# AN INTEGRATED APPROACH TO PORT PLANNING, OPERATIONS & RISK MANAGEMENT THROUGH TECHNOLOGY

by

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## ABSTRACT

Ports and shipping channels are critical components of many nations' transport infrastructure, and make a significant contribution to the economy. With increasing global trade comes further pressures on ports through greater volumes, larger vessels, and more demanding shipping schedules. This is occurring against a backdrop of increasing regulatory, environmental, and social requirements for port authorities and operators that makes development more challenging. Furthermore, port authorities often hold the dual responsibility of facilitating trade and ensuring port safety.

Advancements in technology from a range of fields in the maritime sector are enabling new solutions to these challenges. Developments include improvements in hydrodynamic modelling capabilities, high density bathymetric surveys, improvements in weather forecasting, cost effective access to real time met-ocean data, advancements in environmental data assimilation techniques, broad adoption of AIS and Electronic Navigational Charts (ENCs), and high precision measurement of vessel motions in full scale and real time using DGPS and IMU technologies. Each of these developments individually has provided benefits to the industry. However, the greatest benefits, from the dual perspectives of risk management and efficiency, are realised when they are integrated and implemented across both the planning and operations of a port.

Changes across the industry, and within specific port environments, such as vessel sizes, transit speeds, channel depth profiles, transit times, and changes to port layouts resulting from new berths or dredging can influence the applicability of long standing port procedures and risk management functions, particularly static UKC regimes.

To highlight the changing nature of the port operating environment, this paper presents three separate examples where assumptions about port operations have been incorrect, and consequently, the design or operating procedures have required amendment.

The paper culminates with case studies for the Ports of Port Hedland, Whyalla and Geelong, to examine how a suite of integrated software solutions deliver increased safety and improved operational performance. This is achieved through a consistent approach to port planning, capital and maintenance dredging, vessel fleet planning and chartering, vessel transit planning, and real time in-transit monitoring.

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# 1. INTRODUCTION

Ports and shipping channels are critical components of many nations' transport infrastructure, and make a significant contribution to the economy. In Australia, the daily trade flows through ports is estimated at $1.2 billion (Ports Australia, 2017). With increasing global trade comes further pressures on ports through greater volumes, larger vessels, and more demanding shipping schedules. This is occurring against a backdrop of increasing regulatory, environmental, and social requirements for port authorities and operators that makes development more challenging. Furthermore, port authorities often hold the dual responsibility of facilitating trade and ensuring port safety.

Advancements in technology from a range of fields in the maritime sector are enabling new solutions to these challenges. Developments include improvements in hydrodynamic modelling capabilities, high density bathymetric surveys, improvements in weather forecasting, cost effective access to real time met-ocean data, advancements in environmental data assimilation techniques, broad adoption of AIS and Electronic Navigational Charts (ENCs), and high precision measurement of vessel motions in full scale and real time using DGPS and IMU technologies. Each of these developments individually has provided benefits to the industry. However, the greatest benefits, from the dual perspectives of risk management and efficiency, are realised when they are integrated and implemented across both the planning and operations of a port.

# 2. THE UKC CHALLENGE

*The problem of underkeel clearance is not new; since time immemorial navigators have been concerned to know the minimum depth of water in which they can sail with a ship of given draft. Until quite recently, underkeel clearance requirements were determined almost entirely empirically, and in many cases the rule of thumb values used can be shown to be greater than the requirement of navigational safety would dictate.*

*In the years since the war the pattern of the oil industry has changed and very large ships are now commonly used to carry crude oil cargoes to a large number of ports around the world. It is obvious that use of these ships, with their deep drafts, has meant that a number of expensive dredging projects have been put in hand to provide adequate access to the ports served. Continuing escalation in size means this will probably continue. (Dickson, 1967)*

The above quote was published in 1967, and remains equally true today. Static rules are the mechanism by which most shippers and regulatory authorities manage 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 (PIANC, 2014). The implication is that the static UKC rules typically must account for some level of uncertainty to accommodate the expected range of scenarios and conditions. Adopting a one size fits all approach generally results in an inefficient operation. Furthermore, the assumptions on which the static UKC rules were originally based also change over time. Often, the static UKC rules themselves are not reviewed in line with the changes to the underlying assumptions. Examples of changes to port operations that may influence the applicability of a static UKC regime include vessel size, transit speed, channel depth profile, transit time, and changes to port layout resulting from new berths or dredging.

A general summary of the factors that influence UKC is presented in Figure 1. For a non swell exposed environment, squat is the generally dominant UKC component. 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.

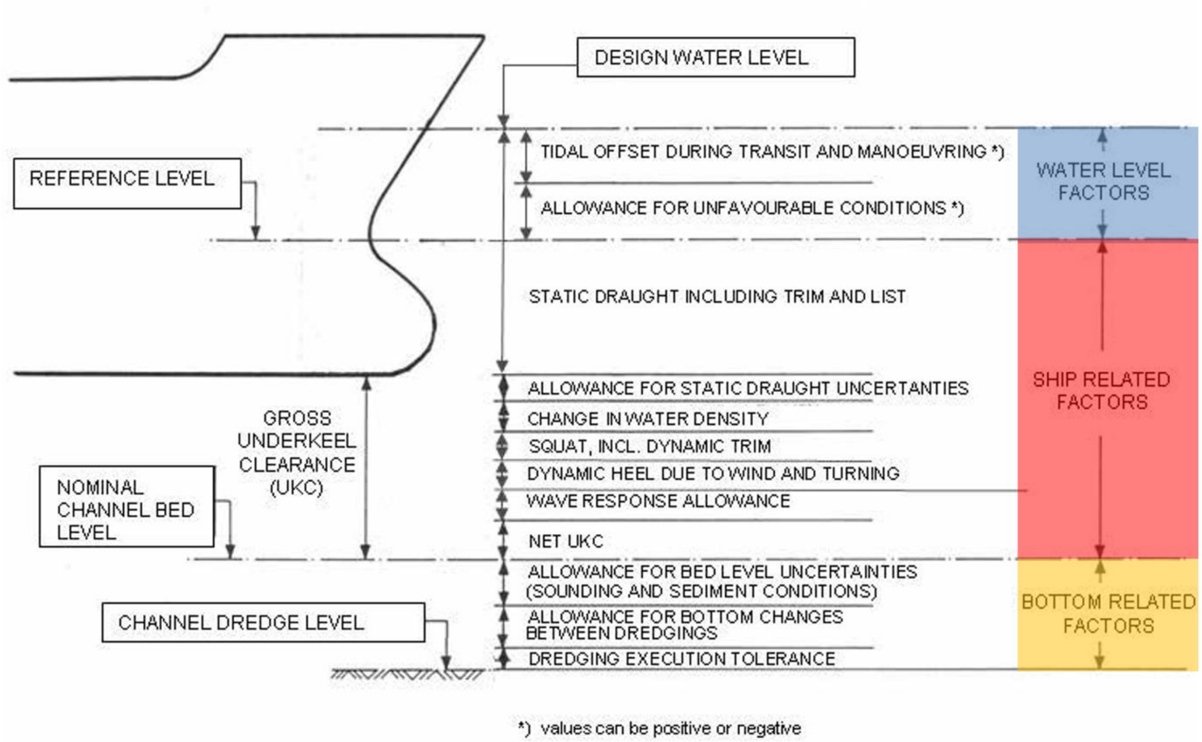


**Figure 1 Channel Depth Factors (PIANC, 2014)**

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.

Secondly, the static allowance is determined with some level of conservativism to account for the individual, but otherwise unknown, UKC factors. This results in inefficiencies when conditions are favourable, as the sailing draft or departure time is restricted by the conservative static rule, with obvious economic implications.

## 3. INCORRECT ASSUMPTIONS

The application of a static UKC rule to the safe operations of a port has inherent assumptions regarding each of the UKC factors and contributing variables. As those variables change over time, the UKC rules should also be reviewed. To illustrate the changing nature of the port operating environment three examples are provided from projects in which the author has been involved where assumptions about the operations have been incorrect, and consequently, the design or procedures have required amendment. Given their nature, these examples are presented anonymously.

### Example 1: Vessel Speed

The author was involved in a UKC assessment for a port. The study involved assessing the risk of grounding. The client provided the vessel speeds for which the analysis should be completed as 10 knots, but allowing for a +/- 1 knot variation. However, when these speeds were later validated against AIS, it showed that the vessels actually often transited at 3 to 4 knots faster than the client had assumed. This variation resulted in 0.60m to 0.90m extra squat than initially calculated, thereby changing the risk profile of the transit considerably. **Error! Reference source not found.** shows the nominated speed profiles plotted against the AIS derived speeds. The Eryuzlu squat curve (PIANC 2014) for the design vessel and channel profile is shown in **Error! Reference source not found.**. The impact on the calculated squat of increasing speed from 10 knots to 12 or 13 knots is clearly evident.

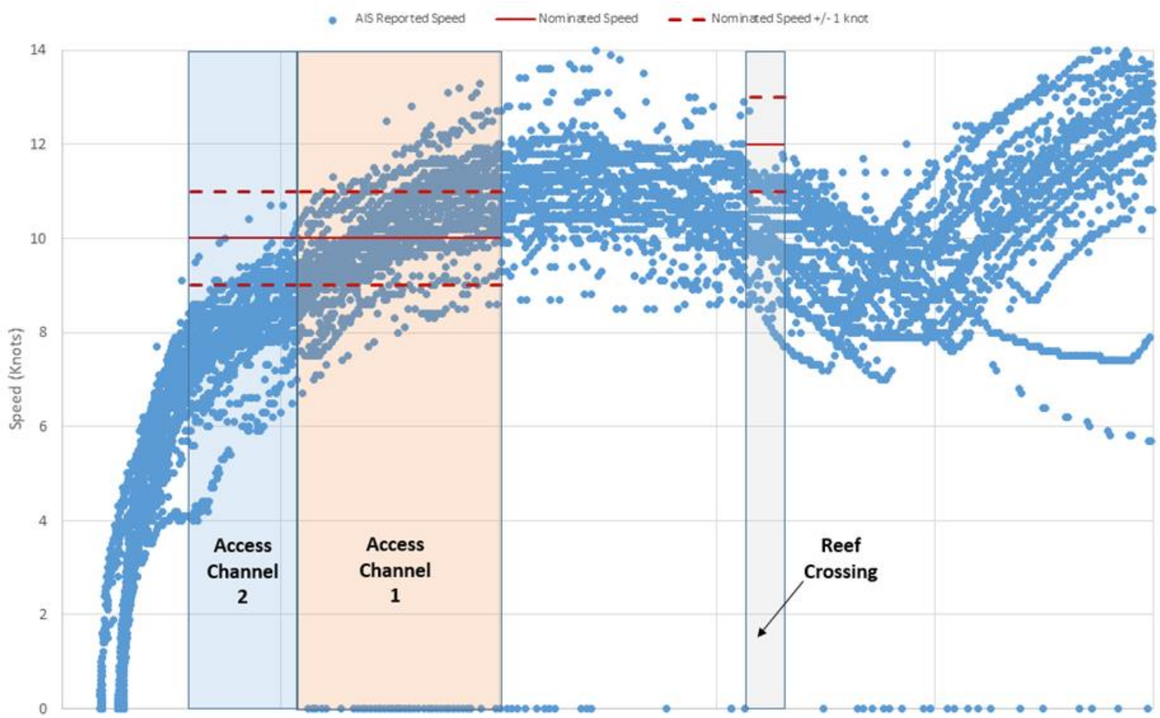


**Figure 2 Vessel Speed Analysis. AIS analysis indicates that vessels transit considerably faster than assumed**

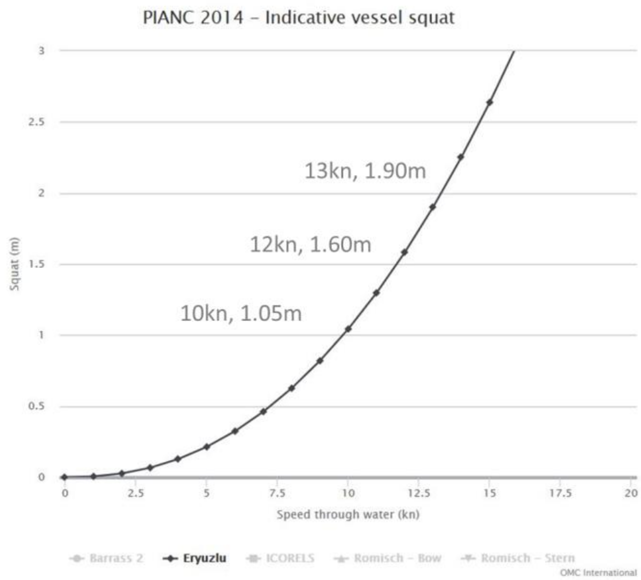


**Figure 3 Eryuzlu Squat Curve. Increasing speed from 1o knots to 12 or 13 knots significantly increases the calculated squat.**

**Example 2: Tidal Assistance**

The second example relates to a port which typically operated with a fixed departure time relative to high water. Their static UKC calculation was based on the high water tide. Operations evolved over time such that the transits commenced up to one hour earlier. Given the large tidal range experienced at the port, the actual tide at departure time could be 0.90m to 1.0m less than the high water tide. Instead of the assumed static UKC of 10% of draft, the actual static UKC was 4% of draft. This had resulted in manoeuvrability issues for some vessels.

**Example 3: Wave Response**

The third example is for a port which experiences beam on swells for Capesize bulk carriers. Following concerns over the wave response, an analysis of the vessel fleet profile highlighted that the typical beam had increased from 45m to 54m. For the same angle of roll, the measure by which the pilots indicatively monitor the wave response, the reduction in UKC for these larger vessels was 20% more than for the vessels for which the static UKC rule was intended.

## 4. INNOVATIONS

**DUKC®**

An alternative approach to UKC management is a dynamic UKC regime, 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 individually, considering the unique specifics of the transit. The transit specifics include 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 dynamic 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.

The concept of a dynamic approach to UKC management is not new, with the first Dynamic Under Keel Clearance System (DUKC®) being operational at the coal export terminal in Hay Point (Queensland, Australia) since 1993. The DUKC® has evolved considerably since then as the supporting technologies have advanced, and has safely facilitated over 159,000 deep draft transits throughout more than 120 port facilities, terminals, and waterways.

The core functionality of the DUKC® is to provide ports, regulators and shippers with dynamic passage planning advice regarding:

- Maximum sailing drafts for known or fixed sailing times;
- Sailing window times for known or fixed sailing drafts;
- UKC and vessel motion information 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 4, or via the DUKC® website. This functionality provides critical real time data to pilots and harbour masters during emergency scenarios (such as engine slowdowns or steering failures) to enable the optimal response to the situation.

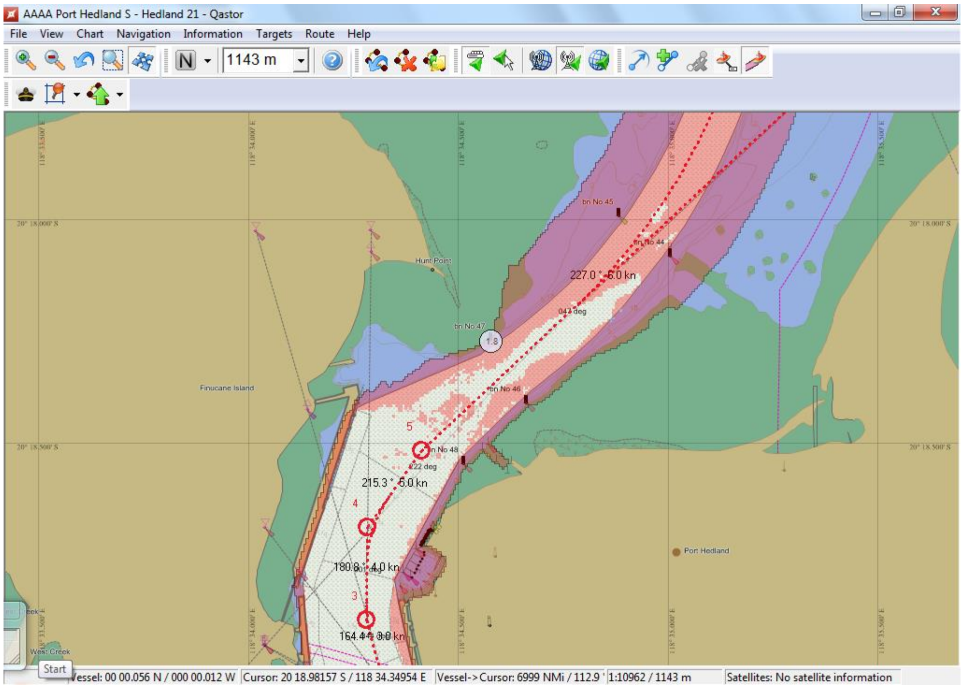


**Figure 4 Chart Overlay (Source: Internal). Pilots have direct access to real time UKC information via the PPU.**

### DPCM®

An advancement of the DUKC® has been into the area of Port Capacity Modelling. The Dynamic Port Capacity Model (DPCM®) is the world's first discrete event simulation model that incorporates the dynamic under-keel clearance calculations. 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.) as well as capital projects including dredging, and new berths.

### Dredge Optimisation

The DUKC® is also utilised in channel design and dredge optimisation. 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. From this analysis, the optimal channel depths required to achieve the desired channel accessibility can be determined.

## 5. CASE STUDIES

### Case Study 1: Port Hedland

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 5 shows the annual export tonnages, and total vessel movements.

Facilitated by innovative port optimisation and risk management technologies implemented by PPA, the port set a number of trade records in 2017 (Pilbara Ports Authority, 2017):

- Annual throughput of 500.9 million tonnes (an increase of ~40m tonnes or 9%);
- A monthly throughput of 47.25 million tonnes;
- A total of 272 vessel visits in a month;
- Exports of 2,183,611 tonnes in 24 hours;
- A total of 1,589,061 tonnes across 8 vessels on a single tide, an increase on the previous record of 77,084 tonnes.
- Sailed more than one million tonnes on a single tide over 60 times, having only achieved one million tonnes on a tide for the first time ever in 2012.

Additionally, the deepest draft to sail is 19.95m for a total of 270,006 tonnes.

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 (Government of Western Australia Department of State Development 2016).

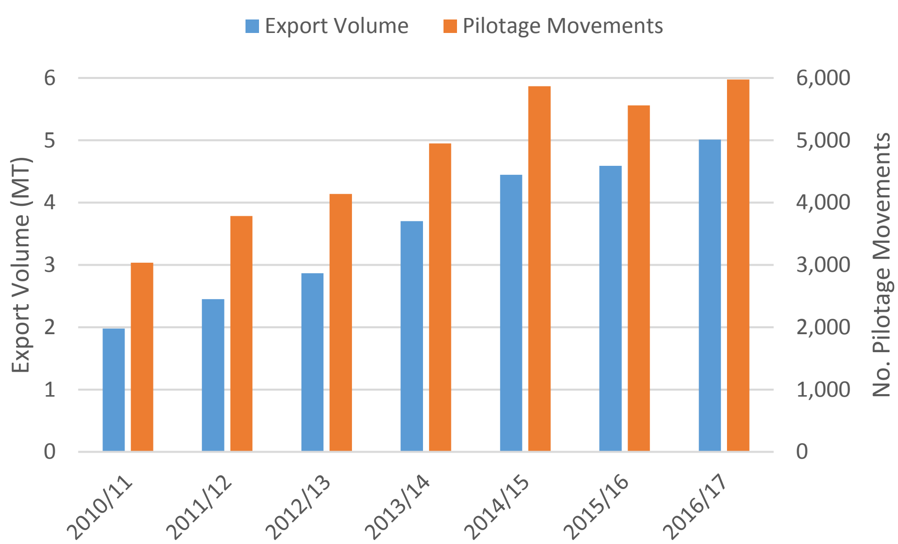


**Figure 5 Port Throughput (Pilbara Ports Authority, 2016, 2017). The volume of trade through the port has grown significantly since 2010/2011.**

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

Figure 6 shows the layout of the channel, which is approximately 42km long and uni-directional.

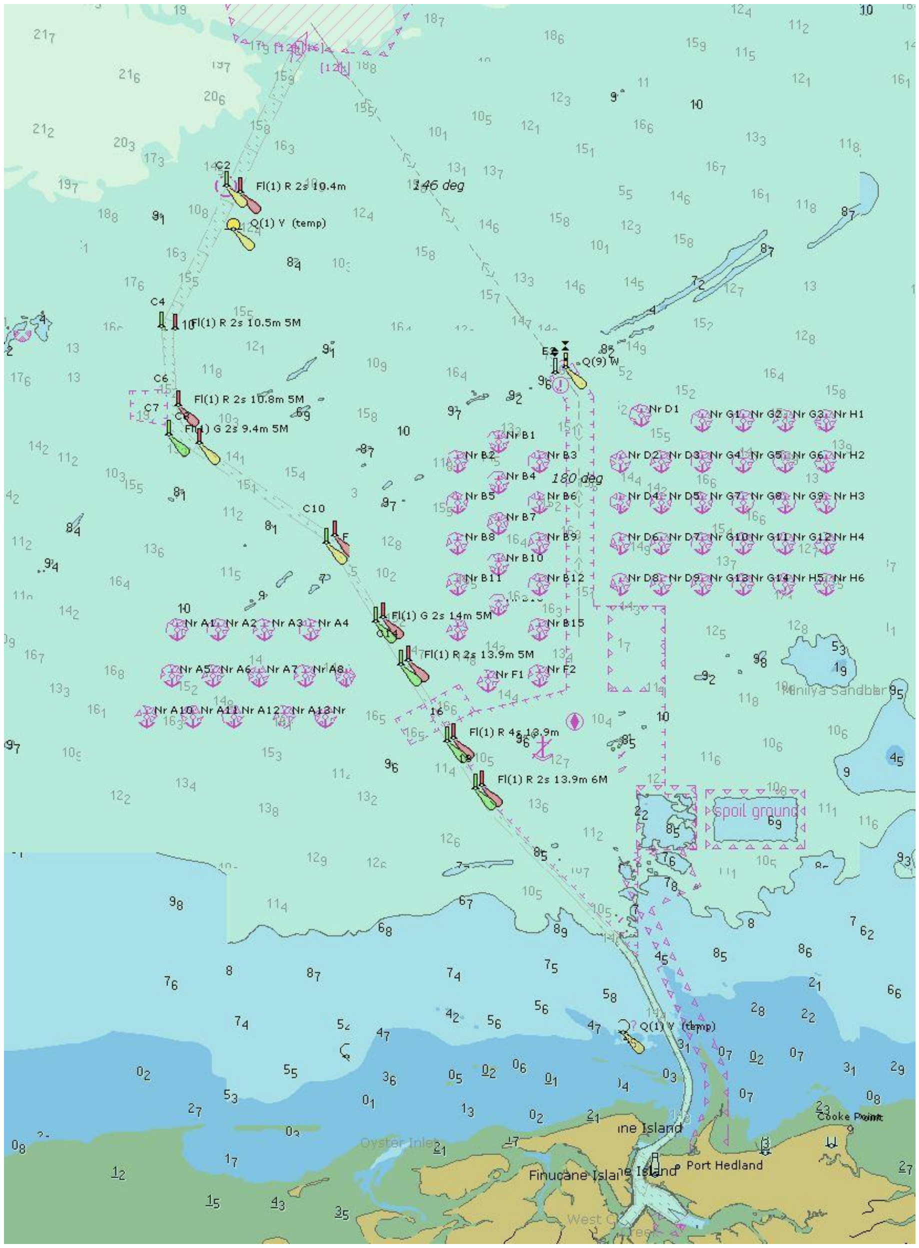


**Figure 6 Channel Layout. The 42km, uni-directional, tidally restricted channel creates a challenging operating environment.**

Access to the harbour is constrained through a 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 (Ayre 2016).

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 **Error! Reference source not found.**.

| Year of Build | DWT (kt) | 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 | 260 | 57 | 327 | 19 |

**Table 1: Evolution of Capesize Vessels. The trend is vessel sizes has been towards longer, wider, and deeper. (Ayre 20016)**

As vessel sizes have increased, the port has seen an corresponding increase in the proportion of large vessels calling, as shown in Table 2.

| Vessel Size | 2009/10 | 2015/16 | 2016/17 |
|---|---|---|---|
| >200k DWT | 10% | 31% | 33% |
| >250k DWT | nil | 7% | 9% |

**Table 2: Port Hedland Vessel Fleet. Vessels greater than 200k DWT account for one third of total vessels. (Fernandes 2018)**

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 (Finch 2016). 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 (Pilbara Ports Authority 2017). 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.

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 (PIANC 2014). 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.

PPA uses DUKC® to mitigate the risks of the port, including the Transit Monitoring and Chart Overlay functionality (Finch 2016). DUKC® assists in managing vessel drafts and sailing windows delivering on average 0.60m to 0.80m additional draft, equating to up to 12,000 tonnes per vessel. Furthermore, as every transit is monitored in real time via AIS, subtle differences or changes in the operating parameters, such as the speed profiles associated with particular vessel classes, can be tracked over time.

An additional key strategy in managing the channel risk currently under development by PPA is the $120m Channel Risk and Optimisation Project (CROP), the budget for which received 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 (Government of Western Australia Minister for Agriculture & Food; Transport 2015). The wider sailing window creates opportunity for increase separation times between vessels, thereby providing optionality in an emergency scenario.

PPA used DUKC® technology in evaluating the proposed CROP channel design depth profiles, and to ultimately quantify the benefits of the project.

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.

PPA initially presented four draft channel design profile options based on their initial assessment of what would likely be achievable from a capital dredging perspective based on existing depths and geography of the channel, their historic knowledge of the geotechnical properties of the seabed, the overall dredge volumes, and their budget targets. OMC performed a preliminary study yielding a preferred profile. From this preferred channel profile, further refinement by the PPA produced an additional four channel profiles for analysis by OMC. Comparing the simulation results with the baseline scenario yielded the expected benefits of each proposed channel profile.

The value of the DUKC® approach to the channel design process was that the PPA's Operations Team was able to identify a channel depth profile that significantly reduced dredging of geotechnically challenging, and therefore costly, areas by over 90,000m2 without any reduction in benefits.

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. This analysis highlighted that utilising DUKC® for dredging optimisation resulted in a considerable benefit over a traditional static UKC approach. To achieve the same level of accessibility would have required a channel profile on average 0.63m deeper, and up to 1.4m deeper.

From a port planning perspective, PPA also utilise the DPCM® innovation. 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 (Government of Western Australia Minister for Agriculture & Food; Transport 2015). This increase is one third of the additional capacity proposed by the now shelved Outer Harbour project, which had an estimated cost of $20b (Environmental Protection Agency 2012).

## Case Study 2: Whyalla / Spencer Gulf

In contrast to Port Hedland, Whyalla is a regional port operated by Liberty OneSteel, a steel manufacturer and iron ore exporter. The port handles on average 10 ships per month through two channels and 3 berths, and a transhipment operation. With a tidal range of 2.7m, complex tidal phasing, and residuals that can reach in excess of ±1m, the challenges facing the operations at Whyalla are significantly different from those at Port Hedland.

The iron ore is exported through two operations: direct loading from the Outer Harbour in Handymax vessel, and transhipment to Capesize vessels which then transit the Spencer Gulf.

The Spencer Gulf is located in the state of South Australia and faces the Great Australian Bight. It is 322 km long and 129km wide. The piloted capesize shipping route from north to south is approximately 85km in length with a transit duration of about 4.5 hours.

The tidal regime in the Spencer Gulf in critical from a shipping perspective for a number of reasons. The tidal ranges reach 2.7m, but given the narrowing of the Gulf towards the north, the tidal ranges are greater at the start of the transit near Whyalla than at the end of the transits at Middlebank. Furthermore, the phasing of the tides is inconsistent such that the time between high waters varies. This complicates transit planning as any variations in the planned vessel speed or transit duration will result in less available water at the end of the transit. An example is shown in Figure 7.

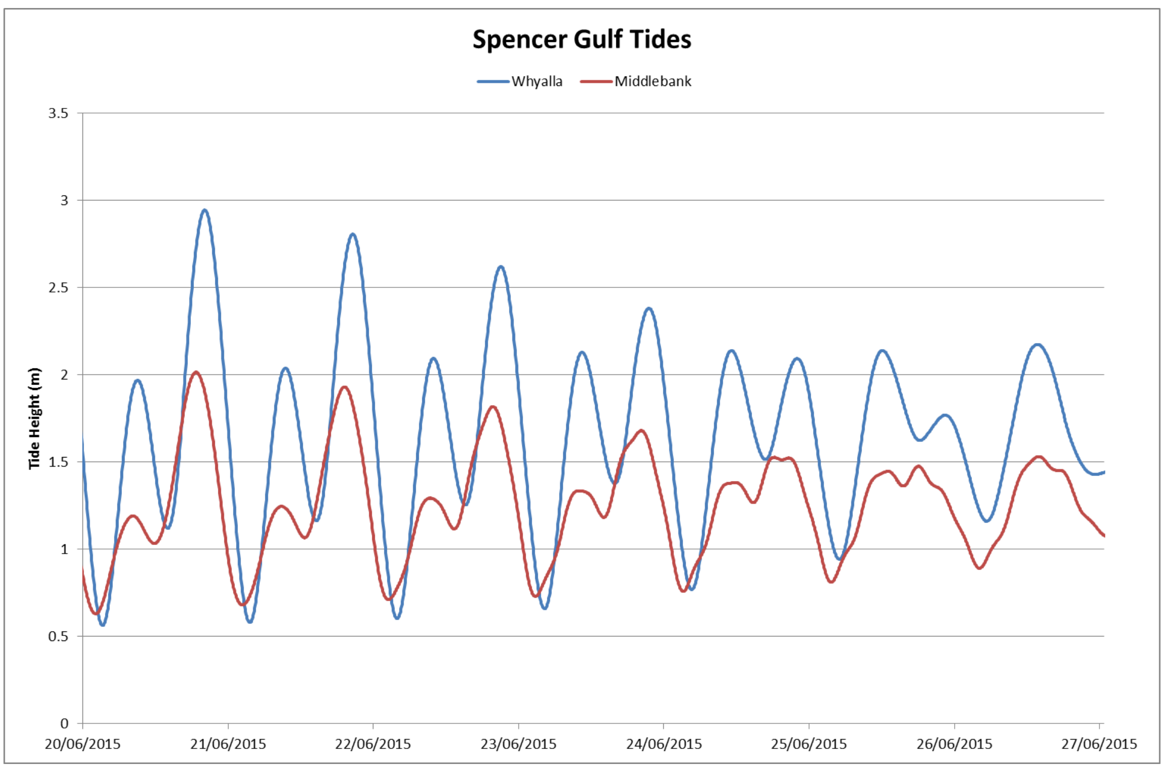


**Figure 7 Spencer Gulf Tides: Complex tidal phasing impacts transit planning (OMC 2014).**

The second key issue with tides is that local weather systems can result is significantly depressed tides (negative residuals). It is not uncommon for these residuals to be in excess of 30cm, which can equate to between 15% and 30% of the total tide, and as much as 1.0m. Failing to account for this loss of water when planning sailing drafts can have potentially serious consequences for safety.

The third key issue for tides is what is locally coined *dodge* tides. A dodge tide is an event where a neap tide has minimal variation of the course of the tidal cycle. This results in a very flat tidal plane. From a shipping perspective this can result in a vessel being unable to sail whilst waiting for a sufficient high water.

The Recommended Track, shown in Figure 8, is mostly deep water. However, there are two locations where underkeel clearance is critical. The first is Yarraville Shoal, which is approximately 9 nautical miles from the transhipment point and has a declared depth of 19.4m. The second shoal is at Middlebank, which is approximately 40 nautical miles from the transhipment point and has a declared depth of 20.1m.

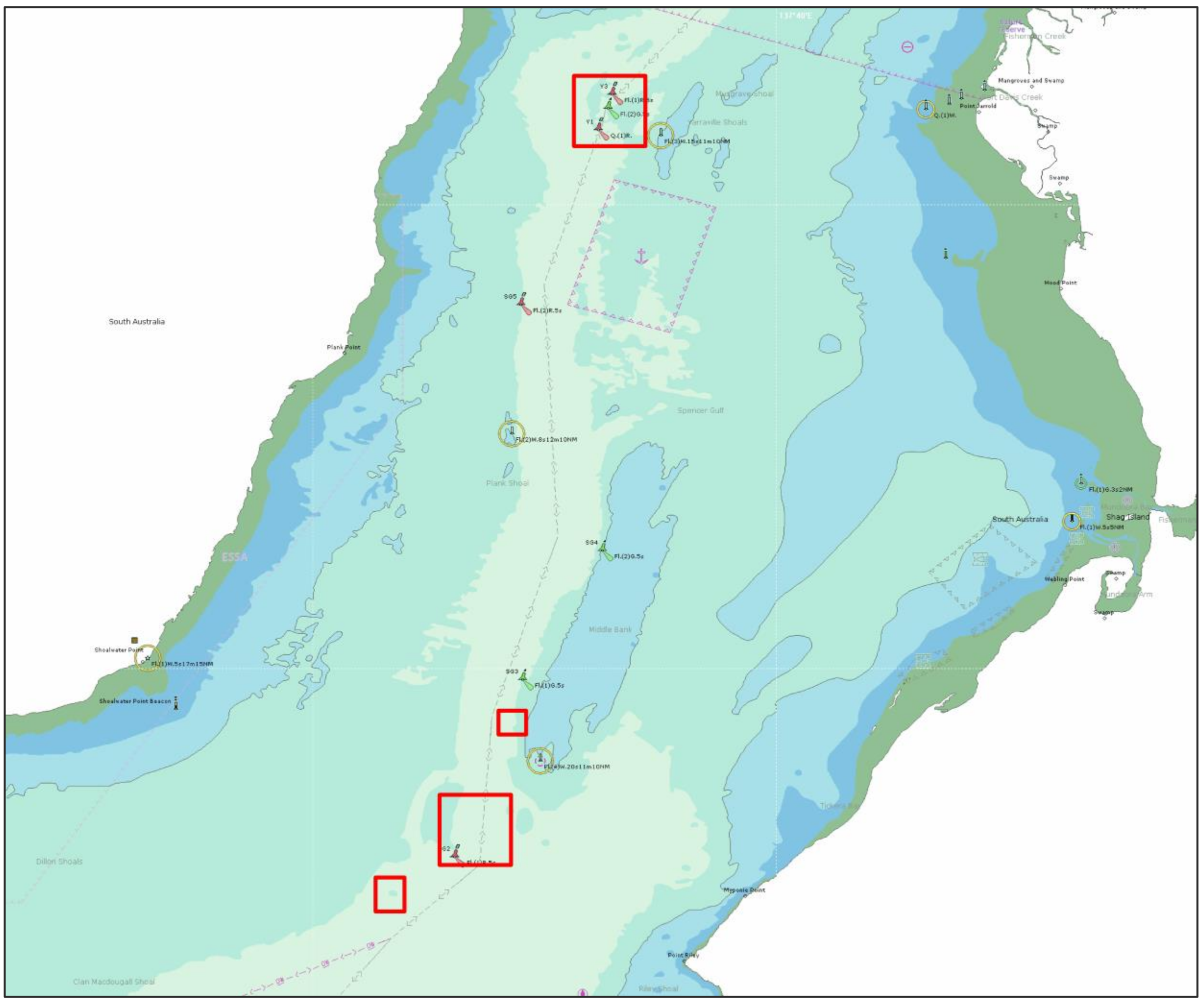


**Figure 8 Spencer Gulf Route: UKC critical locations are several hours apart.**

These known shoals are surveyed to a tolerance of 0.25m and 0.40m respectively. Outside of the areas, the depths are applied as per the hydrographic charts. However, these surveys are known as Class A2, which implies a Zone of Confidence (ZOC) margin of 1m plus 2% of depth. Therefore, a depth reading of 21m could in fact be as shallow as 19.58m.

To account for these uncertainties, the Capesize vessels required a static UKC rule of 15% of draft, with a maximum draft of 18.2m imposed. With the improved risk management functionality achieved with the implementation of DUKC®, the efficiency of the port operations improved significantly.

The Spencer Gulf DUKC® was the first ever application of Dynamic UKC technology to a transhipment operation (Saltbush to Steel, 2015). The technology has improved efficiencies allowing increased drafts and tonnages, leading to new records being set for both. In the first year of operations, a total of 34 vessels were able to load beyond the previous maximum draft of 18.2m. The average increase in draft was 0.11 metres, with the greatest increase being 0.27m. Note that this result was limited by the size of the vessel. The DUKC® could deliver even deeper drafts should larger vessels frequent the port.

In total, the freight savings amounted to US$738,000, far exceeding the base case estimates. Furthermore, an additional tonnage in excess of 50,000t was shipped, providing an increase in revenue of US$2.5m (Curtis 2016).

On October 24th 2015, the MV FPMC B Nature was loaded to 205,700 wet metric tonnes, setting both new record for tonnage and draft at 18.43m (Whyalla News 2015). The draft record was broken twice in December 2015, and again in February and March 2016, with the Lavinia Oldendorff, Lydia Oldendorff, and Leopold Oldendorff all sailing at 18.47m.

This case study highlights the economic benefits available when an investment is made in identifying operational inefficiencies, and understanding the accretive value of improving these inefficiencies. It demonstrates that improved technology can yield significant value even for relatively low volume ports that are naturally deep and not swell exposed.

### Case Study 3: Geelong Port

The third case study to be reviewed is the Port of Geelong. Major port customers include Viva Energy, GrainCorp, and Midway Limited, a publicly listed woodchip exporter. Geelong Port handles over 600 vessel visits every year. The majority of the shipping activity is linked to the bulk liquid berth at Refinery Pier, which serves as an import destination for the Viva Energy refinery. The refinery supplies about 55% of the fuels needs for the state of Victoria, and accounts for 20% of ship visits and 50% of the port’s trade. Recognising a need to attract larger vessels, improve operational efficiency, and increase their competitiveness, the port implemented DUKC®.

In its endeavour to accept larger and deeper vessels, the port faced several challenges including depth and width restricted channels, and a complex tidal regime with a seiching effect and the potential for rapid changes in water levels influenced by local weather systems.

A key innovation for the Geelong Port DUKC® was the implementation of TideCaster. TideCaster is a new approach to water level forecasts that incorporates numerical forecasts with in-situ environmental observations on an operational basis. TideCaster provides the ability to tailor a forecast to achieve a desired level of conservatism across a planning horizon, and can improve the accuracy when compared with astronomical tides, numerical forecasts, and persistence based forecasts (Uslu et al. 2017).

The core DUKC® functionality of the determination of tidal windows and maximum sailing drafts at Geelong Port is complemented by advanced in-transit risk management including Chart Overlays and Transit Monitoring. This enables pilots or VTS operators to adjust the planned vessel speeds in order to achieve a safe UKC profile, monitor the actual transit speeds, and identify the exact location within the channel of low UKC areas (Abraham, 2018). An example of the Chart Overlay function is provided in Figure 9**.**


**Figure 9 Geelong Chart Overlays: UKC critical locations are highlighted.**

The port adopted a phased approach to the implementation of DUKC®, whereby drafts were incrementally increased by 0.10m on subsequent vessels. The first six vessels that sailed at a draft beyond the static UKC rule underwent a full scale validation using high precision differential GPS units on board. This enabled the port to compare the DUKC® computed vessel motions and UKC with the actual vessel motions. In addition to providing evidence as to the accuracy and safety of the DUKC®, the full scale validation gave confidence to the various stakeholders within the port. Some examples of the validation results are provided in Figure 10

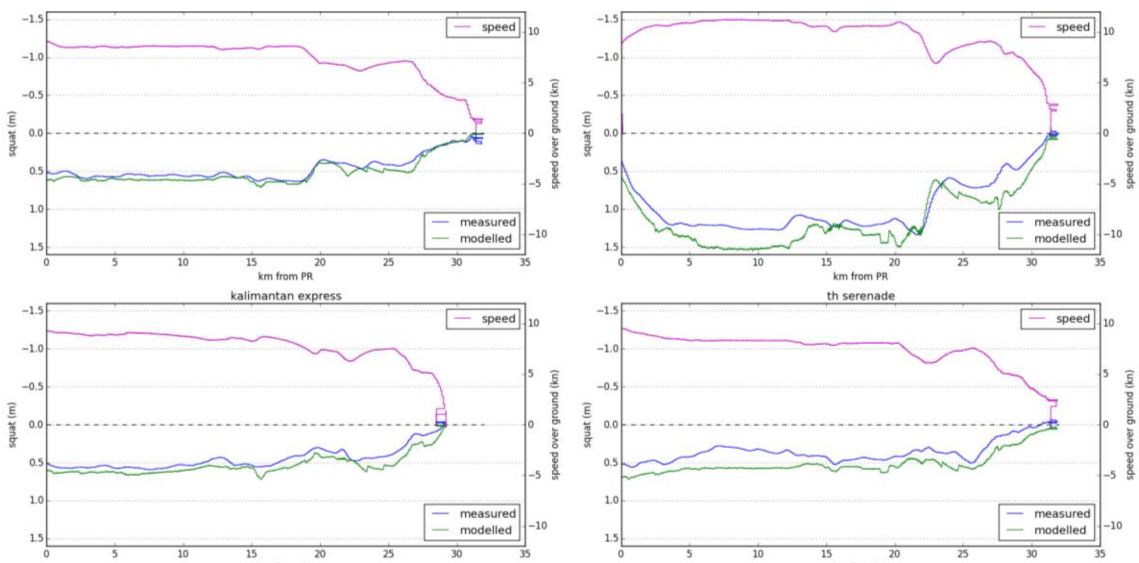


**Figure 10 Geelong Full Scale Validation Results (Abraham, 2018).**

Since the implementation of DUKC®, the port has set several records. The technology has allowed inbound tankers to safely increase their drafts beyond what was previously achieved. With annual cost reductions in the order of $1m for every additional 10cm in draft (Lannen 2016), the DUKC® has delivered multi-million dollar benefits for the port and its customers.

Additionally, the export customers have been able to ship an additional 7,000 to 9,000 tonnes of cargo per ship, thereby increasing revenues and reducing the per tonne freight costs (Lannen 2016). The practical benefits of DUKC® to the shippers are evident in the record tonnages that have resulted since its implementation, including:

- Largest ever draft with the oil tanker *Phoenix Advance* in August 2016 (Lannen 2016);
- Record cargo of woodchips on the *Fujian Express* in January 2016 (Shand 2016);
- GrainCorp's biggest single shipment of canola from Geelong, with the Nord Pollux sailing with more than 61,900 tonnes;
- Its biggest single shipment of wheat fully loaded in Geelong, with the Tomahawk departing carrying almost 61,800 tonnes;
- Its largest shipment of barley fully loaded in Geelong, with the Twinkle Island sailing with about 62,500 tonnes;
- Exporting the most grain ever in a month, more than 393,560 tonnes;
- The Port recording the largest month of exports – grain and woodchips – with total shipments topping 412,750 tonnes. (Victorian Regional Channel Authority 2017)

## 6. CONCLUSION

The ports of Geelong, Whyalla, and Port Hedland differ significantly in terms of operations, volumes, trade, environmental conditions, channel profiles, and port layouts. Despite these differences, and the unique challenges they present, the same risk management technology has been for tailored for use at each to improve the shipping efficiencies, thereby achieving significant increases in throughput, reduced dredging requirements, and reductions in freight costs.

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 with respect to risk management, and be in a position to demonstrate the value delivered from capital investments and operational decisions. The suite of tools presented herein provides port authorities, terminal operators, and shippers with a comprehensive solution to manage risk, and analyse and evaluate decisions, both planning and operational. This helps ports meet their commercial demands whilst always ensuring vessel safety and channel integrity.

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