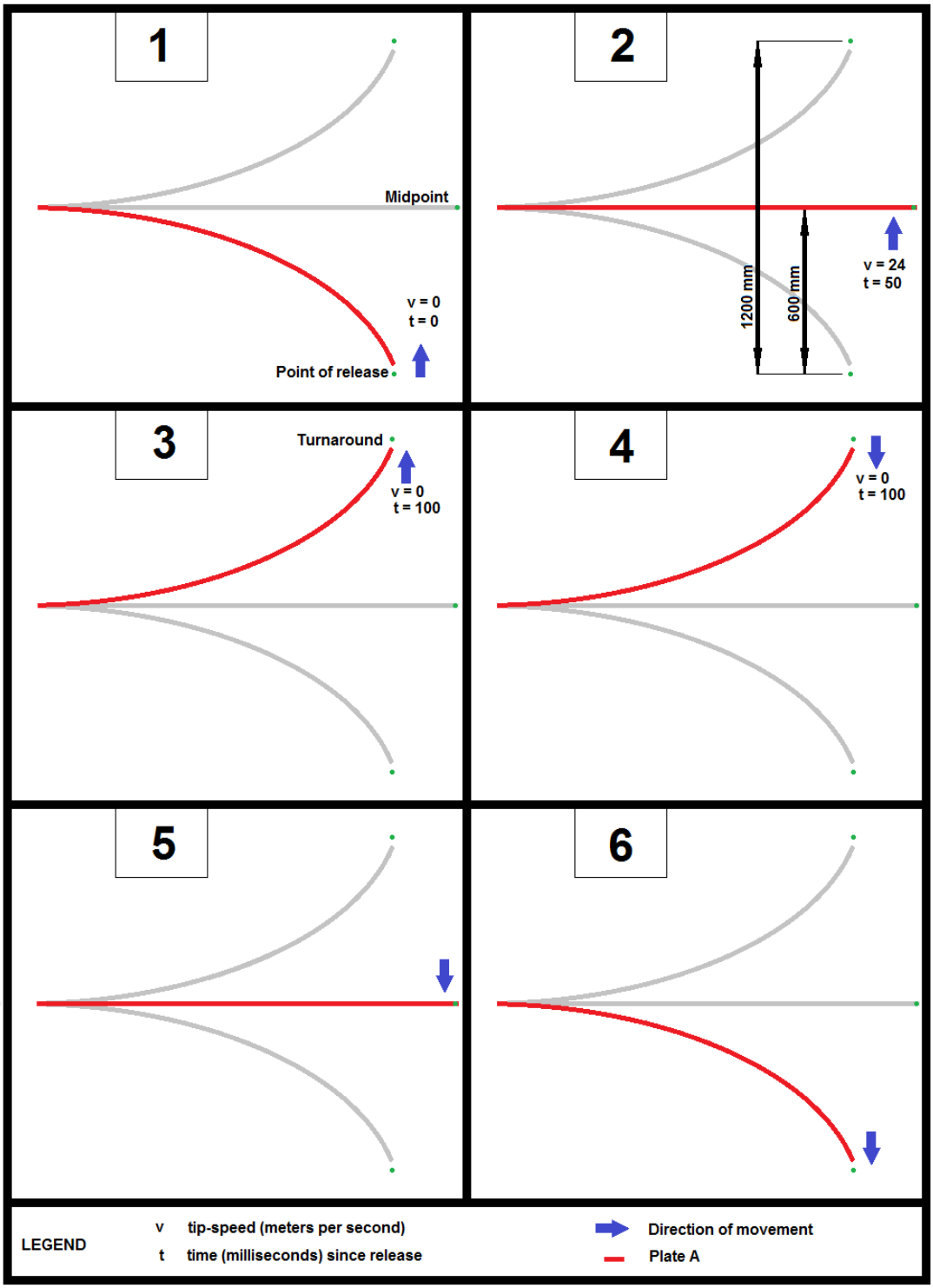
## Plate movement

### Danger zone

Directly after release, the lower horizontal edge (tip) of the plate moved upwards to a position approximately 1200 mm above the point of release. It then stopped and returned to almost the same position where it had been released. The cycle repeated a number of times as shown in **Figure 15**. The amplitude gradually decreased with each cycle until it stopped at a midpoint approximately 600 mm from the point of release. This midpoint is the approximate position where it was found after the incident.

The distance is much higher than the expected distance predicted during the risk assessment.

***Figure 15 - Plate Movement***




## Reaction to plate release

During the first cycle, the tip moved from the point of release to the midpoint in approximately 50 milliseconds. The average human reaction time to a visual stimulus is approximately five times that at 230 – 250 milliseconds. This indicates that it would have been impossible for a person to move out of the way once the plate sprung back.

### Severity of hazard

The severity of the impact experienced by the worker in this incident was estimated to be approximately four times greater than the nominal survivable head impact as determined by the head injury criterion (HIC). This demonstrates the severity of the hazard, with significant risk of fatal injury from plate spring-back.

# Conclusions and recommendations

## Causal factors

The investigation determined a number of causal factors:

- Goonyella Riverside mine conducted modification to the excavator buckets in 2014 without performing a risk assessment as required in GRM-HSE-PRO-0028 *Change Management Procedure*. While it is possible that the magnitude of the risk may not have been identified by the risk assessment alone, it would have given the best possibility of identifying the hazard.
- The design for the external wear plates was changed from the Original Equipment Manufacturer (OEM) design using multiple smaller plates to two large plates, which increased the capacity to store tension and resultant spring-back.
- The mine had insufficient knowledge of what could cause a build-up of stored tension in the large external floor wear plates and did not recognise the potential for the wear plate to spring back.
- Across the coal industry as a whole there is generally an insufficient knowledge of what can cause a build-up of tension in steel plates such as these surface wear plates.
- There was no documented plan for the removal of the wear plates.
- The work group discussed the risk of potential plate spring-back but did not understand the level of risk and did not include it in the JSA.
- The level of illumination in the work area did not meet the requirements of the Australian Standard. It is possible that Mr Springer did not see the cracked vertical welds which may have resulted in changed working practice in performing the repair task.
- The task of gouging required Mr Springer to be in close proximity to the stored energy source. Spring-back occurs faster than human reaction time. He was therefore unable to move away when the spring-back occurred.
- The spring-back event resulted from the sudden release of stored energy and residual stresses that were present in the wear plates prior to the incident. Mechanical analysis showed that the indentation of the wear plates caused during operation led to large residual stresses within the plate.

## Other related findings

The investigation also identified a number of related findings:

- Mr Springer had not been trained and assessed as competent in *Standard Operating Procedure* GRM-SOP-290.01 Hot Work as required by the mine's GRM-STD-0016 Standard for Hot Work.

- There was confusion as to who was supposed to be supervising the IMS activities. The step-up field maintenance shift supervisor did not believe he was responsible for supervising IMS on day shifts Monday to Friday, so therefore Mr Springer and his co-worker had worked unsupervised for their first two-day shifts.
- Goonyella Riverside mine was unable to provide any documented record of the step-up field maintenance shift supervisor having ever been authorised and appointed as a supervisor by the mine's SSE as required under sections 26 and 56 of the *Coal Mining Safety and Health Act 1999,* so therefore the step-up field maintenance shift supervisor was not authorised to be a supervisor at the mine.
- Mr Springer and his co-worker never attended a safe start meeting at the beginning of their day shift on 3 August 2017.
- The mine's SSE did not appear to be the most senior person employed or otherwise engaged by the coal mine operator who had responsibility for the mine as required by section 25 of *Coal Mining Safety and Health Act 1999*.
- The mine's management structure did not state the competencies required for supervisors as required by Section 55 of the *Coal Mining Safety and Health Act 1999*.
- The contract partner, IMS, did not keep the contractor management system checklist up to date as required.
- There was confusion as to who was the contract owner for the IMS contract.

# Recommendations

## Recommendation 1

Excavator buckets: It is recommended that multiple smaller wear plates are used in an alternative wear package. (See **Figure 16**). This design is consistent with the OEM design and is safer because the elastic spring-back potential is much lower than for the large wear plate design used in the incident bucket.

***Figure 16 - Alternative wear package with lower elastic spring-back potential***

## Recommendation 2

Other equipment: The hazard of elastic spring-back is not limited to excavator buckets.

Since the incident, anecdotal- and other evidence found from similar operations highlighted the hazards associated with plate structures that had been indented. A range of equipment types were involved. The common factor for all was that plate material had been plastically and elastically deformed during operations, resulting in residual stresses that later released violently.

Incidents included:

- In two similar but separate incidents, workers were struck whilst removing indented sections near the rim of rear dump truck trays. Injuries occurred.
- Violent elastic spring-back was observed during the removal of an under-tub wear plate from a dragline. The plate had probably been indented when the dragline was walked over an uneven surface.
- A worker was struck on the head when a wear strip on an excavator bucket sprung out whilst he was gouging a weld that attached it to the bucket.
- A worker was hit whilst he was removing a wear liner (push pad) from a dozer blade.

It is recommended that the above be considered before indented plate sections from any equipment are cut for removal.

## Recommendation 3

All mines to ensure that they have a procedure within their SHMS that requires an effective risk management process to be carried out on any modification being made to plant and equipment prior to the modification being carried out.

### Recommendation 4

If a modification to plant and equipment is changing the OEM's design the above procedure must require the mine to consult with the OEM and / or an appropriate technical expert, such as an expert in materials and metallurgical engineering, prior to the modification being carried out.

## Actions taken by DNRME after the accident

### MRE and Directives issued to Goonyella Riverside Mine

At 07:30 pm on 5 August 2017 the lead investigator issued the SSE of Goonyella Riverside Mine with a Mine Record Entry containing two Directives which stated the following:

- The mine is to suspend all work relating to the removal and / or replacement of liner / wear plates on earthmoving equipment buckets. The mine is to also review the safety and health management system for this type of work to ensure the level of risk is at an acceptable level.

### Mining Safety and Health Newsflash issued to industry

On 7 August 2017 a Mining Safety and Health Newsflash was distributed to all surface coal mines in Queensland. This newsflash highlighted the following aspects:

1. Drew attention to the occurrence of a serious incident in the mining industry
2. Increase Risk awareness
3. Promote mines to examine and check that their controls are adequate

### Postal Mine Record Entry and Directive to industry

On 7 August 2017 a Postal Mine Record Entry and Directive was sent to all operating surface coal mines in Queensland requiring the following to be conducted:

The mine's site senior executive is to have elements of the safety and health management system that relate to the removal and replacement of wear / liner plates on earthmoving equipment (buckets, truck trays, dozer blades etc.) reviewed so as to ensure that the risk is at an acceptable level. The mine must also have documented evidence of this review having been completed.

### Safety Alert to industry

On 22 September 2017 a Safety Alert #347 "Fatal injuries to coal mine worker performing maintenance work on a large excavator bucket" was published on the DNRME's website and distributed to the Queensland coal industry. This safety alert provided some information on how the incident occurred, and also made the following recommendations to coal mines:

- Review the safety and health management system including the following:
    1. Review any procedures for the identification of stored energy situations
    2. Review any standard operating procedures and associated controls for hot work, cutting and welding
    3. Develop specific work instructions for dealing with similar wear packages
    4. Ensure any permit systems include controls for stored energy hazards
    5. Ensure 'line of fire' is identified
    6. Ensure tasks that may identify critical hazards are fully assessed by appropriate persons

- Make persons aware of the potential extent of the stored energy hazard carrying out similar tasks
- Review and assess the potential risk associated with the different types of wear packages fitted to buckets
- As part of bucket repair tasks ensure previous repair history is assessed prior to commencement of work
- Conduct comprehensive non-destructive testing to identify condition of bucket and include findings in task assessment