Enhancing an investigators tool kit – 4 forgotten analytical tools

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Abstract

Conducting effective incident investigations forms a critical part of the actions taken by organisations to enhance the safety of their employees and promote ongoing learning. Comprehensive evidence collection and application of effective analysis tools is integral to developing recommendations that will reduce the likelihood of repeat incidents. Although there is guidance around how to identify and effectively collect evidence, there is limited direction around the identification and application of appropriate analytical tools. This paper starts to address this gap. Whilst there is a number of commercial analytical tools available to investigators there is also a range of readily accessible analytical methods that can form an effective part of an investigators tool kit.

Introduction

This paper will explore a number of publicly available analytical tools that investigators can use to examine an incident. It will provide guidance on how to apply the most appropriate tool or tools, explore what they can or cannot tell us, and consider their strengths and limitations. The Upper Big Branch Underground Mine Explosion has been sued as a case study to show how to use these tools. The primary resource for this work is the Mine Safety and Health Administration investigation report. Please note, the paper does not re-investigate the incident, nor focus on the conclusions and recommendations generated by the original reports.

Upper Big Branch – Underground Mine Explosion

The Upper Big Branch Underground Mine Explosion occurred on the 5th April 2010. A comparatively small methane explosion occurred in the presence of float coal dust and coal dust generating a massive explosion that killed 29 underground miners and injured two. The investigation determined that the original ignition started at the longwall 21 shearer, travelled to the goaf of longwall 21 where additional methane had accumulated and generated a methane explosion. This explosion occurred in the presence of float coal dust and coal dust that then generated the massive explosion. More than 20 rescue teams worked to locate and rescue the miners and it was not until the 9th of April that all miners were found. It took several attempts to retrieve the dead miners, the last being returned to the surface on the 13th of April. It was approximately 24 hours after the incident that the correct number of missing miners was determined.

Upper Big Branch Mine consisted of 4 active areas: the 21 longwall, headgate 22, tailgate 22 and the barrier section (room and pillar). The largest section of the mine had previously been mined and sealed off. Figure 1 displays the location in the mine where the incident began and where the explosion forces travelled.

The MSHA investigation identified several mine site activities that contributed to the incident. The predominant activities are included only. These were activities that promoted and enforced a production over safety culture. Miners reported being intimidated by management to not raise or address safety concerns or their jobs would be jeopardised. The approved ventilation plan for preventing unsafe levels of methane (and other dangerous gasses) and provide breathable air was not complied with. Ventilation practices led to erratic changes in air flow volumes and airflow direction. The approved roof control plan was not complied with. Installation of supplemental roof supports was not undertaken leading to a roof fall in an airway limiting air airflow. Furthermore the investigation determined that significant amounts of float coal dust, coal dust and loose coal were permitted to accumulate in the mine. Finally, there had been 3 previous gas related incidents – 1 non-fatal ignition / explosion, and 2 gas inflow incidents.

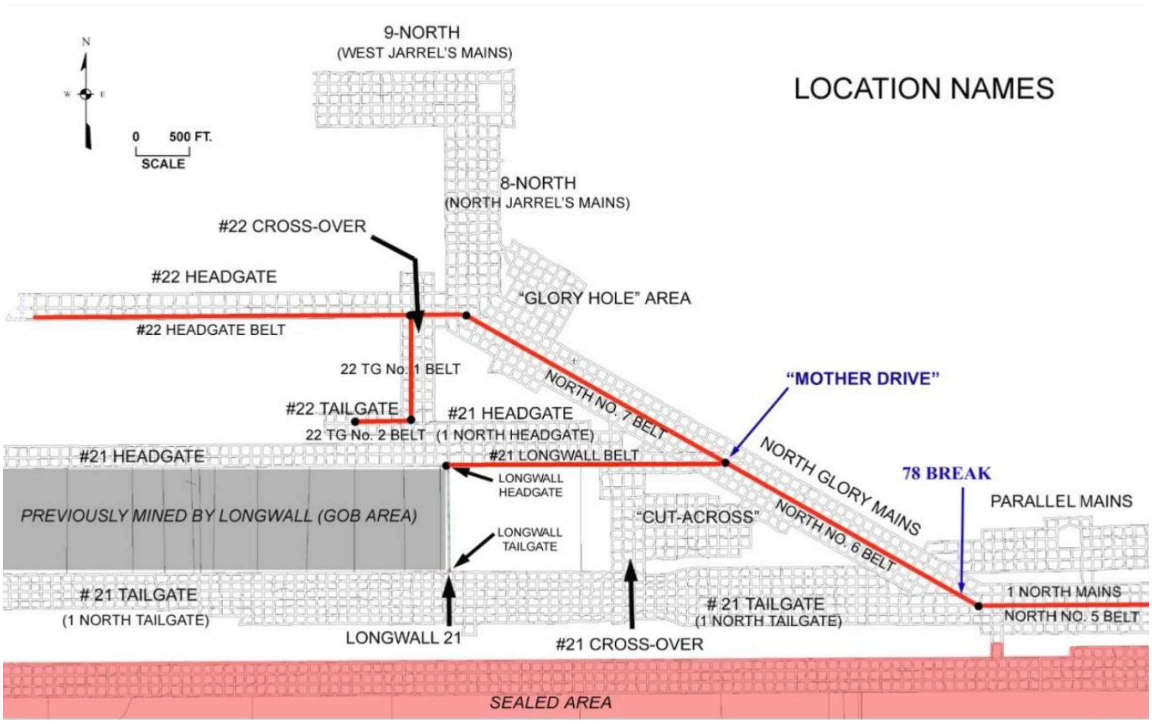

Figure 1: Map showing (West Virginia Office of Miners' Health Safety & Training (2012). Report of Investigation into the Mine Explosion at the Upper Big Branch Mine April 5 2010; p.2).

The next section will use evidence and findings primarily from the MSHA investigation report and apply several analytical tools. Please note there may be differences in the examples provided in the paper and in the presentation due to paper length limits.

Application of Analytical Tools

The Upper Big Branch Mine explosion was used as the case study because the investigation conducted was extensive, large amounts of evidence was collected and analysed, and the report was publicly available. Based on my review of the MSHA report I identified four tools that once applied had the potential to expand our understanding of the Upper Big Branch Mine explosion. The selected tools were the sequence of events chart, events and conditions chart, bow tie analysis and Accimap. The paper begins with the application of a sequence of events chart using the information available in the investigation report. As the paper progresses the tools increase in complexity. This reflects the increase in information that becomes available as an investigation progresses, learnings generated from the previous tools, and the complexity of the issues that require understanding during the investigation.

Sequence of events chart

Sequence of events charts are a practical place to start to understand an incident and can begin shortly after commencing the investigation. They generate a detailed timeline that captures the key pre-incident events, the incident itself and extends to post-incident events. Developing a sequence of events chart can start shortly after the incident occurs. As the investigation proceeds it becomes more detailed as evidence becomes available. It is useful for identifying gaps or inconsistencies in the evidence. Over time these gaps may resolve themselves. Where they don't the investigator can source additional information. For example, the number of miners underground at the time of the incident varies across the first 24 hours after the incident. It was not until the next day that the number of missing miners was determined. This provides valuable information about miner tracking activities and what further enquiries the investigation team need to pursue. Another example is the evacuation of underground miners after the incident. Two mining teams exited the mine up to an hour after the incident not having been notified. This provides valuable information about evacuation practices.

Sequence of events charts can be used to generate follow-up questions, identify conflicting details in the timeline, and identify additional evidence that needs to be collected. When applied thoroughly the sequence of events chart can communicate to the reader key events that occurred during the incident. However, it does not provide information on why the incident occurred. In order to understand the 'why', other analysis tools are required. See Figure 2 for a worked sequence of events chart.

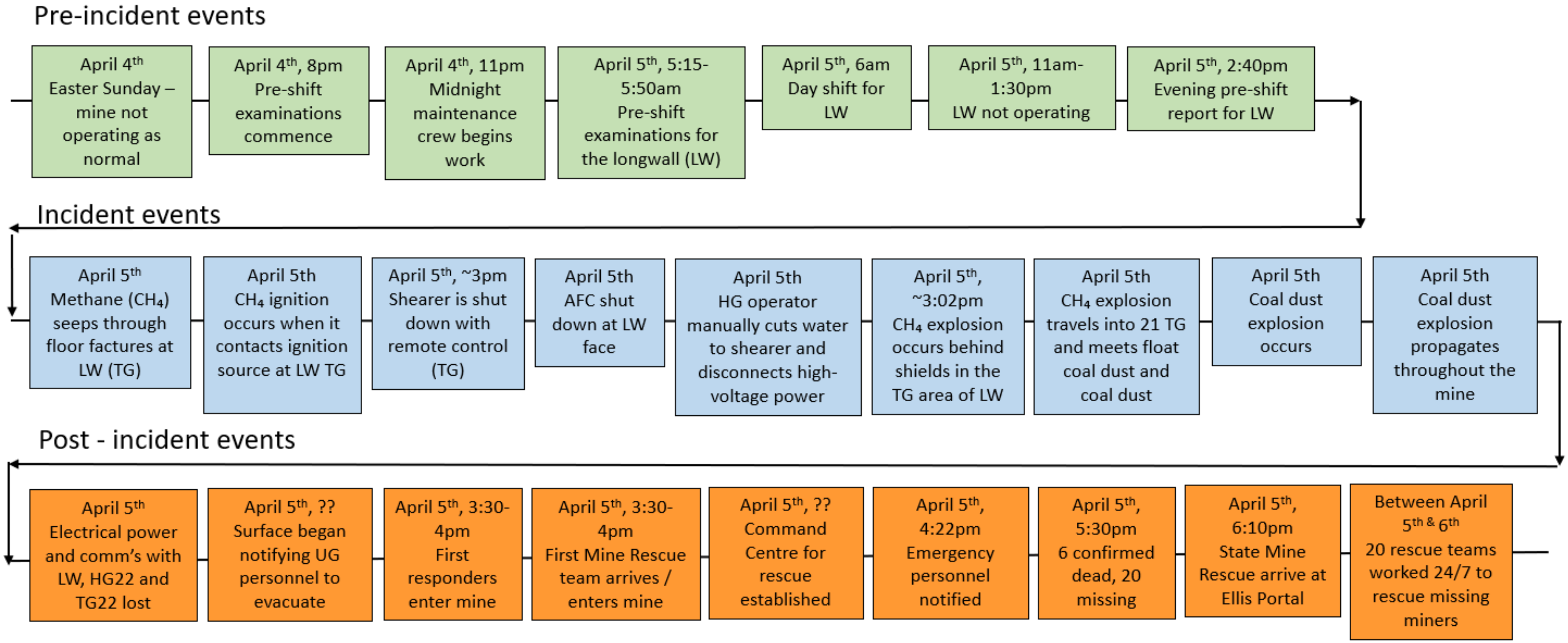

Figure 2: Proposed sequence of events chart for the Upper Big Branch Mine incident.

Events and conditions chart

Events and conditions charts were developed to enable investigators to focus on why operators took the actions they did and why operators believed these actions would result in successful performance. Data is captured on the operators' work objectives, and the knowledge and information they had at the time for making decisions. Events and conditions charts firstly display the incident timeline from pre-incident and incident, through to post-incident. The decisions made by the operator prior to their actions are captured. Finally, links between those decisions and the knowledge the operator had at the time, their objectives, and where their focus was at the time of the decision is portrayed. Investigators are then able to identify the workplace and organisational factors that influenced operators' decisions. Figure 3 shows an events and conditions chart for the Upper Big Branch Incident.

When applied to the Upper Big Branch case study the investigator can explore why events occurred. For example, why the methane ignition occurred? One pathway explores why gas monitors did not detect a methane concentration between 5 and 15%. Handheld gas monitors were not used as required by miners, and the airflow around the shearer directed air under the gas monitor not over it. Another pathway focuses on why gas monitoring at the tailgate did not detect a potential pool of methane. Gas monitoring was not being done at the tailgate as access had been restricted due to roof falls. Events and conditions charts can be used to look beyond the errors operators made during an incident and to identify what factors influenced their decisions. By identifying the links or relationships between relevant events and conditions, investigators are able to identify the workplace and organisational factors that impacted operator decisions. In addition, where a sequence of events chart has been generated it can be useful to compare the two and identify any differences. Discussion can then occur to determine why such differences exit. Whilst events and conditions charts identify the actions people performed and why those actions were believed to meet task objectives, it does not specifically focus on other controls that were, or were expected to be, in place at the time.

Bow Tie Analysis

Bow tie analyses are used for identifying and reviewing controls that are designed to prevent and mitigate the causes and consequences of an unwanted event. Traditionally used for risk management, investigators that use the bow tie tool for incident investigation, can capture the controls that were intended to prevent each specific cause from generating the unwanted event. They can also capture the controls the organisation had in place to prevent each of the actual outcomes or consequences. In this incident there were five outcomes. One of which has been explored, 'employee injury and / or fatality'. Figure 4 shows the bow tie analysis applied to the Upper Big Branch Incident.

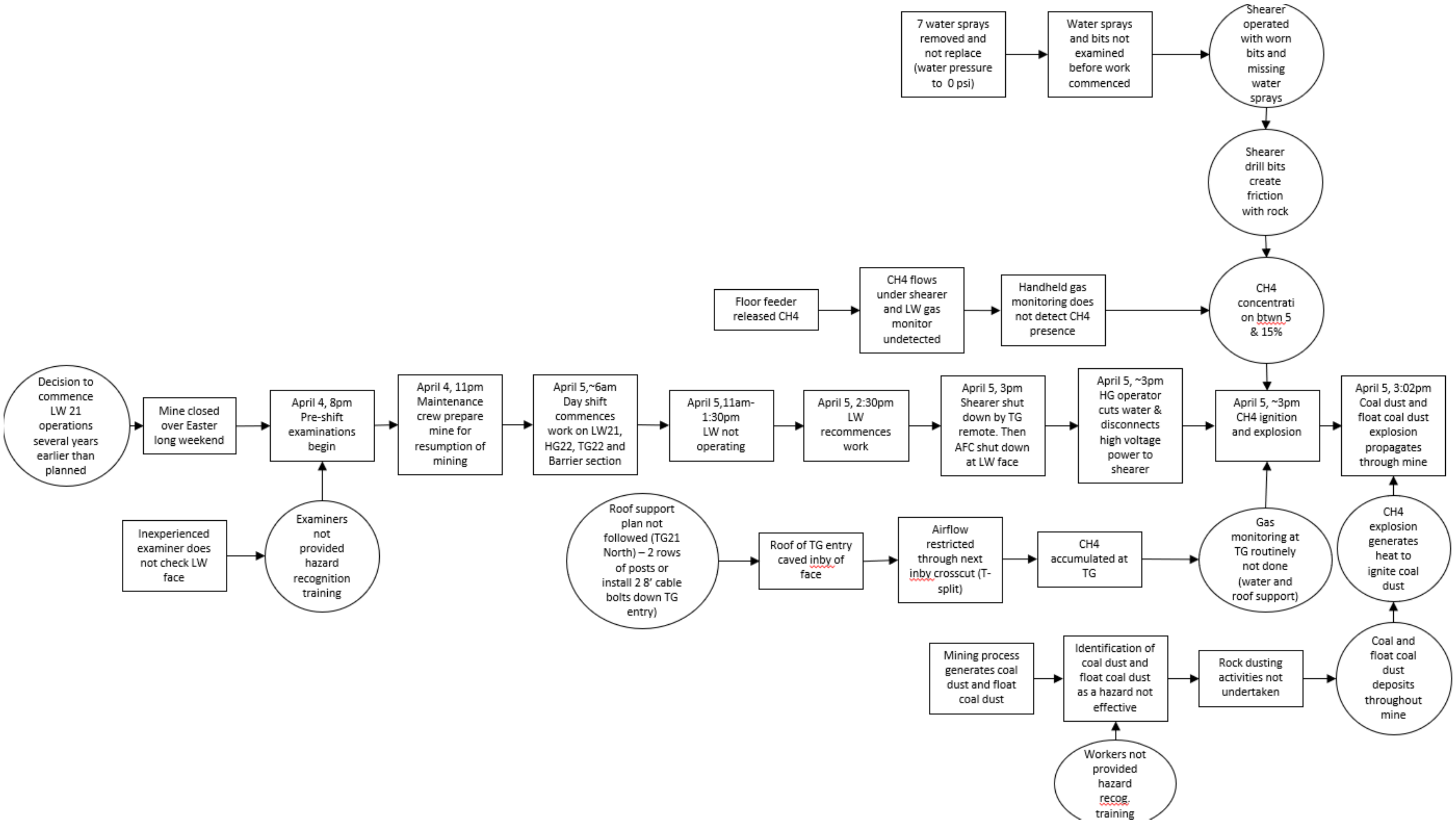

Figure 3: Proposed events and conditions chart for the Upper Big Branch Mine incident

When applied to the Upper Big Branch incident the investigator can focus on what controls were in place to prevent explosive methane levels presenting with an ignition source. If we focus on the cause 'ignition source', there are three controls to prevent it from meeting explosive methane levels. If we focus further on the control 'water sprays on shearer drum…', the investigator can determine how effective the control was. In this incident seven sprays had been removed from the drum and water pressure had been reduced to 0 psi.

Once the controls an organisation expects to have in place at the time of the incident are identified, the investigator can focus on assessing how effectively they performed. They can then determine what factors impacted each controls' performance. Where organisations have previously conducted bow tie analyses as part of their risk management activities for that unwanted event, it can be used to determine whether the expected controls were implemented, available and effective (both as controls and their ongoing maintenance). Investigators are then able to determine whether gaps existed in the controls. They can then use this information to develop recommendations to prevent similar incidents in the future. When there is a secondary event, as was the case with the Upper Big Branch incident, a second bow tie is necessary to explore its specific preventative and mitigation controls as it cannot be undertaken in the same analysis. Limitations exist with the bow tie tool as it doesn't handle complex inter-relationships between causes, therefore, the investigator will need to undertake further analysis.

Accimap

Jens Rasmussen first developed Accimap to graphically map the events and decisions that occurred across all sociotechnical levels of an organisation that contributed towards an incident. The strength of this tool is that it recognises that organisations do not function in a vacuum and are influenced by the decisions made by external bodies such as governments and regulators. Accimap also clearly displays the inter-relationships between each of the levels. For system safety to be achieved, decisions at the higher levels of an organisation need to transfer down the hierarchy and be reflected in the decisions and actions that occur at lower levels in the organisation. Conversely, critical information about how the system is functioning needs to transfer up the hierarchy to inform decisions and actions that occur at the higher levels of the organisation. The Accimap graphically displays the decisions and actions that contributed to the incident across all sociotechnical levels. It displays how these actions and decisions either influenced and/or were influenced by activities across the other levels. This enables investigators to identify where these inter-relationships are and promotes greater understanding of their influence on system safety. Figure 5 shows the worked Accimap. Please note for this article only the preventative risk controls for the methane ignition have been included. The risk control for the second incident, float coal and coal dust explosion, have not been included to simplify the figure.

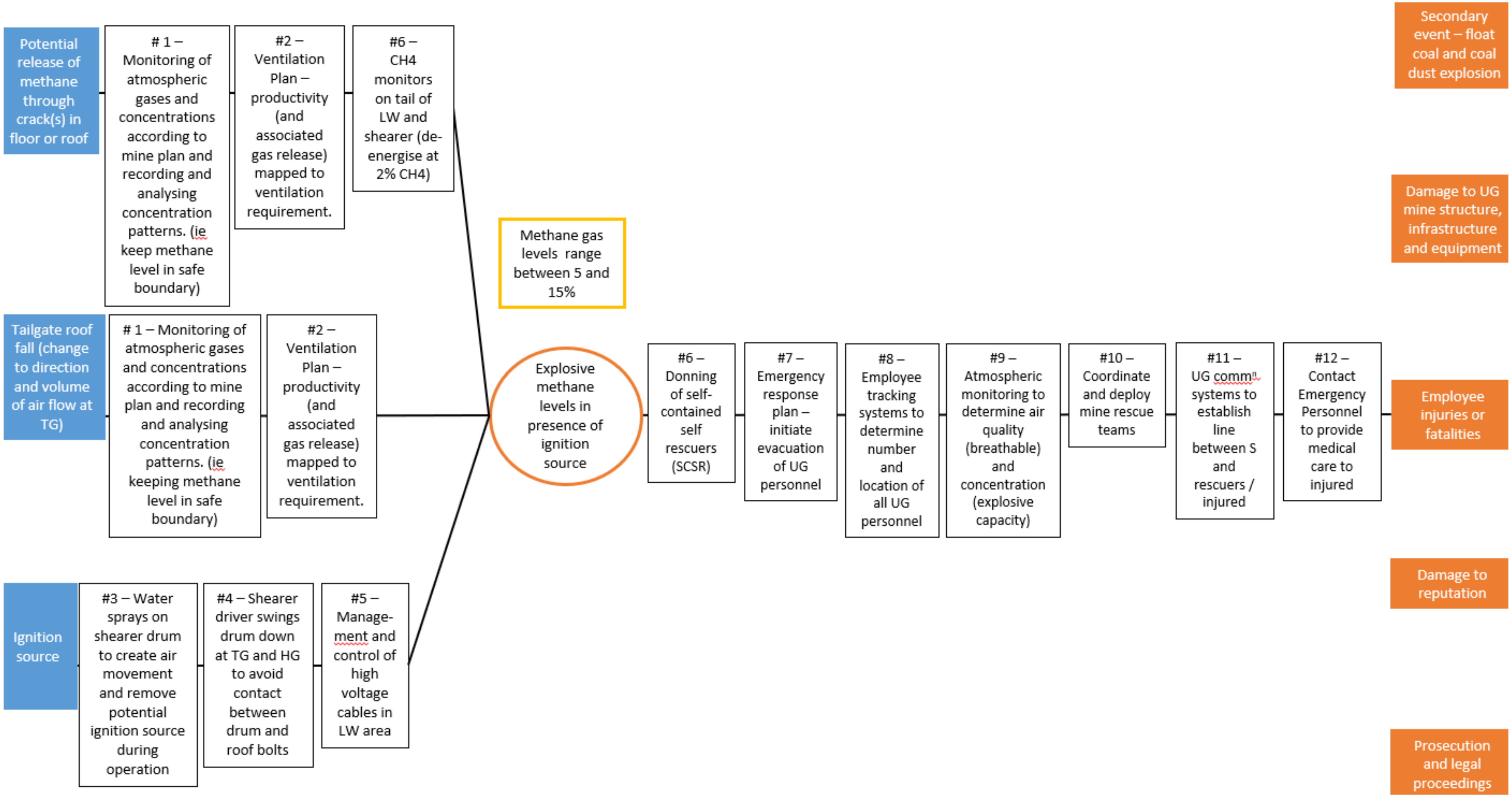

Figure 4: Bow tie analysis for the Upper Big Branch Mine incident

When applied to the Upper Big Branch incident, the Accimap identifies several important decisions / actions that have an influence across several levels of the organisation. For example, 'senior management's commitment to production over safety'. This decision impacts the implementation and ongoing effectiveness of several risk controls, develops a work place where bullying and intimidation are routine and impacts the activities that are undertaken to ensure safety, and finally has an impact on the decisions and actions made by the miners.

The levels for analysis are also intended to be flexible. For example, the original framework did not include a layer for risk controls however I have included here. The inclusion of the risk control level enables the investigator to identify where in the organisation the decisions and actions have (or have not) been made that identify the need for each control and generation of resources for procurement. This is also where the power is to ensure control implementation and ongoing maintenance, as well as assessments to ensure controls are working as intended and continue to prevent / mitigate unwanted events over time. To effectively undertake an Accimap, significant time is required. It is also best undertaken within a team so discussions between members can generate deeper understanding of the incident.

Discussion

This paper has introduced a number of analytical tools that can be used to supplement existing incident investigation processes. They are designed to assist the investigator to better understand the incident and identify areas where additional evidence requires collection. Sequence of events provide a graphic way of communicating to others what happened in an incident. Events and conditions charts extend this knowledge to include insight into why the actions of operators were performed. Bow ties can focus the investigator on the controls designed to prevent and mitigate the consequences of an unwanted event. Finally, the Accimap identifies the decisions and actions that contributed to the incident across all levels of the organisation. It can also be used to focus on the decisions that influenced the implementation and ongoing effectiveness of risk controls designed to prevent incidents. There is no right or wrong tool as such. Some tools will provide more useful output than others and this is influenced largely by the nature of the incident. Each can provide a different perspective on the incident and assist the investigator understand the incident and therefore guide the development of recommendations.

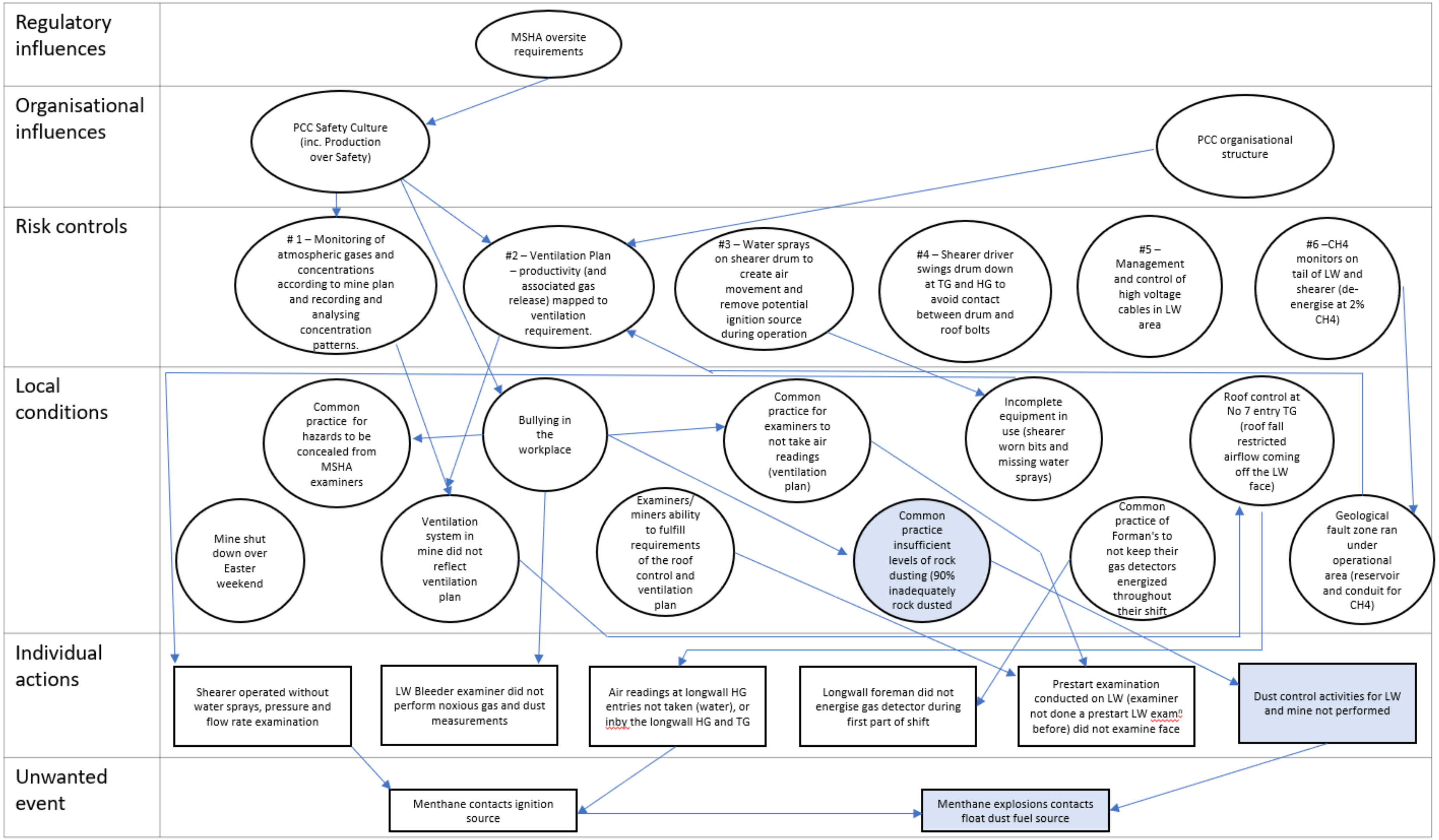

Figure 5: Accimap for the Upper Big Branch Incident

NB: The blue filled boxes identify some of the events and conditions for the float coal dust and coal dust explosion event. These were included to enhance understanding.