CHANNEL OPTIMISATION AND RISK MANAGEMENT THROUGH TECHNOLOGY AT THE WORLD'S LARGEST BULK EXPORT PORT

BRENDAN CURTIS[1]

[1] OMC INTERNATIONAL, MELBOURNE, AUSTRALIA; B.CURTIS@OMCINTERNATIONAL.COM

ABSTRACT

The Port of Port Hedland is the world's largest bulk export port. The Pilbara Ports Authority (PPA) facilitates approximately $100m of trade through the port every day, resulting in around 6,000 vessel movements per year. All this is achieved through a uni-directional and tidally constrained 42km channel, with up to eight vessels carrying more than one million tonnes of iron ore sailing on a single tide.

In May 2016, PPA received WA State Government approval for the Channel Risk and Optimisation Project (CROP). CROP is a $120m dredging project aimed at mitigating the risk of disruption to the port in the event of an adverse incident, and improving the overall export capacity of the channel through increased drafts and wider sailing windows.

All deep draft vessels departing Port Hedland do so under advice of the Dynamic Underkeel Clearance System (DUKC®). In determining the CROP's optimum design, PPA used DUKC® technology in evaluating the proposed channel design depth profiles, and to ultimately quantify the benefits of the project.

Drawing on the experiences from the PPA's marine operations team, this paper outlines the operational challenges that exists at the Port of Port Hedland. The details of PPA's CROP are provided and an analysis of how it will work to address the operational issues is provided.

The channel design methodology is presented in detail, highlighting how integrating the operational under keel clearance (UKC) management system and the design processes yields the dual benefits of minimising the dredging volumes, thereby reducing costs and environmental impacts, and providing certainty regarding the benefits of the project.

With ever increasing scrutiny on the financial and environmental credentials of ports, and higher expectations from ports' customers, stakeholders and local community, particularly

with respect to dredging, it is imperative that ports continue to apply best practice and be able to demonstrate the value delivered from these investments.

Keywords: channel design, dredge optimisation, UKC.1 Port of Port Hedland Operations

1 PORT OF PORT HEDLAND OPERATIONS

The Port of Port Hedland is the world's largest bulk export port by volume, and has seen considerable growth over the past decade. Figure 1 shows the annual export tonnages, and total vessel movements.

In the 2015/2016 financial year, the port set a number of trade records [3,9]:

- Annual throughput of 460.4 million tonnes;
- A monthly throughput of 42 million tonnes;
- Exports of 2,174,533 tonnes in 24 hours;
- Sailed more than one million tonnes on a single tide 60 times.

Additionally, the record tonnage on a single tide is 1,511,877 tonnes, and the deepest draft to sailing is 19.95m for a total of 270,006 tonnes [9].

Iron ore dominates the port's trade, representing 98% by volume. This is significant not only in the context of the port, but also nationally. The Port of Port Hedland accounts for just under 60% of Australia's iron ore exports, equating to more than a quarter of the global seaborne iron ore exports [4].

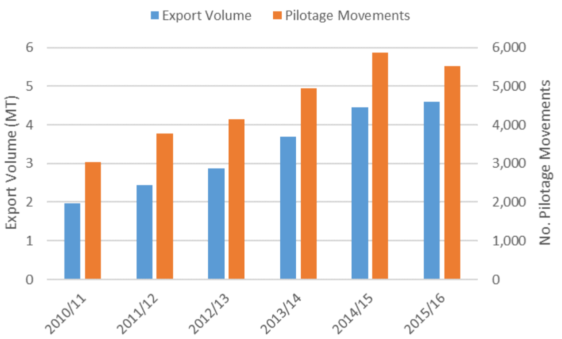


Figure 1 Port Throughput (Source: [9,10]). The volume of trade through the port has grown significantly since 2010/2011.

Whilst the sheer volume makes the shipping challenging, the operations are further complicated by the geographic layout, and environmental conditions of the port.

Figure 2 shows the layout of the channel, which is approximately 42km long and uni-directional.

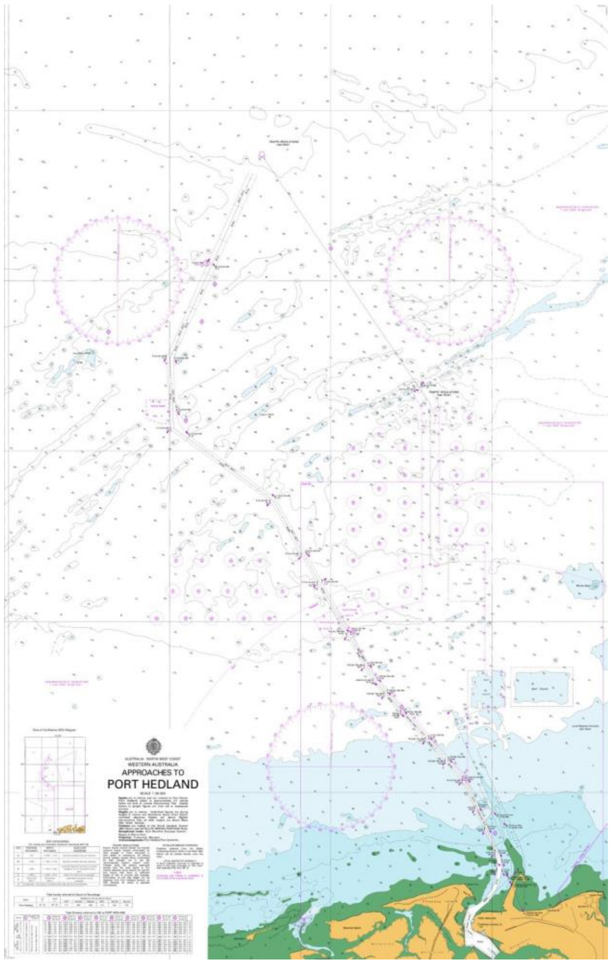


Figure 2 Channel Layout (Source: [1]). The 42km, uni-directional, tidally restricted channel creates a challenging operating environment.

Access to the harbour is constrained through single entrance with a minimum channel width of 162m. Furthermore, with a minimum channel depth of 14.6m, the departures are tidally restricted. The tidal range is up to 7.4m and tidal currents up to 3.5 knots [1,11].

In addition, the profile of vessels calling the port have also changed dramatically in the past 30 years.

Specifically, they have become, wider, longer and deeper as shown in

Table 1.

Table 1 Capesize Vessel Profile Evolution

Year of Build	DWT (k)	Beam (m)	LOA (m)	Draft (m)
1981	138	43	270	16.8
1990	149	43	270	17.3
2000	171	45	288	17.7
2010	180	45	292	18.2
2011 Wozmax	250	57	330	18.2
2011 'N' Class VLOC	297	55	327	21.4
2017 FMG	260	57	327	19

To achieve the current port volumes, laden capesize bulk carriers transit in convoy, with up to eight vessels on a tide. The vessels typically transit with 30 minutes separation between them. If a vessel towards the front on the convoy breaks down, there is a risk of the following ships grounding or colliding with the lead vessel [2,3]. There are currently two shallow escape areas where a vessel can anchor outside of the channel. However the ability of a ship to safely reach an anchorage is dependent on numerous factors including the time available to react, the availability of tugs, the sailing window, and the prevailing environmental conditions.

The practical implication is that any incident within the channel has the potential to block access to the port. Given the value of trade through the port, approximately $100 million per day, this would have far reaching consequences to not only the operation of the port and its customers, but also the economies of the State and Australia [11]. Therefore, the risks must be carefully managed having consideration for all the operational factors, including the channel profile, environmental conditions, geographic constraints, and vessel characteristics.

2 MANAGING RISK

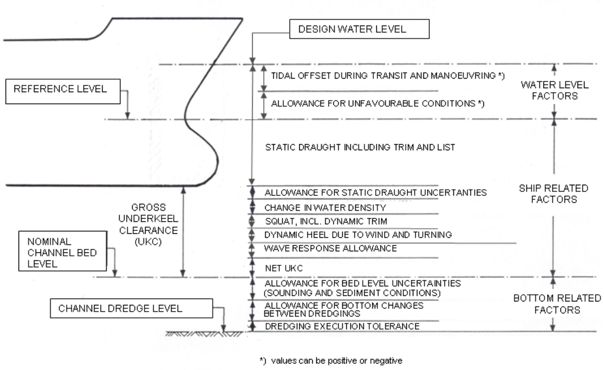
PPA adopts numerous strategies to mitigate the risks of the port including implementing the highest standards for pilotage, towing and hydrographic surveying, and adopting technological solutions including maritime simulations, Portable Pilot Units (PPUs), and DUKC® Series 5 [1,2,3].

An additional key strategy in managing the channel risk currently under development by PPA is the $120m CROP, the budget for which received WA State Government approval in May 2016. CROP involves the delivery of an emergency passing lane alongside the shipping channel to mitigate the risk of disruption to the port's operations in the event on an adverse incident by allowing vessels in the convoy to continue safe navigation. Furthermore, an existing refuge zone will be enhanced to allow anchorage over low water. Targeted dredging will also enable existing channel depths to be fully utilised, increasing the available draft and tonnage to laden outbound vessels, and extending sailing window [5]. The wider sailing window creates opportunity for increase separation times between vessels, thereby providing optionality in an emergency scenario.

3 DYNAMIC UNDERKEEL CLEARANCE (DUKC®)

PPA has employed DUKC® to assist in managing vessel drafts and sailing windows since 1996 [11], and is currently running the latest iteration, Series 5.

DUKC® Series 5 is a software as a service (SaaS) system based on the DUKC® methodology. With more than 140,000 successful transits through 22 ports and waterways, DUKC® is a recognised e-Navigation technology, and is considered as best practise for UKC management.



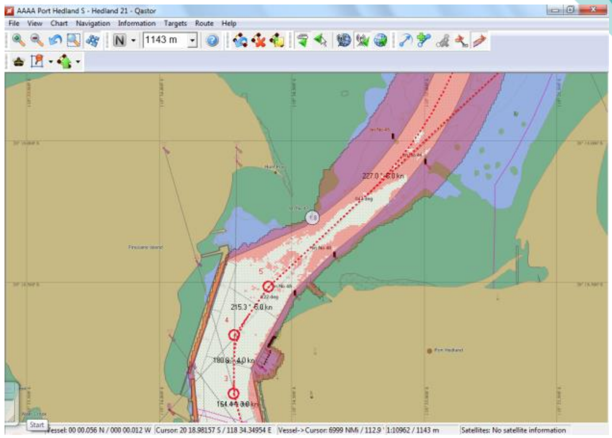
The core functionality of the DUKC® has been to provide the PPA with dynamic passage planning advice on:

- Maximum sailing draft for a known or fixed sailing time;
- Sailing window times for a known or fixed sailing draft;
- UKC for a specific transit with a known departure time and draft.

This planning functionality is complemented by critical risk management functions such as vessel speed control, and real time UKC monitoring capabilities through AIS, including dynamically updated chart overlays which display high risk areas within the channel on the portable pilot units (PPUs) as shown in Figure 3.

Figure 3 Chart Overlay (Source: Internal). Pilots have direct access to real time UKC information via the PPU.

Static rules are the mechanism by which shippers and regulatory authorities have



traditionally managed the under keel clearance (UKC) of a vessel. Static rules typically comprise a fixed UKC requirement to determine times of sailings and/or maximum sailing drafts. This fixed UKC requirement must account for a range of conditions, and does not consider individually the factors that influence UKC.

In reality these factors change dynamically depending on vessel, channel and environmental conditions. A general summary of the factors that influence UKC is presented in Figure 4.

Figure 4 UKC Factors (Source: [8]). Underkeel clearance is affected by various factors which can be specific to the vessel, channel or transit.

For the Port of Port Hedland, the dominant UKC components are typically tide, squat and, with prevailing swells, wave response. The speed of a vessel can have a significant effect on the UKC as it directly influences squat. While many various squat formulas exist, actual squat depends on characteristics of the vessel, the channel being traversed, speed through water as well as water depth [8]. Furthermore, given the length of the channel and tidal range, the speed is critical in determining the position of vessel along the channel at any time, and therefore the available water.

As an example, consider a vessel departing at five hours before high water, with a high water tide of 6.35m. The tide level at the start of the transit is 1.83m. By the time the vessel reaches the end of the transit, the tide is 4.93m. A vessel departing at high water on the same tide has 6.35m at the start of the transit, but only 3.20m tide at the end of the channel. Each of these vessels will have extremely different UKC profiles, and therefore, different risk profiles. Furthermore, assume circumstances are such that the vessel sailing at high water arrives at the final waypoint 20 minutes later than expected. In this case, the available tide will be 2.84m, resulting in 0.36m less UKC than originally planned. If not managed effectively, this could pose a significant risk to the safety of the vessel.

Applying static rules is effectively a variable risk approach to UKC management, as the gross allowance is allowed for and assumed to be sufficient to cover all cases but at any particular time the nett UKC is effectively unknown. This yields two implications.

Firstly, as the static UKC margin is assumed to cover all situations, the actual nett UKC varies and thus the risk of grounding for any given sailing is unknown. Furthermore, situations may exist where the gross allowance is actually inadequate to ensure the risk of grounding remains acceptably low.

DUKC® methodology, as applied through the DUKC® software, takes a different approach to UKC management, which can be described as a fixed risk approach. This approach defines a minimum nett UKC allowance that must be maintained throughout the transit. Allowances for each of the relevant UKC components are then computed individual, considering the unique specifics of the transit, including depths, speeds, vessel type and characteristics, and environmental conditions. The final UKC requirement is a summation of the individual component allowances and the nett UKC allowance. By varying the UKC allowance to accommodate the prevailing conditions, the DUKC® approach can ensure that the safety margin is not breached. Through a more comprehensive understanding of the risk profile, the risk can be maintained at the required level, whilst maximising operational efficiencies with respect to vessels' drafts and sailing windows.

4 CHANNEL DESIGN

PPA used DUKC® methodology in the design process for the CROP. This involves individually calculating each of the factors (wave response, squat, heel, etc…) that contribute to reducing UKC at all points of a transit through a restricted waterway. Consideration is given to the actual environmental conditions (waves, tides), vessel dimensions, stability characteristics and speeds and actual channel configuration. The result of this analysis is a nett UKC profile for each vessel transit.

To capture a true representation of the concurrence of environmental events and vessel sailings, thousands of vessel movements are simulated using DUKC® under a time series of environmental conditions to determine UKC requirements along all points of the channel.

For the CROP analysis, a baseline scenario was first established by using the existing Port of Port Hedland DUKC® configuration and bathymetry. Vessel transits were simulated over the analysis period for each tide cycle. From each simulation, the available departure drafts were calculated over a tide cycle. An example of the output is provided in Figure 5. As Figure 5 demonstrates, depending on the departure time of a vessel relative to high water, the available maximum sailing draft varies considerably.

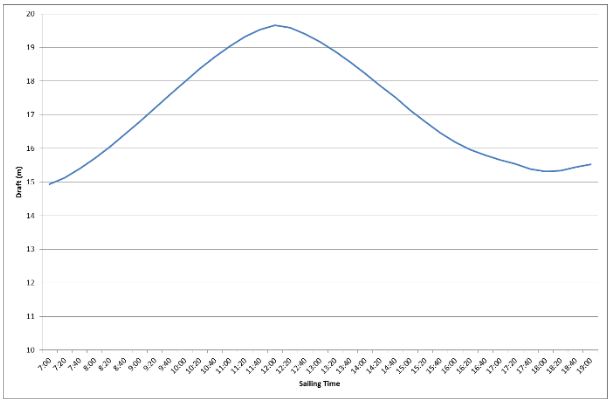


Figure 5 Maximum Draft Curve Example (Source: [7]). An example of the output generated for every high water in the analysis period.

PPA sought a total of nine channel profiles for evaluation. PPA initially derived four channel options based on an initial assessment of what would likely be achievable from a dredging perspective given existing depths and natural contours of the channel, the known geotechnical properties of the seabed, the overall dredge volumes, and budget targets. Following on from that process, OMC performed a preliminary study yielding a preferred profile. From this preferred channel profile, further refinement by the PPA produced an additional five channel profiles for analysis by OMC.

For each channel profile, the transit simulations were run for same conditions as the baseline scenario, and the maximum drafts determined for all sailing times over the analysis period.

Comparing these results with the baseline scenario yielded the expected benefits of each proposed channel profile.

5 BENEFITS ANALYSIS

A valuable finding from the channel design process by PPA's dredging team was that there were proposed depth profiles which yielded no additional benefit over alternatives which required less dredging. The preferred channel profile for CROP resulted in potentially substantial benefits, including an average increase in draft across all departure times of 0.24m, an average increase in draft of 0.56m for a high water departure, and an average increase in the sailing window closing time of 33 minutes for an 18m draft vessel. This sailing window result is critical as the separation distance required under the existing vessel movement guidelines is 30 minutes. The CROP therefore potentially provides an additional sailing slot on the tide.

The assessment of the potential impact of the CROP was taken one step further by simulating the revised channel profiles within the Dynamic Port Capacity Model (DPCM®).

The DPCM® is a discrete event simulation model of the Port of Port Hedland operations that incorporates the DUKC®. The purpose of the DPCM® is to provide a tool to assess the impact on port capacity of changes to variables such as ship loader rates, vessel fleet profiles, cyclones, asset availability (tugs, pilots, etc.). The performance of the DPCM has been validated each year since its development against the actual port throughput. Analysis undertaken utilising the DPCM® was the basis by which the declared port capacity of Port Hedland was increased by 16 per cent from 495 mtpa to 577mtpa in 2015 [5,11].

The DPCM® analysis highlighted the impact of the CROP on the short-loading of vessels, the benefits of which accrue through both increased tonnages and reduced dead-freight claims for the ports' customers. The analysis indicated that the CROP would reduce both the occurrence of short-loading vessels, as well as the amount of short-loading when it does occur.

In assessing the value of applying DUKC® methodology to the channel design in conjunction with using DUKC® operationally, an analysis against the static UKC was performed.

Using the CROP channel profile, the DUKC® Series 5 resulted in an average increase in draft of 0.63m across all sailing times. Importantly, for vessels sailing at the opening of the tidal window (3-5 hours before high water) where they are typical most draft constrained, the DUKC® provided an average benefit over the static UKC of 0.81m. For this same departure window, the CROP channel profile yielded no benefit when operating under a static UKC rule.

This analysis has highlighted two important factors in the operations at the Port of Port Hedland. Firstly, DUKC® provides a considerable benefit over static UKC rules for the port, allowing vessels to safely transit at deeper drafts, thereby carrying more cargo. Secondly, there are conditions where the static rule provides underkeel clearances which do not meet the minimum accepted requirements. Therefore, the DUKC® reduces the risk of grounding by making the necessary allowances for the conditions during a vessel's transit.

By utilising the operational technology in the channel design process, the overall dredged volumes, and associated costs, could be effectively reduced without compromising the benefits.

6 SUMMARY

The Port of Port Hedland has experienced significant growth in volumes over recent years, making its operations critical to the economy at both a state and national level.

The geographic constraints of the long, uni-directional channel, coupled with large tidal ranges and potential exposure to swells, makes the operating environment difficult. Given the significant potential consequences of any incident within port or channel, the effective management of risk is a high priority.

However, PPA has a strategic objective to facilitate trade. Therefore, optimising operations and continually pursuing efficiencies are also important.

This paper has examined some of the technologies aimed at achieving this balance of maximising throughput whilst ensuring safe operations. These include the use of DUKC® by the VTS, and Chart Overlays by the pilots. However, PPA's marine operations team has demonstrated that applying the operational DUKC® technology in the channel design and validation phases enables the design be optimised, and the potential benefits to be well understood prior to proceeding with the project. Furthermore, rather than considering the channel in isolation, the application of the DPCM® enabled the CROP to be assessed with the context of the overall operations of the port, giving consideration to the unique circumstances of each of the proponents within the port, including individual loader rates, berth restrictions, fleet profiles, and tug allocations.

7 REFERENCES

[1] Ayre, M. (2016). Best Practises Pilotage Standards in Port Hedland, Proceedings of the Safe Ships, Safe Port Forum (8 September, Perth).

[2] Fernandes, M. (2016). Potential High Impact Incidents, Proceedings of the Safe Ships, Safe Port Forum (8 September, Perth).

[3] Finch, J. (2016). Managing Growth and Channel Risk, Proceedings of the Safe Ships, Safe Port Forum (8 September, Perth).

[4] Government of Western Australia Department of State Development (2016). Western Australia Iron Ore Industry Profile.

[5] Government of Western Australia Minister for Agriculture & Food; Transport (2015). Extra capacity for Port Hedland channel, media statement (13 November).

[6] Government of Western Australia Minister for Health, Culture & the Arts (2016). Key Port Hedland port projects gain momentum, media statement (5 July).

[7] OMC International (2016). R6146 CROP Channel Analysis Report.

[8] PIANC (2014). Report No. 121 Harbour Approach Channels Design Guidelines.

[9] Pilbara Ports Authority (2017). Media Statement – Largest Iron Ore Shipment departs Port Hedland (2 March 2017).

[10] Pilbara Ports Authority (2016). 2015/2016 Annual Report.

[11] Pilbara Ports Authority (2016). Port Handbook – Port of Port Hedland.