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Practical application of mXrap Damage Mapping application at Nova nickel mine

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Abstract

Damage mapping at the Nova Operation previously utilised pen and paper methods. There was little to no follow up reporting compiled to mine management regarding the status of ground support, corrosion or rock mass damage levels and changes over time, nor comparison against numerical modelling forecasts.

The mXrap Damaging Mapping application was implemented to improve the damage mapping process. The benefits that Nova has seen when using the mXrap damage mapping application include:

- *Fast, consistent input and ease of use for geotechnical staff; no more pen and paper underground.*
- *Simple reporting through to mine management of changes in ground conditions; a simple summary table and the ability to view mine plans in 2D or 3D.*
- *The ability to query a damage mapping database to identify trends in rock mass conditions, ground support conditions or corrosion levels through time.*
- *The ability to inform rehab requirements (ground not under supported or over supported) or rehab being done too early/too late.*
- *Improved granularity of damage mapping; user can view sidewalls, shoulders, backs level of detail rather than just a single section of a drive.*
- *Geotechnical data is stored in an appropriate database that allows for easy analysis and can be cross-correlated with other data sources (e.g. reconciling with numerical modelling forecasts for rock mass damage).*

Since the successful implementation of the damage mapping application, capital inspections have also been migrated to use the system for further simplification. An underground inspection app (for daily inspections not focusing on damage mapping) was also developed to migrate these from pen and paper to an electronic database format.

Keywords: *damage mapping, ground support, inspections*

1 Nova nickel mine background

IGO's 100%-owned Nova Operation (Nova) is 160 km east-northeast of Norseman in Western Australia (WA), Australia, and 380 km northeast of the Port of Esperance. Nova is a conventional underground mining operation and produces Ni concentrates (containing payable Cu and Co) and Cu concentrates that are sold to customers in WA and offshore. In the 2022 financial year, Nova mined over 1.6 million t of ore at an average nickel grade of 1.85% and copper grade of 0.75% (IGO Limited 2022).

2 Damage mapping process

Previous damage mapping processes at Nova were a manual process using pen and paper. This made underground mapping more cumbersome and increased the risk re-work due to plans being lost or damaged. There was also an additional data entry step into mine planning software to be able to track the damage mapping. The limitations with mine planning software are that damage mapping is limited to 1 m sections of the full profile and specifics on rock mass damage, ground support damage and corrosion levels are lost. There was also no way to see changes in the mine through time without loading multiple layers at once and changing visibility levels. An example of the results of the damage mapping are given in Figure 1.

Figure 1 Example of old pen and paper damage mapping results

In order to overcome these challenges, Nova adopted the mXrap Damage Mapping app as described in Cumming-Potvin et al. (2019). Switching to mXrap allows damage mapping to be completed on a windows-based tablet. This provides the benefits of removing pen and paper from the process, reducing the risk of losing work underground, carrying only a tablet and not multiple level plots, along with removing double handling of data from collection and data entry into another program. Using mXrap means data goes through one step to be entered into a centralised database.

Another significant benefit is that more granular data is available. Data about damage on sidewalls, shoulders, backs, and floor (rather than a single entry for the entire profile) can be collected. Details on individual support elements used in the ground support installed is collected. Rock mass characterisation and rock mass damage are also easily mapped.

Having the ability to review damage mapping results in 3D on the surface and plotted as 2D plans for presentation to other technical services and mine management adds to the usefulness of the data collected.

By switching to mXrap damage mapping, the damage mapping process is streamlined for geotechnical engineers. This means more consistent quality and quantity of mapping, and geotechnical engineers are more likely to undertake regular data collection if the process is easy to do.

3 Reporting

Previously, there was no easy way to report on damage mapping monthly utilising mine planning software. Changes over time were not easily viewed and there was no colour coding of level plans for various changes in ground support status, corrosion status or rock mass damage status. As the mine planning software is not designed for damage mapping, there was also a reluctance to produce monthly reports as this was a time-consuming task each month.

Presentation of the data is also simplified and standardised, and regular monthly damage mapping reports presented to mine management are colour-coded based on changes to ground support damage levels (Figure 2) or corrosion levels (Figure 3)and can be viewed over the whole mine or level-by-level. The Damage Mapping app also allows engineers to save pre-defined ‘views’ so these can be loaded easily to show exactly what is required for monthly reporting with a single click.

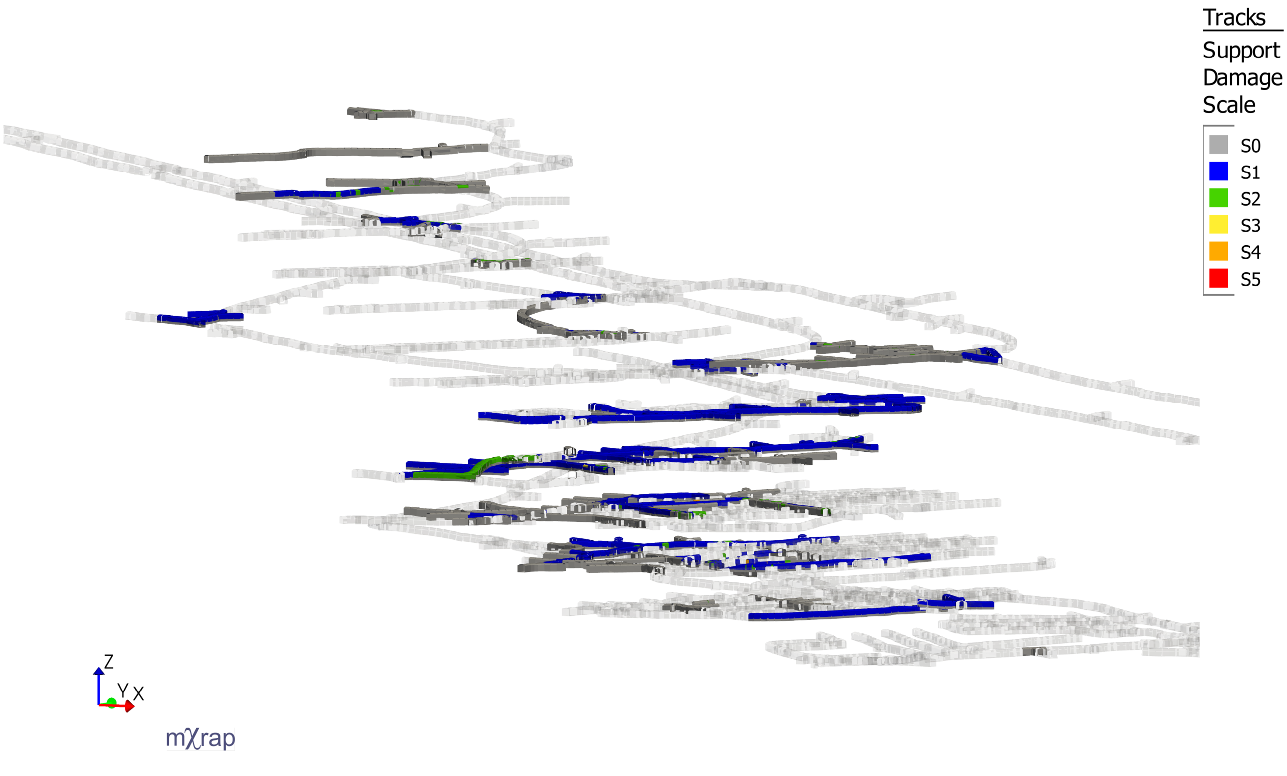

Figure 2 Support damage scale used in monthly reporting

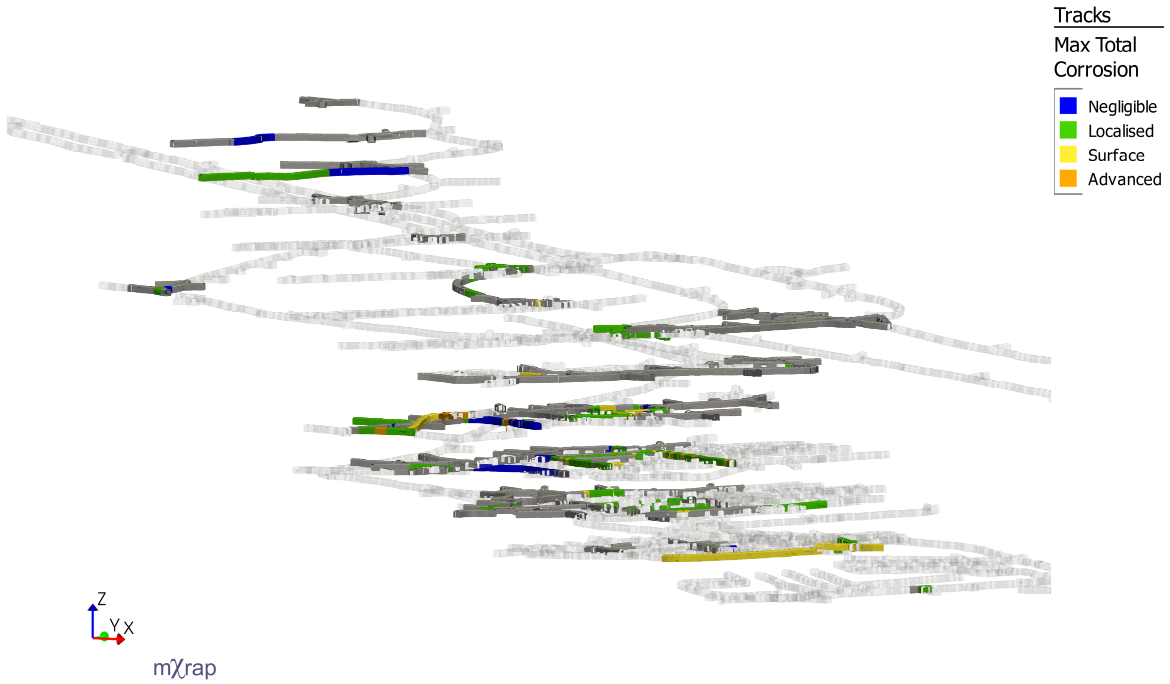

Figure 3 Corrosion levels used for monthly reporting

4 Trend analysis and rehab

Trends in ground support and rock mass damage are reviewed monthly by geotechnical engineers while compiling monthly reports. This may be a simple review in 3D from month-to-month or more detailed review using the trend analysis app within the Damage Mapping app. Some examples of trend analysis for bolt failure mechanisms and mesh failure mechanisms are shown in Figures 4 and 5. Review of data like ground support failure mechanisms can help identify trends relating to quality control issues, installation issues or failures resulting from geotechnical factors such as deformation, seismicity, or corrosion. Figure 6 shows trends for linear metres of each level of damage severity per level. Analysis like this allows trends to be found based on factors such as depth in the mine, lithology, ground support installed and rock mass quality.

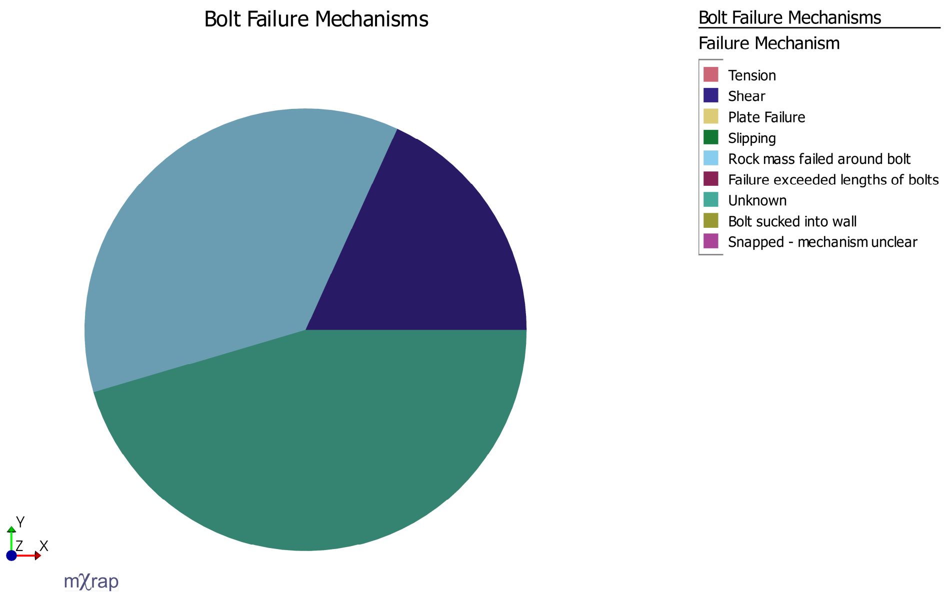

Figure 4 Trend analysis of bolt failure mechanisms observed

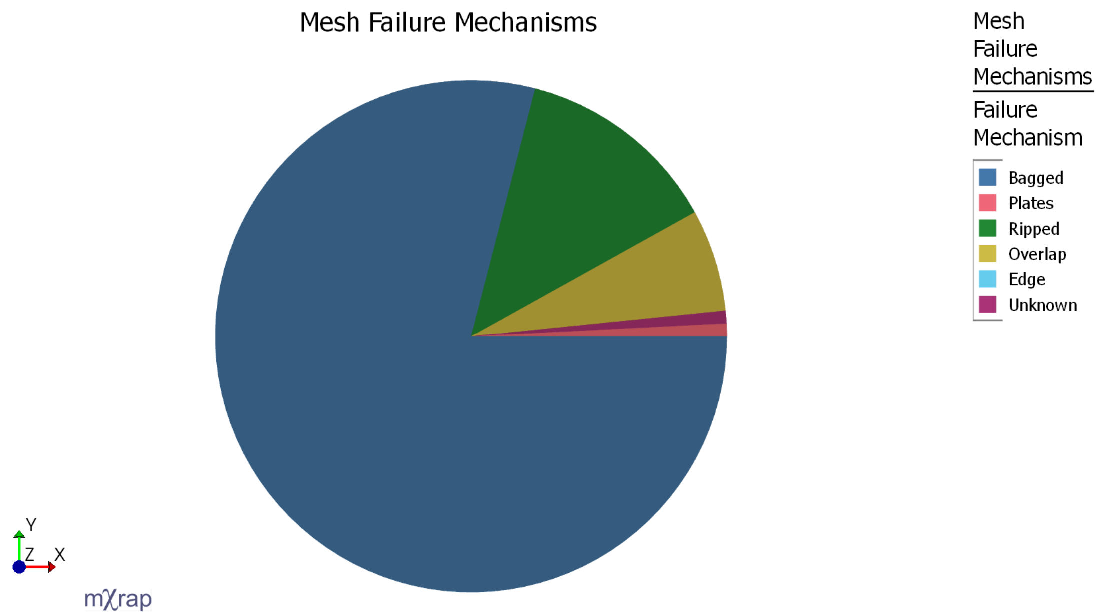

Figure 5 Trend analysis of mesh failure mechanisms observed

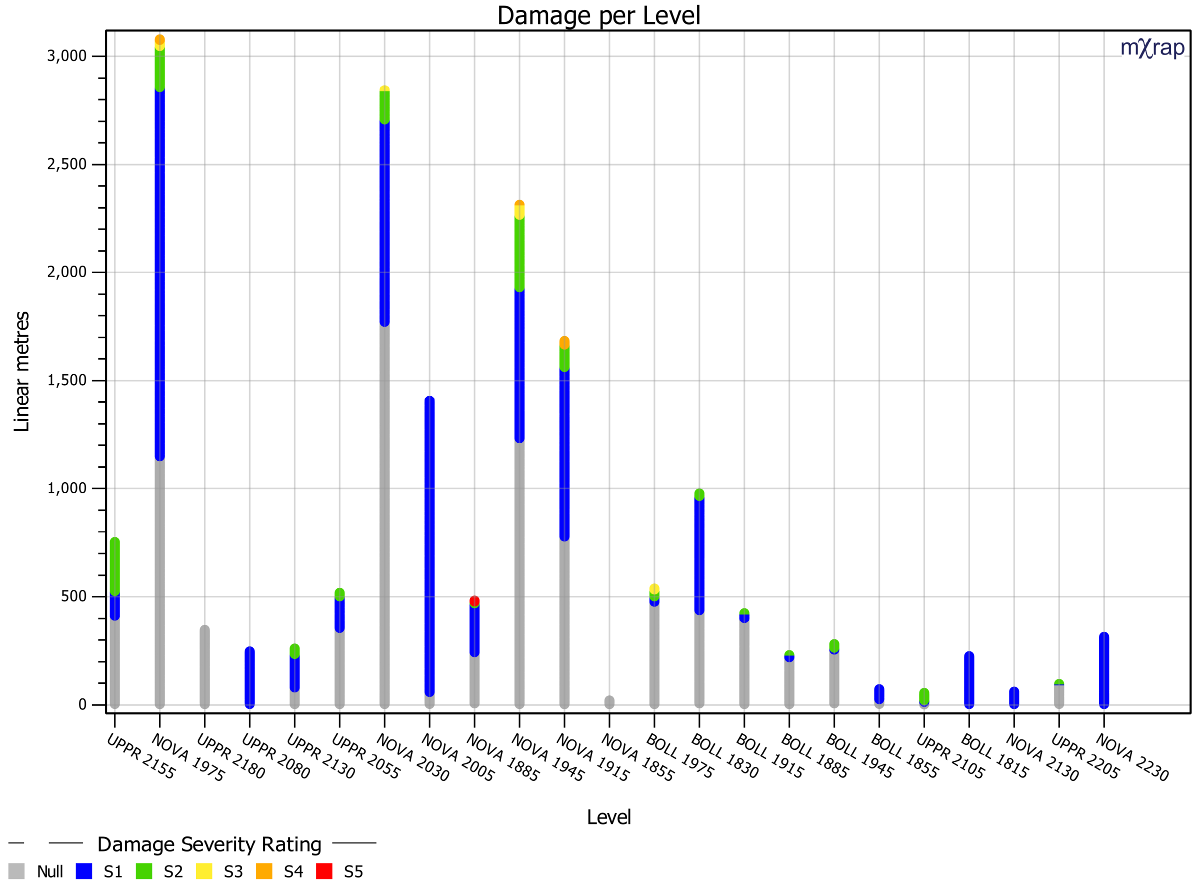

Figure 6 Trend analysis of linear metres of damage severity per level

The Damage Mapping app also enables geotechnical engineers to decide if ground support and rock mass damage is at an acceptable level, or when rehab is required. At Nova, when rock mass damage levels meet or exceed R3 damage levels, as per Kaiser et al. (1992) (Table 1), and ground support damage levels meet or exceed S3 (or SC3 for shotcrete) (Table 2), as per Kaiser et al. (1992), rehab is required. This means there is a consistent and prescriptive way for assessing rock mass and ground support damage and the requirement for rehab. It removes any need for interpretation from geotechnical engineers and allows for consistency of rehab requirements across the geotechnical department. As fibrecrete and mesh are both used independently and together at Nova, the two surface support elements are measured according to the system proposed by Kaiser et al. (1992).

This system also aligns with the simplified damage scale proposed by Mikula & Gebremedin (2017) and means that ground support damage which is tolerable, with the installed ground support remaining functional and not presenting a threat to personnel or equipment, does require rehab or replacement. There is still a risk of smaller rocks being able to fall through mesh aperture; however, the ground support is still able to prevent a potential fall of ground.

Table 1 Rock mass damage scale rating guidelines for rock mass and excavation damage (Kaiser et al. 1992)

Rating level	General description	Rock mass/excavation damage
R0	Conditions unchanged	No new damage due to rockburst
R1	Excavations undamaged but first signs of distress detectable	Rock shows fresh but minor, small fractures and cracks Small shards of rock may have been displaced
R2	Slight damage to excavations. Only ‘loose’ displaced	Slight sloughing from backs and walls of unsupported sections Small shards and chunks of rock displaced in supported excavations Rock mass shows only minor new fracturing
R3	Minor damage to excavations. ‘Loose’ displaced and new rock failure	Unsupported drives sustain damage <200 kg of rock displaced Drives supported with mesh and bolts show damage <1,000 kg of rock displaced Moderate bagging of mesh by fractured rock Clear evidence of newly fractured rock, possibly displaced violently
R4	Moderate to considerable damage to excavations. Violent displacement of ‘loose’ and freshly broken rock	Unsupported drives sustain damage at multiple locations Drives supported with mesh and bolts only show damage <10,000 kg of rock displaced Rock heavily fractured and displaced violently
R5	Serious or severe damage to excavations. Opening collapsed	Unsupported drives completely closed Drives supported with mesh and bolts heavily damaged >10,000 kg of rock displaced Rock is highly broken and fractured

Table 2 Support damage scale rating guidelines for ground support damage, modified from Kaiser et al. (1992)

Rating level	Steel support	Shotcrete damage
S0 (SC0)	No damage	No damage
S1 (SC1)	First signs of distress	Hairline cracking
S2 (SC2)	Loaded, plates deformed, mesh bagged but functional	Minor cracking, small plates dislodged
S3 (SC3)	Heavy loaded, few broken, mesh bagged, some torn/open	Cracking or fractured, starting to debond from rock mass
S4 (SC4)	Major damage, broken bolts, mesh failed or bagged to capacity, rock ejected	Heavily cracked and broken, separated from rock mass
S5 (SC5)	Complete failure of support components	Shotcrete failed, debonded from rock mass, no longer providing function

5 Data storage

The damage mapping data is held in a structured database within the mXrap root folder. This means that data from particular sources can be correctly attributed to other data tables, for example, the major structures mapped are linked to the locations underground. The databases are all in .csv format so that they are easily human readable and easy to share with third parties.

The photos are stored in an existing filing system with a folder per mining area, level and heading. The photos are linked to the damage mapping locations after the fact and can be displayed in mXrap. This allows the engineers to easily pull up the photos from an area for any date they did damage mapping in that location.

6 Calibration of numerical models

The damage mapping data is used to calibrate numerical modelling at a high level. Outputs of numerical modelling in terms of expected levels of rock mass damage have been well defined previously by Kaiser et al. (1995, 1992) and Sandy et al. (2010) and are summarised by geotechnical consultant reports for numerical modelling completed at Nova to date. The expected rock mass damage and ground support damage levels are periodically checked against the damage mapping results. Where significant variation between forecast and actual performance occurs, further investigation is undertaken by geotechnical engineers. Detailed exports in .csv format of rock mass damage can be exported for more refined analysis if required.

7 Updates

The level plans and ‘tracks’ (discretisation of the mine drives with a length of approximately 4 m to align with current mined cut lengths) need to be updated on a regular basis. At Nova, these are updated every month as part of the monthly processes embedded in the department. If a new track is needed (for example, if a new cut has been taken in a development heading), it can be added while using the tablet underground, without the need for an update of the entire level.

8 Additional apps

During the trial and implementation phase of the Damage Mapping app, additional mXrap apps such as the Extensometer app, Rock Mass Data Analyser app and Stope Reconciliation app were also trialled and implemented to allow for cross-functionality between each for sharing data and inputs. An additional custom Inspections app was also developed between the Nova geotechnical department and mXrap. This made undertaking regular geotechnical inspections to be completed using a tablet and moving away from pen and paper and Excel-based inspection registers. The trial and implementation of the additional mXrap apps is not covered in this paper; however, these apps also streamlined the geotechnical processes and allowed for the creation of an integrated geotechnical database to consolidate information at Nova. This integrated database creates a single place where data is held (making it easy for engineers to find the relevant information) and allows for complex multi-source analysis.

There are also plans to extend the mXrap Damage Mapping app to allow for simultaneous visualisation and cross-referencing with laser scanning data. This is not a critical addition for Nova, as the mine does not have significant convergence issues.

9 Conclusion

Switching to mXrap for damage mapping has brought geotechnical data collection into a more modern age with damage mapping being able to be undertaken rapidly using a single pass system while underground with easy analysis of the captured data once on the surface. This has also improved monthly reporting processes and allows for geotechnical information regarding ground support performance and rock mass response to mining to be easily reported to mine management on a regular basis. There is also the added benefit meaning routine damage mapping gets completed more regularly, as the task is easier than before and there is consistency across the geotechnical department. The ability to store data in a database that can be queried easily also means data analysis can take place quickly and can be reviewed over different time periods if required.

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