Case Study -1

Mine 1 commenced mining the South Pit towards the end of 2014. As the planned blast polygons were close to the existing residential property, there was a need to model the blast vibrations more accurately. Current site law vibration model was not predicting reliably due to variable geology and close distances.

The site requested the author to utilise their Advanced Vibration Modelling capability:

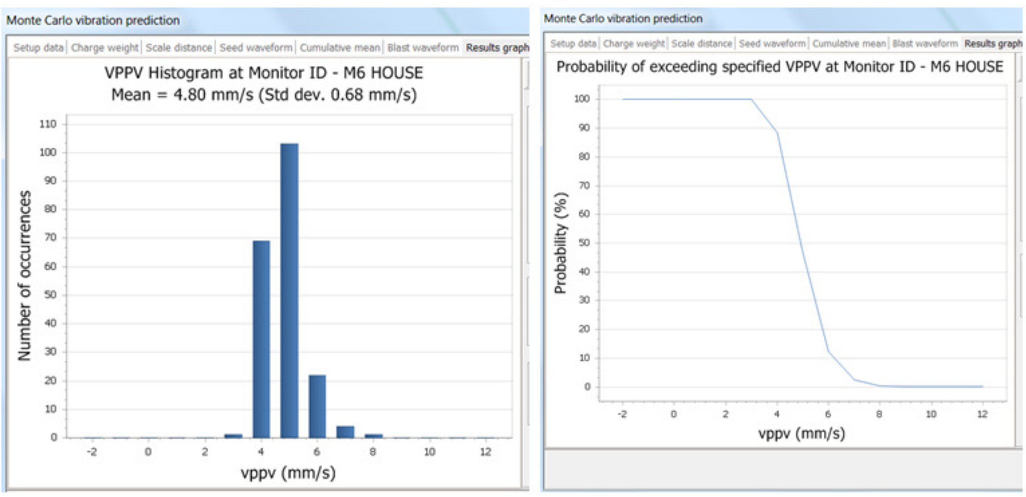
- To improve the reliability of the vibration predictions in this area of the pit.
- To meet the limit of 5mm/s vibration at the residence with a 95% confidence limit with a maximum limit of 8mm/s.
- To maximise the opportunity for the Tier One mining fleet to achieve the 1850bcm/hr budget target when mining through this area of the pit.

We have developed a model based on a Monte Carlo approach which includes as input to the model: measured waveforms; a single hole site law; ground p-wave velocity; and spatial and temporal aspects of a blast design. The seed waveform durations were rather long with dominant surface waves due to the complex geology in the affected area of South Pit.

The local p-wave ground velocity was determined as 4322±295 m/s. This value was rather high as compared to other coal overburden data's seen which usually lies between 1500-3000m/s. High K and p-wave velocity values indicate the ground's potential to channel the vibration energy rather fast to the property. Vibrations were found to be reflecting from rock types with varying densities resulting in dominant surface waves.

To date, 10 blasts were monitored from RL215 to RL200 and one blast from RL200 to top of coal. The results obtained from these blasts met the needs of the site (environmental KPI's and budget excavator dig rate).

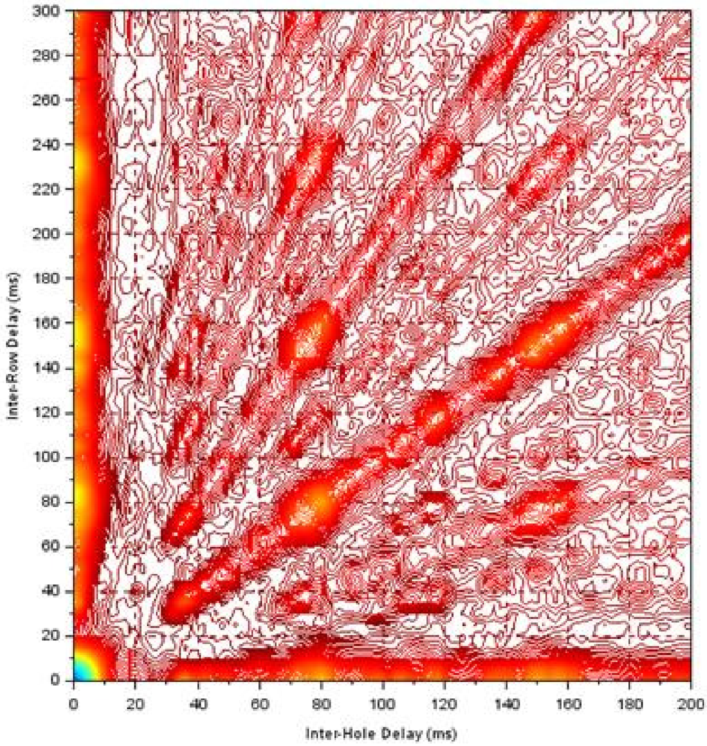
To assist in assessing the risks involved and developing a process to continue mining, a risk-cost benefit methodology combined with the standard site risk assessment process was used. Critical risks that were identified were the damage to the reputation and the effects on the production. A total of approximately $700,000 was calculated for risk-based value of the Project if the Projects goals are achieved. All KPI's were managed. If there was not an advanced vibration model, the site would have had to deck the non-electric blasts with potential poor dig rates and slower loading times as well as higher risk of exceedence.



(after Esen and Arana, 2015 – internal report, unpublished)

Case Study -2

Mine 2 engaged Esen Mining Consulting to assess the vibration data, review the vibration standards used in different countries and recommend the designs to manage the vibrations. The author reviewed the monitor installations and recommended a database structure to capture the data relevant to the project. The data was recorded at two nearby villages. In addition, single test holes were also fired to collect seed waveforms. Delay times were suggested to achieve the minimum vibration. The model integrates the Fourier Map which allows us to identify the optimum delays and review the delay versus frequency relation.



The study showed that

- Vibrations are below limits given by major standards (USBM, Australian and German- Line 2) and therefore should not cause any damages to the structures. In addition, vibration values are even lower than German standard -Line 3(yellow) which suggests 3 mm/s for the sensitive (old/historical structure and buildings).
- Given the poor condition of the residential structures, the mine should adopt 3 mm/s (German Standard- Line 3) as the target.
- Modelling work suggests that the probability of exceeding 3 mm/s is 0 provided that current blast designs are continued. Measured PPV data to date confirms this.
- Site laws were established to control the vibration using 2016 database to achieve the internal PPV limit. In addition, presplit blasts are now fired in groups resulting in reduced vibrations at the villages.
- Vibrations are less from blasts fired at Phase 3b than Phase 3 at a given scaled distance.
- At Phase 3, it is shown that vibrations from west and south west zones are slightly higher than south and south east zones.
- In general, variation in PPV is around 0.3-0.6 mm/s from the mean value for a given scaled distance. Delay scatter, geology (between blast and the monitor), pit geometry and delay combinations cause these large variations.
- Significant variation was found with the nonelectric system due to the inherent delay scatter with the detonators. Design improvements (different delay times, choice of initiation points, blast polygon shape etc) are usually masked by this (scatter in the nonel delay times). The only way to reduce the variation is to use

the electronic system. However, having about 1.1% of the shots in the range of 2-3mm/s is reasonable using nonel system.

The author also suggested combined production and trim blasts site. Vibration measurements and modelling works were carried out during the project. Remarkable results were obtained to date. Key benefits were:

- Eases restrictions on production scheduling.
- Improves productivity of shovels by reducing the instances of small blasts and reducing shovel movement times.
- Reduces oversize generation by eliminating the edge effect created by the free face in trim blasts.
- Increases productivity of blast charging crew by eliminating small blasts.