THE IMPACT OF MET-OCEAN FORECASTS ON EXPORT SHIPPING OPERATIONS ON THE NORTH-WEST SHELF OF AUSTRALIA

GREG JAMES1 AND GREG HIBBERT1
1 OMC INTERNATIONAL, MELBOURNE, AUSTRALIA.
EMAIL: G.JAMES@OMCINTERNATIONAL.COM

ABSTRACT

Along the North-West Shelf of Australia, mining export operations must work in tune with nature's whims. This paper discusses some of the refinements that have been made to enable loading and mooring operations to work more effectively with the environmental conditions on a daily basis for the port of Cape Lambert. This approach is shown to have a positive impact on moored vessel safety and port throughput efficiency.

Though infrequently dangerous to deep draft vessels, the swells that propagate along the North-West Shelf (some from as far away as the Antarctic ocean) can on occasion threaten safe sailing opportunities due to ship motions and under-keel clearance concerns. Furthermore, large swells, along with strong winds and currents, can be dangerous to moored vessels, causing increased line tensions and potential line breakage.

Depending on port operations, shippers may have pro-active measures to manage hazardous conditions, such as deploying tugs to assist moored vessels. However, deploying such measures comes at a cost, for instance burning thousands of litres of fuel and exposing operations to dangerous conditions. Therefore, users require accurate information on the potential levels of line breakage to help make informed decisions between the 'do-something' and 'do-nothing' options, i.e. balancing the costs of deploying preventative measures with the potential costs of line breakage.

To operate safely and economically, shipping operations make use of stochastically enhanced forecasts to ensure that modelling inaccuracies are accounted for, and that local observations can also be used to inform predictions. All the data sources (waves, wind, and currents) are incorporated into a single model which generates warning levels, giving users an easy-to-understand idea of the potential dangers to moored vessels without having to view and interpret multiple data sources which may be difficult and imprecise.

Keywords: mooring, forecasts, modelling, coastal warnings

1. INTRODUCTION

Safe and efficient mooring operations are an important part of modern maritime transport. If the vessel motions of moored ships are too large it can cause cargo handling efficiency to reduce [1]. Additionally, vessel motions of moored ships can cause the breakage of mooring lines, which can have serious safety implications for workers, as well as to the safety of the port infrastructure.

For ports to operate safely and efficiently it is necessary to have procedures in place when ship motions are too large. Examples of procedures include slowing or halting loading operations [1], or deploying tugs to assist moored vessels from being pushed off their berths. As all these procedures have a financial cost associated, it makes economic sense for ports who are regularly exposed to hazardous conditions to be able to both monitor and predict the occurrence of hazardous conditions.

The port of Cape Lambert, in WA's Pilbara region (Figure 1), is an example of a port which is regularly exposed to hazardous coastal weather conditions. To manage the safety and efficiency of port operations, a *Berth Warning System (BWS)* has been commissioned to both monitor and forecast mooring line tensions and vessel motions under prevailing weather conditions. This system utilizes measured environmental data to monitor vessel motions in real time; as well as environmental forecasts to predict vessel motions in the near-future. The system alerts port operators of dangerous conditions via a web interface.

Figure 1: Location of Cape Lambert on the coast of Western Australia. (Source: Google maps).

For berth warning forecasts to be operationally useful they must be sufficiently conservative to warn users of upcoming dangerous conditions, without yielding too many false alarms. As with any early warning system there are four classifications for forecast results [2], which are:

- True positives – correctly identified events
- True negatives – correctly identified non-events
- False positives – misclassified non-events, or *false alarms*
- False negatives – misclassified events, or *missed alarms*

False alarms may cause safety measures to be enacted unnecessarily as well as eroding user confidence; missed alarms may lead to mooring lines breaking, having both safety and economic impacts. As the classification of *hazardous conditions* is subjective, and port operators are in the best position to give feedback on correctly and incorrectly identified hazardous events, it is critical to get user feedback and to work with users to refine the BWS models. This allows forecasts to be tuned to an appropriate level of conservatism for use in operations.

The aims of this paper are: to describe how environmental forecasts are utilized to improve the safety and efficiency of mooring operations in Cape Lambert; to describe how user feedback was utilized to improve the Berth Warning System; and to suggest potential improvements to the BWS in the future.

1.1 CAPE LAMBERT BERTH CONFIGURATION AND ENVIRONMENTAL CONDITIONS

Cape Lambert operates two major iron-ore terminals, as well as a service wharf. Four of these berths are modelled in the BWS, which are Cape Lambert A (CLA) Berths 1-4 (Figure 2).

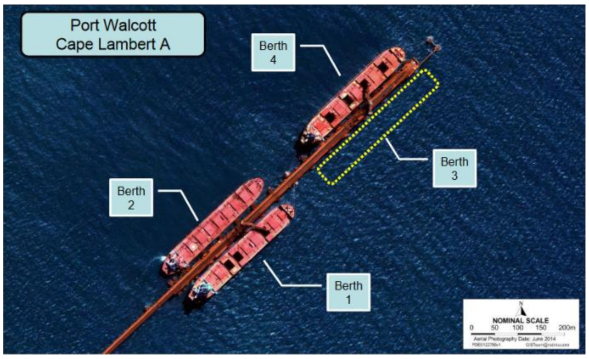

Figure 2: Layout of CLA Berths 1-4 (Source: Port Handbook: Dampier and Port Walcott [2])

The Cape Lambert berths are regularly exposed to swells which can present a hazard to moored vessels. Furthermore, due to the large tidal range at Cape Lambert of up to 5.5m, berthed vessels can experience strong currents of up to 1.2 knots, as well as winds of up to 35 knots [3] under normal conditions. Wind speeds can increase to exceed 50 knots during pre-cyclonic and cyclonic conditions.

Due to the layout of the berths, with vessels mooring on opposite sides of the iron-ore terminals, vessels can experience very different mooring tensions; forces coming from one direction may push vessels moored on one side towards the berth, while vessels on the opposite side are pushed off the berth. As such each berth is modelled separately in the Berth Warning System.

2. BERTH WARNING SYSTEM MODELS AND INPUTS

Cape Lambert's Berth Warning System works on the basis of inputting wave, wind, and currents data into a vessel response simulation to determine the peak vessel motions and mooring line tensions. It is necessary to calculate both vessel motions and mooring line tensions as there are cases where mooring lines may be at a safe capacity however vessel motions are too high for berthing operations to work safely.

The methodology for calculating vessel motions and line tensions is: to first run a hydrodynamic model to compute the expected vessel response coefficients, in six degrees-of-freedom, for a pre-defined vessel in three load states: ballast; 50% loaded; and laden. This hydrodynamic model takes into account the damping effects the mooring lines will have on vessel response.

Once the expected vessel response coefficients have been calculated, a time-domain model is run to determine the maximum expected vessel displacements, which are then used to calculate mooring line forces. This time domain is run using both measured data to determine the real-time mooring line forces; and forecast data to determine the expected mooring line forces in the near-future.

2.1 BWS DISPLAY

To display berth warnings in an easy-to-understand way, users are presented with warnings as a percentage, displaying the maximum of either: the percentage of vessel motions to the acceptable limit; or the percentage of mooring line tensions to the acceptable limit (Figure 3). For example, a warning level of 50% would indicate that either vessel motions or line tensions are at half of their acceptable limits, whereas a warning level >100% would indicate that vessel motions or line tensions are in excess of their safe operating limits.

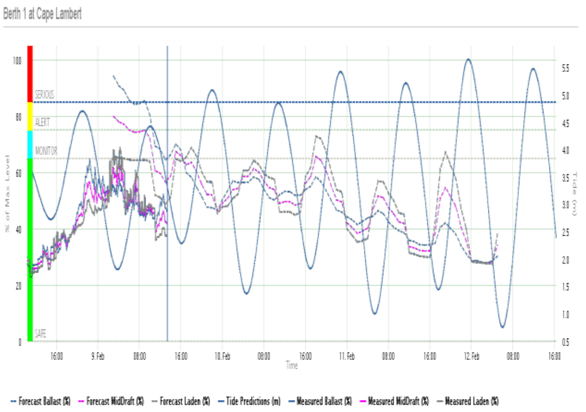

Figure 3: Warning level graph displayed by the Berth Warning System. Warning levels are categorized into four colour-coded brackets.

Warning levels are categorized into four colour coded brackets, which are:

- 0-65% - Safe (green)
- 65-75% - Monitor (blue)
- 75-85% - Alert (yellow)
- >85% - Serious (red)

The maximum warning level for each berth, from either measured or forecast warnings, is used to colour a *traffic light* on a dashboard display (Figure 4). This allows users to monitor all berths simultaneously.

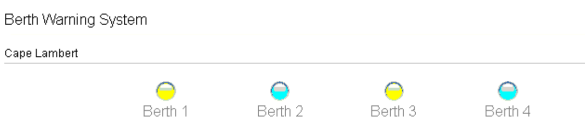

Figure 4: Traffic light warnings for all Cape Lambert berths.

2.2 ENVIRONMENTAL INPUTS

Cape Lambert uses the following environmental inputs for its BWS calculations (measured device locations shown in Figure 5):

MEASURED WARNINGS

- Measured wave data from Beacon 28 AWAC
- Measured currents data from Dolphin 33 AWAC
- Measured wind speeds from Beacon 28 Meteorological station

FORECAST WARNINGS

- Forecast wave spectra from the Bureau of Meteorology's (BoM) AUSWAVE-R model, for the point *Dampier Nearshore*
- Astronomical currents predictions
- Forecast wind speeds from BoM's AUSWAVE-R model for Port Hedland

Forecast wave data and wind data are statistically transformed to the Beacon 28 measured wave location. These statistical transforms are derived from analysis of historical forecast and measured data, and are necessary as the conditions at the forecast points are different to those at the measured locations.

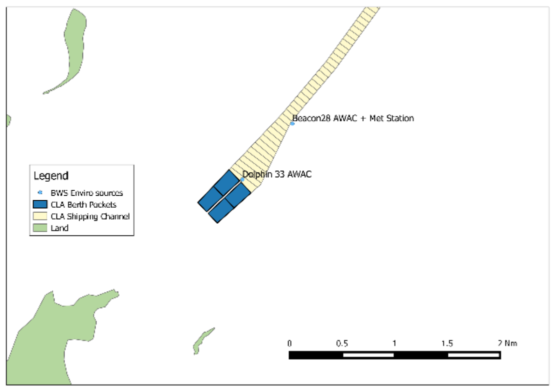

Figure 5: Location of BWS measured data sources

3. USER FEEDBACK AND MODEL REFINEMENT

Cape Lambert have been using their Berth Warning System since August 2013. Initial feedback from users was that both measured and forecast warnings were not conservative enough, leading to a number of missed alarms for events. The following sections discuss how the measured and forecast warnings have been improved based on user feedback, and suggest potential improvements for the future.

3.1 NOVEMBER 2014 MODEL RECALIBRATION

In November 2014, a BWS recalibration study was performed [4]; at this stage, most of the feedback from BWS operators was that the system generally performed in an under-conservative manner. For this study, approximately 1 year of measured environmental data was analysed, from November 2013 to November 2014; warnings were retrospectively generated based on this measured data. Port operators provided a list of times when incidents occurred with moored vessels, which were used to validate the warnings produced by the BWS; eight of those events coincided with times where measured environmental data was available.

Using the initial BWS configuration it was found that the system did not produce any warning levels of *Alert* or *Serious* for the eight events. Based on this, three major changes were made to the BWS configuration to give more appropriate warning levels:

- Use of gust wind speed instead of sustained wind speed in the vessel motions model.
- Revision of wave transformation to the berths.
- Revision to the categorization levels of warnings (Table 1).

Warning level	Initial Configuration	Revised Configuration
Monitor	75% - 85%	65% - 75%
Alert	85% - 95%	75% - 85%
Serious	>95%	> 85%

Using these configuration changes, the BWS went from reporting zero events at *Alert* or greater, to five events at *Alert* or greater; two of which were categorized as *Serious*. The new configuration is much more sensitive to prevailing environmental conditions, and correlates significantly better with the operational experience and recorded incidents at Cape Lambert A.

It was found that for two of the recorded mooring incidents the BWS displayed *Safe* warning levels, even with the recalibrated configuration. It is theorized that these events were caused by factors not modelled in the BWS, such as mooring line fatigue or incorrect tensioning of lines. These factors are difficult to account for as trying to capture these cases could make the BWS too conservative, leading to much higher rates of false alarms.

3.2 REFINING WARNING LEVELS DURING CYCLONIC/PRE-CYCLONIC CONDITIONS

Users have reported that warning levels are lower than expected during times of severe weather (in cyclonic or pre-cyclonic conditions). During these times, there will be extreme winds and waves which present a threat to moored vessels.

When a cyclone approaches Cape Lambert all vessels are sent out to sea to sail clear of the storm's radius; this protects the safety of the vessels and their crews, as well as protecting the port infrastructure. Because of this evacuation procedure the assumption was made that BWS warnings would not be used during such an event, and the wave modelling was only done for swells up to a height of 0.8m, under the assumption that there would be no vessels moored when wave conditions exceeded this height due to an impending cyclone.

Feedback from users is that they would like to see forecast warning levels more reflective of approaching cyclones. However, since there should never be a vessel moored while a cyclone is approaching Cape Lambert, it is difficult to validate whether vessel motions and warning levels calculated by the BWS will be *accurate* under these conditions. Furthermore, since the wind and wave forecasts used in the BWS come from regional weather models, they are often inaccurate during localized weather events such as cyclones. Cyclone forecasts are produced by specialized models which predict their likely tracks and magnitudes, and this information is not always well captured by regional models.

To better capture cyclonic conditions in the BWS a number of improvements could be made to the system. Firstly, the wave modelling could be extended beyond swell heights of 0.8m to allow the modelling of larger waves in the system. Secondly, specific cyclone models could be incorporated into the wave and wind forecasts using an ensemble-based approach, which could improve the accuracy of forecast inputs used by the BWS during these events.

Finally, severe weather warnings could be displayed to users on the BWS interface, alerting them that extreme weather events are being forecast for the area. This would alert users that there is a cyclone in the area, and to check other forecast sources as to whether it will impact the port.

3.3 ONGOING REFINEMENTS OF FORECAST WARNINGS

The refinement of forecast warnings is an ongoing process, and has proven to be more difficult than the refinement of measured warnings for a number of reasons. Some of the major inaccuracies in forecast warnings are discussed in the following sections, as well as potential improvements to the BWS to make forecast warnings more accurate.

3.3.1 Astronomical currents predictions are inaccurate around *turning points*

The BWS is highly sensitive to currents, particularly to the direction of currents. Currents produce the greatest mooring tensions when pushing vessels directly off the berths. For these times when currents are pushing vessels off the berths, the astronomical predictions can be off by 0.1-0.2kts as well as having incorrect directions. These inaccuracies cause a number of *false alarms* and *missed alarms* due to the sensitivity of the system.

One possible way to improve currents forecasting is the use of a statistical model to look the previous currents measurements, and use this data to predict the currents in the near future. One such method is looking at the lags and biases of previous *turning points* in the direction perpendicular to the berths, i.e. look at maximum and minimum currents values pushing vessels directly onto of away from the berths. A turning-point based approach has been shown to improve tide forecasting for the port of Weipa [5], and could be theoretically applied to currents forecasting at Cape Lambert given that the sinusoidal behaviour of tides and currents are very similar.

3.3.2 SHORT TERM FORECAST WARNINGS ARE WELL ABOVE MEASURED VALUES

As measured data is not being used at all to generate forecast warnings it common to get now-time and short-term forecast warning levels well above the latest measured values. This commonly leads to *false alarms* in short-term forecasts.

To make short-term forecast warnings more consistent with measured warnings it is possible to combine measured data with forecast data for short-term predictions (e.g. 0-6 hours), and blend to using purely forecast data for longer term predictions. This would increase the consistency between the two data sets, and could increase the accuracy of forecast warnings for short horizons.

One possible drawback of combining measured and forecast data is the potential increase of missed alarms in short-term forecasts: forecast data may predict sudden wind and wave events which could then be masked using measured data for short-term predictions.

Therefore, having forecast warnings that are completely independent of measured data be both a strength and a weakness of the BWS. Combining measured data into forecast warnings would significantly change the behaviour of the system, and the implications of this change would need to be discussed with users before implementation.

4. CONCLUSION

Cape Lambert have commissioned a Berth Warning System to assist with the monitoring and prediction of hazardous conditions for moored vessels. After refinement based on user feedback, the BWS is providing accurate now-time warnings based on measured environmental data (wind, waves and currents). Forecast environmental data is used to generate predicted warnings, however the forecast warnings generated are not as accurate as the measured warnings. Several suggestions have been made to improve the accuracy of forecast warnings.

5. ACKNOWLEDGEMENTS

Authors wish to thank the port of Cape Lambert and Rio Tinto for their continual feedback during the commissioning and continual operation of the Berth Warning System.

6. REFERENCES

[1] PIANC (1995), Criteria for movements of moored ships in harbours – a practical guide, PIANC GENERAL Secretariat, p. 5

[2] Flatch, P. (2012), Machine Learning: The Art and Science of Algorithms that Make Sense of Data, Cambridge University Press, pp. 53-55

[3] Rio Tinto (2016), Port Handbook: Dampier and Port Walcott, Rio Tinto, pp. 20-23

[4] OMC International (2014), Cape Lambert: A BWS Recalibration Report, unpublished, pp. 4-15

[5] Uslu, B. et al (2015), Ensemble turning-point water level predictions for uncertainty estimation for short-horizon planning and risk assessment, Australasian Coast & Ports Conference 2015, pp. 1-6