El MEJORAMIENTO DE LA SEGURIDAD DE LA NAVEGACÍON UTILIZANDO EL SISTEMA DUKC®

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ABSTRACT

El mejoramiento y el mantenimiento de la seguridad de la navegación es una prioridad para todos aquellos involucrados en el ambiente marítimo. El mejoramiento es posible atrevas de mejores disensos, entrenamiento y la incorporación de información en el proceso de toma de decisiones de la navegación. El impacto contra el fondo y la perdida de maniobrabilidad del buque por la falta de distancia bajo quilla son riesgos constantes para la seguridad de la navegación. En un ambiente fluvial con cambios continuos de fondo, salinidad, corrientes y niveles del agua los pilotos se ven desafiados a controlar la velocidad del buque para maniobrarlo evitando tocar el fondo por exceso de velocidad o insuficiente espacio bajo quilla.

Recientemente la seguridad de la navegación de la vía navegable del rió Weser en Alemania fue mejorada por medio de la adopción del sistema DUKC® (Sistema de margen de seguridad bajo quilla). De DUKC® es un sistema único al controlar la distancia espacio bajo quilla (UKC) en tiempo real que permite a las personas que lo usan a mantener el espacio bajo quilla de los buques que transitan la vía navegable. El asesoramiento que el DUKC® ofrece es calculado tomando en cuenta todos los factores que influyen la distancia bajo quilla como las dimensiones del buque, carga de datos, ultimas medidas y pronósticos de las condiciones ambientales (marea, salinidad, corrientes y oleaje) y datos de batometría de alta densidad. En la parte fluvial del rió Weser la marea, las corrientes y la salinidad son los factores ambientales principales, mientras que en la boca del rió la respuesta al oleaje es también un factor importante. Por la actualización constante de los últimos datos de batometría (realizadas por las mediciones suministradas) el DUKC® asegura que las decisiones sean tomadas considerando la información mas reciente.

Aunque el sistema DUKC® ha sido ya instalado en más de 15 puertos alrededor del mundo, el río Weser ha sido el primer puerto fluvial que ha adoptado esta tecnología. Los tiempos de transito largos que el Weser presenta han introducido una serie de retos para la tecnológica del DUKC®. Como los pronósticos largos son más inciertos, las márgenes de seguridad mas largas serán requeridas. Eso creara un impacto en los beneficios económicos del sistema. Estos retos fueron sobrepasados por el uso de la tecnología DUKC® In-Transit. Esta tecnología brinda a los operadores de VTS (sistema de tráfico de naves) asesoramiento sobre margen de seguridad bajo quilla en tiempo real. El sistema DUKC® VTS permite monitorear la dimensión vertical durante el pasaje de una nave. Cuando una brecha potencial ha sido identificada los operadores son alertados. Los operadores y los pilotes pueden entonces determinar el curso de acción a seguir para evitar la brecha.

Las temas de seguridad de la navegación encontradas en el río Weser son similares a ésas encontrado en el río de la Plata y río de Paraná. El uso de la sistema DUKC® In-Transit tecnología en esos vías navegables prometería mejoras parecido de la seguridad de la navegación. Por la utilización de un método científico y exacto de identificación y predicción de los componentes relevantes de la distancia bajo quilla el DUKC® asegura que la seguridad de la vía navegable del río Weser cumpla con los mejores estándares de calidad gracias al manejo del DUKC®. La introducción de la tecnología DUKC® en los puertos y vías fluviales Latinoamericanas es un paso lógico en el mejoramiento de la seguridad de la navegación de la región

1. INTRODUCTION

In 2008, after an internationally tendered process, OMC-International (OMC) was contracted by the German Waterways and Shipping Directorate (WSA) to develop a Dynamic Underkeel Clearance (DUKC®) system for the Weser River. The motivation of WSA in implementing a dynamic UKC management system was to account for the unknown as the waterway and its utilisation began to

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change. The waterway authority was planning an extensive dredging campaign with the objective of increasing the declared depth in the river. Additionally, very large deep draft vessels were beginning to arrive on a regular basis. These vessels included E-Class Maersk container vessels, with a capacity of approx 14700 TEU. Because of their larger size and deeper draft, these vessels challenged the existing operational standards that were based on experience and were forcing waterway regulators and pilots to operate outside their experience and empirical knowledge. The implementation of a DUKC® system, which was designed to alleviate these issues by providing scientifically based forecasts of the UKC requirements of vessels transiting the waterway, allowed the authority to actively manage the UKC of vessels in the waterway.

The development and implementation of the DUKC® system for the Weser waterway introduced a series of challenges for OMC. These included:

- Institutional,
- Technical,
- IT, and
- Logistical challenges.

The institutional challenges arose from the multitude of stakeholders involved in the project and the institutional complexity involved in dealing with them. The stake holders comprised of 2 separate pilot groups, 2 waterway authorities (based in Bremerhaven and Bremen), and 4 ports that were to be modelled in the system. Each of these parties had different requirements and expectations of the system that needed to be met. Until this time the application of the DUKC® system had been limited to marine ports where water density variations were minimal, the bottom sediments were hard rock or marine sands, and the transit lengths were relatively short being at most 3-4 hours. The riverine ports along the Weser and its extent - 135 km of waterway including river, estuary and sea sections - presented new environments for the DUKC® system that required technical modifications to the underlying DUKC® models. As the Weser waterway encompasses the jurisdiction of two waterway authorities, the deployment of the system was complex. Both authorities ran separate VTS centres and both centres required access. Synchronisation of the system between the two centres was essential to maintain continuity as vessels passed from one jurisdiction to another. Additionally the incorporation of AIS feeds and the transmission of the UKC reports to the different pilot groups combined to present a complex technical exercise. Finally, OMC faced a series of logistical issues given the nature of the project: the deployment of a large system in Germany practically the opposite side of the world from OMC’s head office in Melbourne.

The Weser DUKC® system is now in the second year of a 24 month trial process. And its development is the focus of this paper. The areas that will be covered are some background of the Weser and the project requirements, a discussion on the DUKC® and its principles, and how it was configured for Weser. The operational procedures of the DUKC® and its use will be covered and finally some thoughts on the applicability of DUKC® to other waterways based on the Weser experience.

2. WESER WATERWAY

The Weser river is one of the main rivers in Germany and with the River Elbe provides the main route of direct maritime contact between Germany and the sea. Germany is also indirectly connected to the North Se through the Rhine River which enters The Netherlands downstream and terminates in Rotterdam. Between the sea and the city of Bremen there are many minor ports with 4 major ports located along the river: Bremerhaven, Nordenham, Brake, and Bremen. The Weser waterway is used to transport a wide variety of cargo. Bremerhaven is the 4th largest container port in Europe and handled 5.4 million TEU’s in 2008 and transported over 1.3 million cars. Bremen handled over 14 million tonnes of cargo in 2008. This includes the import of petroleum, coal and iron ore and the export of steel (Facts and Figures 2008).

While the river itself is over 450 km in length, the navigable section for deep draft vessels only extends to Bremen. The navigable section comprises 135 km of waterway. This covers a sea section that is exposed to the North Sea, an estuary section that extends from the barrier islands to Bremerhaven and a river section from Bremerhaven to Bremen. The geographic extent of the Weser waterway is indicated in Figure 1.

Figure 1: Map of the Weser and major ports. The extent of the waterway is indicated by the aqua line. source: Google Earth

The physical processes that are relevant to vessel underkeel clearance vary significantly along the river. In the North Sea, the water level is dominated by a semi diurnal tidal regime. The large tidal extents combined with a gently sloping bathymetry generate strong tidal currents. Owing to the influence of the river, an asymmetry exists in the current magnitudes with the Ebb current of slightly greater magnitude than the Flood. This asymmetry decreases further out to sea and increases upstream as the influence of the tide reduces. The outer sections of the channel are fully exposed to waves generated in the North Sea. The estuary sections of the waterway are more sheltered and by the river section the waves that influence ships are not present. Similarly, the salinity and consequently the density of the water, vary significantly along the waterway. In the North Sea the salinity is typically 32PPU, whereas in Bremen this value has reduced to around 5PPU or less. Additionally the salinity in the river is not consistent spatially but varies with the tidal current and the strength of the flow upstream. Typical salinity levels over the tidal cycle can be established for a location, but in times of flood the fresh water entering at Bremen flushes the brackish water downstream disturbing this equilibrium.

3. DUKC® SYSTEM

Traditionally, waterways have operated under fixed (or static) rules which govern the minimum under keel clearance (UKC) permitted for transit along port approach channels. To ensure safety, these fixed UKC rules are determined using conservative scenarios. At the same time, because the fixed UKC rules are conservative, on average, ships carry less cargo than the maximum safe level. This is done to reduce the probability of a vessel transporting excessive cargo for the conditions and having safety jeopardised by a grounding.

The DUKC® developed by OMC replaces the static UKC rule with a dynamic UKC rule whereby the UKC allowance of each transit in a waterway is calculated separately. The dynamic UKC depends on the characteristics of the vessel, its transit, load state and the prevailing environmental conditions. This is achieved by combining customised ship and environmental models to calculate the UKC requirements of the particular ship sailing in the particular waterway in the environmental conditions at the particular time.

UKC requirements are determined based on the actual vessel particulars, load and stability parameters, real-time met-ocean conditions (wave height, period and direction, water levels, currents, tidal plane, and wind), and vessel transit speed and waterway configuration, including detailed bathymetry, at the time of sailing. Wave spectra, ship speed and water depths vary along the transit and the effect of these variations is computed by the numerical ship motion model used in each DUKC® system. In addition, wave spectra and tidal residuals will change over time, and these effects are accounted for in each system. With respect to squat, individual ships and the pertinent characteristics of the approach channel are modelled in each DUKC® system, including the effect of temporal and spatial variation of tidal currents.

The accuracy of the numerical models used in the DUKC® System has been validated by undertaking more than 200 ship transits to obtain full-scale measurements of vessel speed, track and vertical displacements. These validation tests have been undertaken for a wide variety of channel widths, configurations and lengths, vessel types, sizes and stability conditions, vessel speeds, wave conditions, tidal regimes and current speeds.

DUKC® has assisted more than 50,000 ship transits over the past 17 years, without incident. It is now used by 20 ports in four countries. On average, there is now a DUKC®-assisted ship movement every two hours, somewhere in the world.

3.1 Benefits

The three key areas of benefit from an operational DUKC® system are safety, environmental protection and economic.

Safety – DUKC® systems greatly reduces the risk of ships running aground. Some examples of groundings that might have been avoided with DUKC® include two large tankers that grounded in the channel leading to New Zealand's only oil refinery at Marsden Point in 2003 where it was later shown that a DUKC® would have prevented both these near catastrophic environmental disasters. The Maritime Safety Authority of New Zealand imposed significant draft limits on the port following these groundings – these restrictions were not lifted until a DUKC® System was implemented at the Port.

Environment – DUKC® has been developed and is currently being trialled to ensure adequate under keel clearance for piloted ships transiting through Torres Strait and the Great Barrier Reef, one of the great natural marine wonders of the world. The ecological consequences of a ship running aground here, or anywhere, are clearly serious.

Economic – In port operations, the estimated economic benefits of DUKC® in increased vessel drafts, widened tidal windows and reduced demurrage charges exceeds US$5 billon to date.

3.2 Port Operations

DUKC® Technology can be incorporated into two phases of port operations: Dynamic Passage Planning, and Dynamic Passage Monitoring, Advice and Direction.

The core functions of DUKC® systems have always been to provide ports and users with dynamic passage planning advice on:

- maximum draft for tides,
- earliest and latest sailing times (tidal windows), and
- UKC for specific transits.

These core functionalities are required by planners, terminal operators and regulators to determine safe draft levels for planned transits.

Recent innovations have allowed the development of DUKC® InTransit technology that can be taken onboard ships by pilots (PPU) or integrated into Vessel Traffic Services (VTS). Both applications allow monitoring and control of under keel clearance by management of vessel speed during transit. Both applications are configured to provide a seamless transition from the shore based DUKC® Dynamic Passage Planning System. DUKC® InTransit provides Pilots and Vessel Traffic Operators with look-ahead predictions of minimum under keel clearances during a transit.

Specifically DUKC® InTransit allows the user to:

- Monitor that the actual speeds are within the speed envelopes generated by the DUKC® Passage Plan.

- Determine where it is safe to travel at speeds outside those generated by the DUKC® Passage Plan and to what extent it is safe to do so.
- Investigate alternative speed/sailing options in situations where the passage does not proceed as planned. This could include situations such as vessel breakdowns, vessel delayed leaving the berth, vessel loaded in excess of its planned passage draft, vessel not performing as expected or deterioration in the environmental conditions.
- Identify speeds that will maximise UKC or minimise transit time without exceeding safe UKC limits.

The DUKC® VTS System provides VTS Officers with a tool to monitor the effect of vessel speed on under keel clearance during transit. If shore-based pilots have access to this system, they can use it to advise on-board pilots (who may not have access to a DUKC® PPU unit) to adjust speed as necessary, especially when problems develop with maintaining planned passage speed.

The VTS application has been operational at Port Hedland, Western Australia, since mid-2007 and the PPU application has been operational at Melbourne since mid-2009. At Port Hedland, it was used on at least three occasions during the first four months of operation to help on-board pilots determine the best option in dealing with UKC issues arising from engine breakdown during transit.

4. CONFIGURATION

While all based on the same DUKC® technology, each DUKC® system is configured to the particular waterway where it is applied and to meet the particular requirements specified by the client. As well as configuring the vessel types and the berths and transits, this includes the development of environmental models to forecast the environmental parameters (water level, currents, water density and waves) that impact on vessel UKC. Analysis of soundings is also performed to ensure that the latest bathymetry information is incorporated into the system. Once configured the bathymetry information can be regularly updated as new soundings are received.

4.1 Requirements

With multiple stakeholders involved in the Weser DUKC®, the requirements of all the parties needed to be incorporated. In particular, this configuration varied from previous versions because of the large number of possible transits that were required, the particular bed-material in the Weser, and the need for PPU monitoring and synchronisation amongst the many stakeholders.

To accurately predict the UKC requirements of a vessel its transit must be well described. A transit consists of a berth and destination together with the planned speeds throughout the passage, as well as the location and type of any manoeuvres that are planned. With this information the position and time of the vessel at any stage during the transit can be calculated given a transit start time. This is required to intersect the vessels time at a location with the environmental conditions predicted at the location. A typical DUKC® system may have around a few hundred transit combinations. The complexity of the Weser system was seen when the Waterway Authority identified over 10,000 transit combinations that needed to be accounted for. Previously, transit configuration had been performed manually, but to enable a feasible configuration an automated method for configuration was developed.

The bed material of many ports in Northern Europe – and riverine ports in particular – often consists of what is described as fluid mud. The difference between this bed material and that of other ports, for example those with sand gravel or hard rock beds, is that the bed depth is difficult to define. There is no clear interface between the water and the bed material. The muddy bed material is partly suspended in the water column and the density of the water column gradually increases with depth as the concentration of suspended mud increases. To deal with the lack of an obvious boundary (and following PIANC guidelines) these ports often define a series of bottom depths through which vessels vessels are able to pass; navigable mud. These depths are defined by sonar reflectance frequencies. The lower the frequency of the sonar, the higher the density of the material that it can reflect off and thus the further it can penetrate into the muddy water. The DUKC® was configured to enable the various depth options used in the Weser As depth surveys and ongoing maintenance are undertaken continuously, the new sounding sets are received fortnightly by OMC, and these data are regularly updated by OMC engineers.

As a significant driver for the application of the DUKC® system in the Weser is the ability to monitor advise and direct the UKC of vessels already underway, an additional IT requirement was to make the system accessible to the multiple stakeholders. Because of the multiple stakeholders, including the 2 VTS centres and 2 regulatory offices, in 2 different cities with over 20 staff, plus over 150 pilots in pilot radar rooms, pilot offices and pilot cutter moored 50km offshore it is essential that the system is available to all uses at all times and that the system is synchronised so that all users view the same data.

The collection of data, calculation of transits, and distribution of results was achieved using the IT setup illustrated by the network diagram of Figure 2. Primary and secondary servers were situated in Bremerhaven. These servers were connected to the DUKC® and Environmental data bases. Other computers in the network connect to the servers via VPN connections.

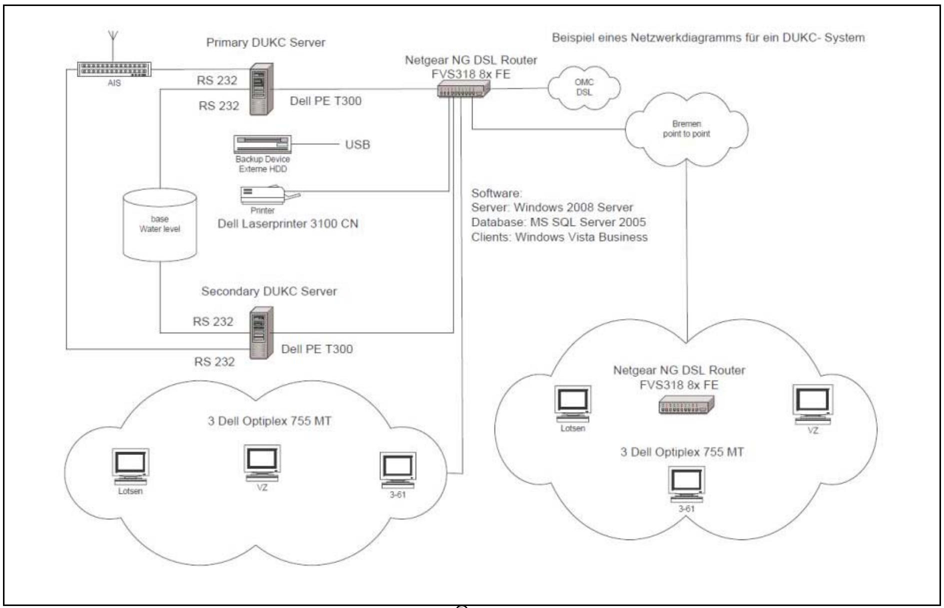

Figure 2: Network diagram of the Weser DUKC® system.

4.2 Instrumentation

Fundamental to DUKC® technology is the use of real time measurements of prevailing environmental conditions. This data is not only the basis for assessing the UKC now, but latest measurements provide the initial conditions for forecasting models that predict future environmental conditions. Being an extensive waterway, a large number of real time instruments were available to the system. In addition to collecting the data, filtering and quality checking steps must be performed to ensure that the data provided by the instruments is reliable and accurate.

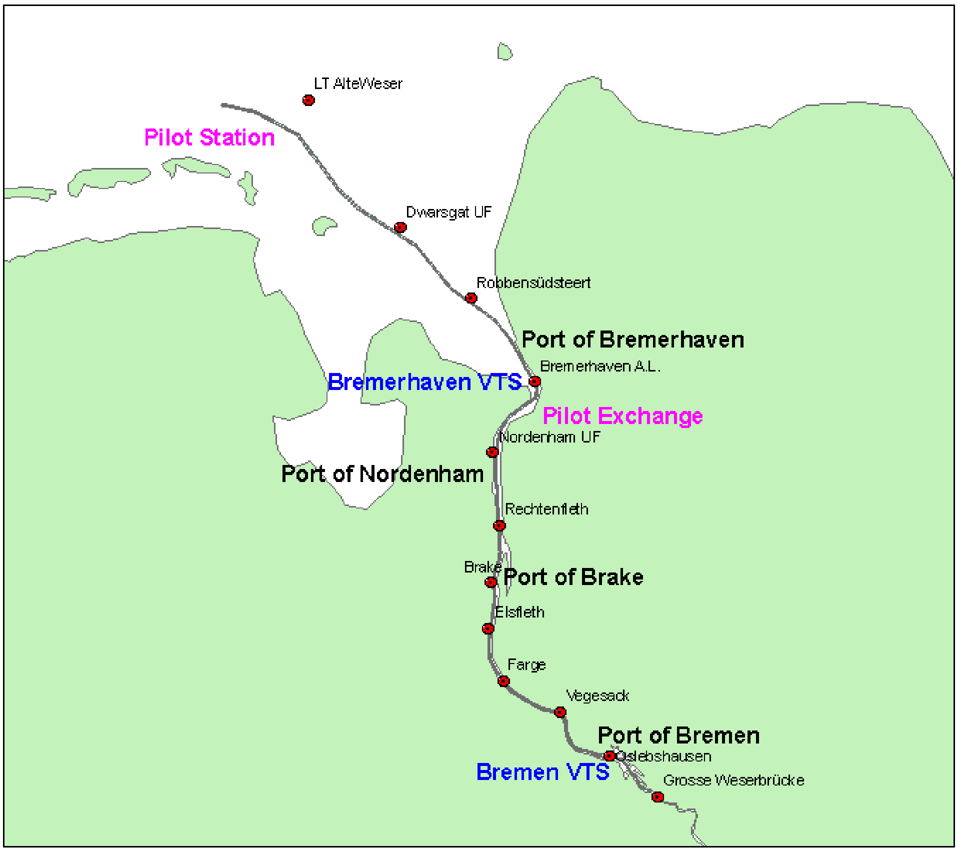

Figure 3: Map of the Weser indicating tide and wave monitoring instruments.

Real time wave data for the system is available from two sources. A lookdown laser device is mounted on the Alte Weser Lighthouse (LT Alte Weser), located in the North Sea (Figure 3). While able to provide an accurate assessment of the distribution of wave energy with frequency, the device is unable to measure wave direction and so worst case wave directions must be assumed. A directional device is also available in the form of a wave rider buoy located near the entrance to the Elbe River approx 30 km east of the Weser River. An important finding of the data analysis is that although the waves experienced can be very energetic, generally the energy is restricted to frequencies that do not induce ship motions.

Although, over 12 tide instruments were situated in the Weser (see Figure 3). The water level modelling has been limited to the data from six locations Alte Weser, Bremerhaven, Rechtenfleth, Brake, Elsfleth, and Bremen. In addition to the real time data collected by the instruments, astronomical forecasts of data were obtained from the German Federal Maritime and Hydrographic Agency (BSH).

By contrasting the astronomical predictions, with historical measurements a sense of the tidal residuals could be gathered. Because of the relatively shallow enclosed nature of the North Sea depending on the atmospheric conditions and particularly wind direction large variations in water level from astronomical predictions can occur (over 1.5m). Understanding and predicting these is vital for a dynamic UKC system as changes in water level obviously change the amount of water available for vessels. It was known that a driver of the water level residual in the Weser was the wind. This is well demonstrated by Figure 4. The upper panel shows the time series of measured and astronomical forecasts of water level, the middle panel shows the difference of water level residual and the lower panel shows the component of measured wind speed in the North Sea aligned at 135 degrees. When the wind speed component is positive (29 Jan 2007), the wind is blowing towards the German coast and consequently water level residuals are strongly positive. In contrast when the wind speed component is negative (11 Feb 2007), the wind is blowing away from the German coast and consequently water level residuals are strongly negative.

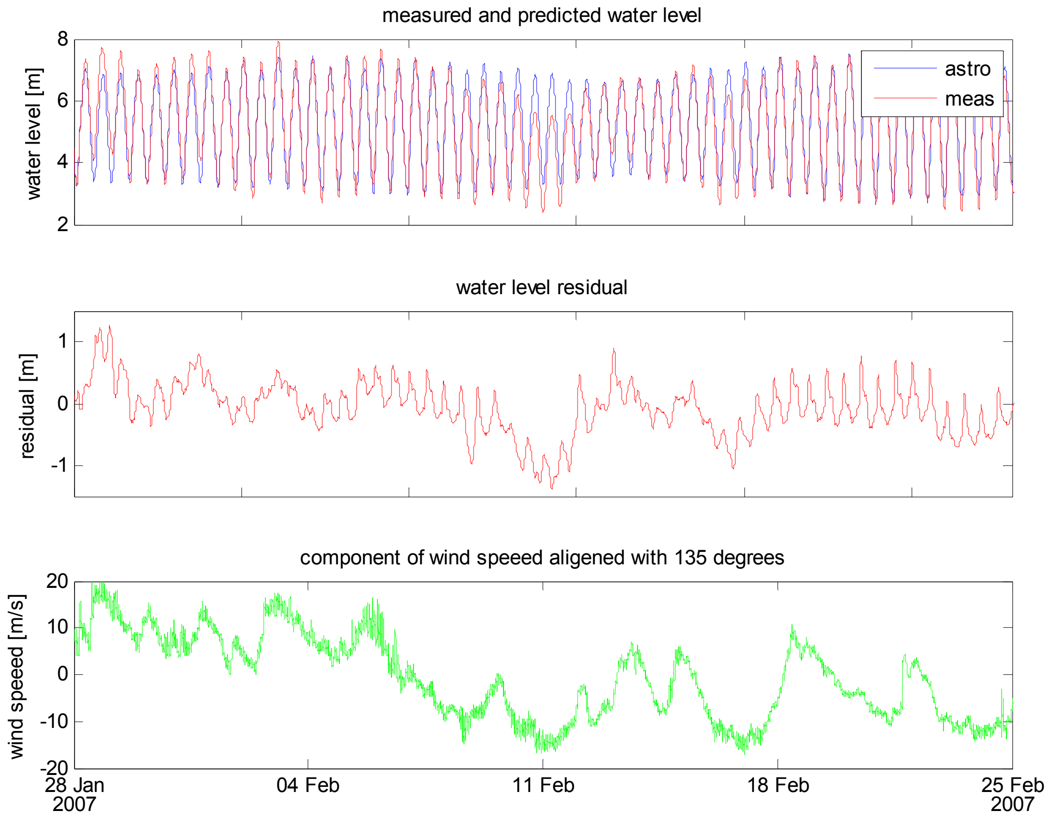

Figure 4: Time series of water level and residuals at Rectenfleth and the corresponding North Sea windspeed measured at LT Alte Weser.

In addition to understanding how the water level varies from its astronomical predicted value at a point, the DUKC® system also requires information on how the water level changes spatially. Because the confining river bank provides a frictional resistance to the propagation of flood current in addition to the downstream river flow, the time of the high water varies along the Weser. This is clearly illustrated by Figure 5 which plots the measured time series of water level at a series of tide gauges moving progressively upstream. Focusing on the high water times, it is seen that the high water at Elsfleth about halfway between Bremerhaven and Bremen occurs about 3 hours after the high water at the start of the Weser channel at Alte Weser.

Understanding and being able to accurately predict the spatial and temporal variation in water level is vital for the planning of transits. For import vessels travelling upstream the transit is straight forward as they can ride on the food tide as it moves upstream. In contrast export vessels have to time their departure and draft carefully as the tide is continuously dropping away ahead of them as they progress downstream.

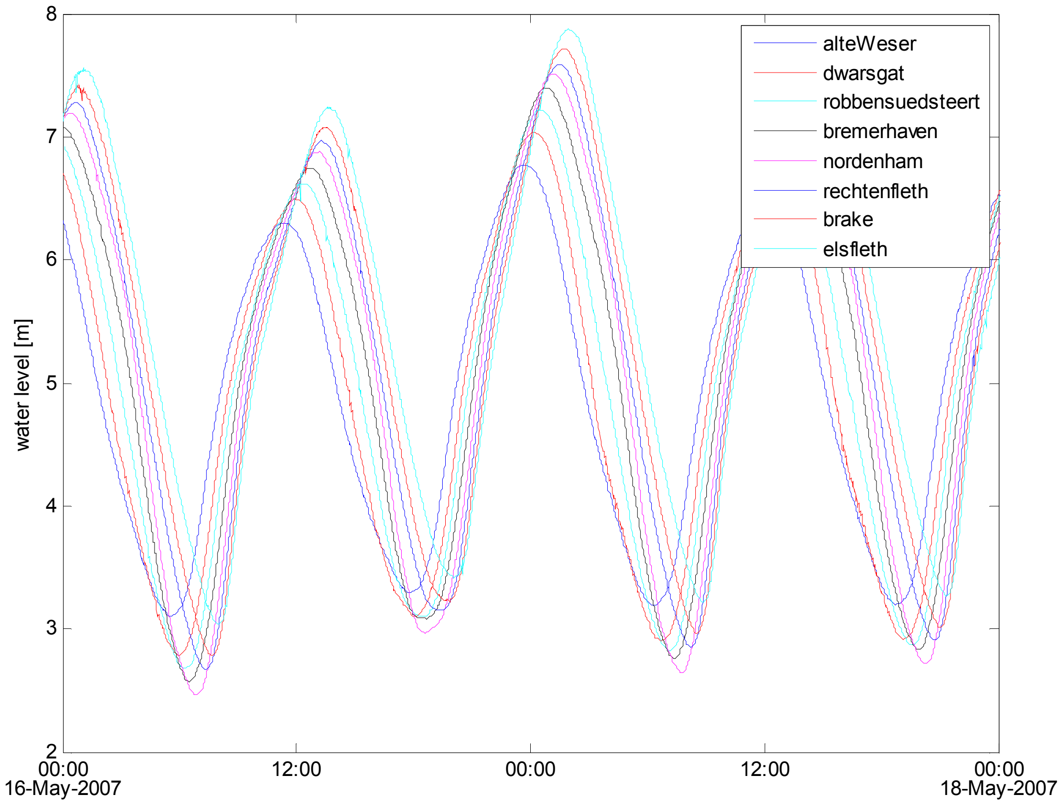

Figure 5: Time series of water level variation with location along the Weser

As well as altering water level, the regular tidal flow mixes fresh water flowing downstream with the saline North Sea water changing the salinity and hence the density of the water. For shipping predicting the water density is important because through buoyancy the amount of water displaced by the vessel and hence its draft depends on the weight or density of the water. In fresh, less dense water the vessel's draft is deeper than in more saline sea water. The change in draft may be in the order of 0.2-0.3 m depending on the initial draft, and so prediction of the spatial and temporal variation in salinity is necessary. The changing salinity also alters the trim of the vessel.

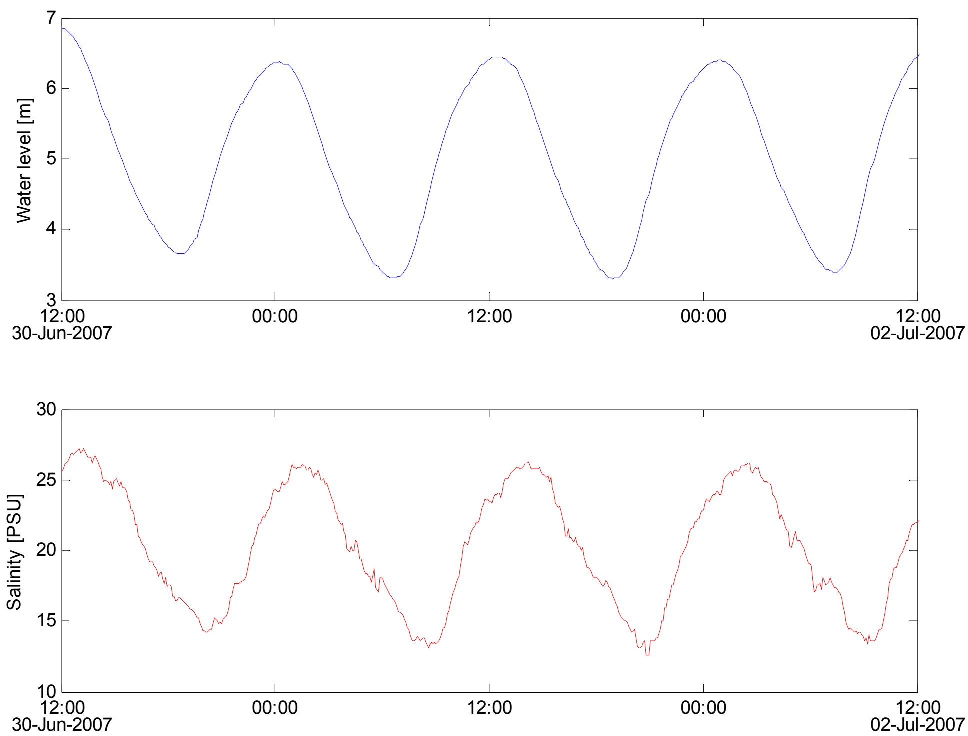

Figure 6: Time series of water level and salinity at Rectenfleth.

Salinity data is monitored at six locations along the Weser: Alte Weser, Dwarsgat, Robbensudsteert, Bremerhaven, Nordenham, and Rectenfleth. The basic relationship between the salinity and the tidal cycle can be seen in Figure 6. As expected the salinity peaks with the high water as saline water is pushed upstream by the flood tide. During the ebb tide as fresh river water moves downstream the salinity reduces. This simple relationship is complicated by the neap spring cycle and so the salinity magnitude is also related to the amplitude of the tidal range as well as the phase in the tidal cycle. Furthermore, during floods when larger than normal volumes of water enter from upstream the salinity can be reduced further than normal as the flood effectively flushes the system.

4.3 Modelling

While the real time data collection from the instruments and its analysis is important, for the DUKC® configuration the next step is to encapsulate this knowledge of the physical processes into spatial and temporal prediction models that allow the information from real time data from instruments be transmitted other times and locations. The Weser DUKC® system includes spatial and temporal models of waves, currents, water level (tidal plane) and salinity.

For water level modelling it was clear that the forecasting of the water level might pose difficulties. This is because the residual in the future is the result of a complex interaction between future atmospheric states and the North Sea. Rather than attempt to model these processes and source meteorological predictions, the BSH already produced forecasts of tidal residuals (in addition to astronomical forecasts) for a series of locations along the Weser and these forecasts could be easily incorporated into the DUKC® water level model.

A representation of the salinity model constructed at Rectenfleth is shown in Figure 7. The 2-dimensional nature of the model illustrates how the salinity not only varied with tidal phase but also with tidal range. Using this model, the salinity can be predicted at Rectenfleth, given knowledge of the tidal phase and the tidal range. Similar models are produced for other sites along the Weser. By interpolating between these sites the salinity at any location and at any time can be predicted.

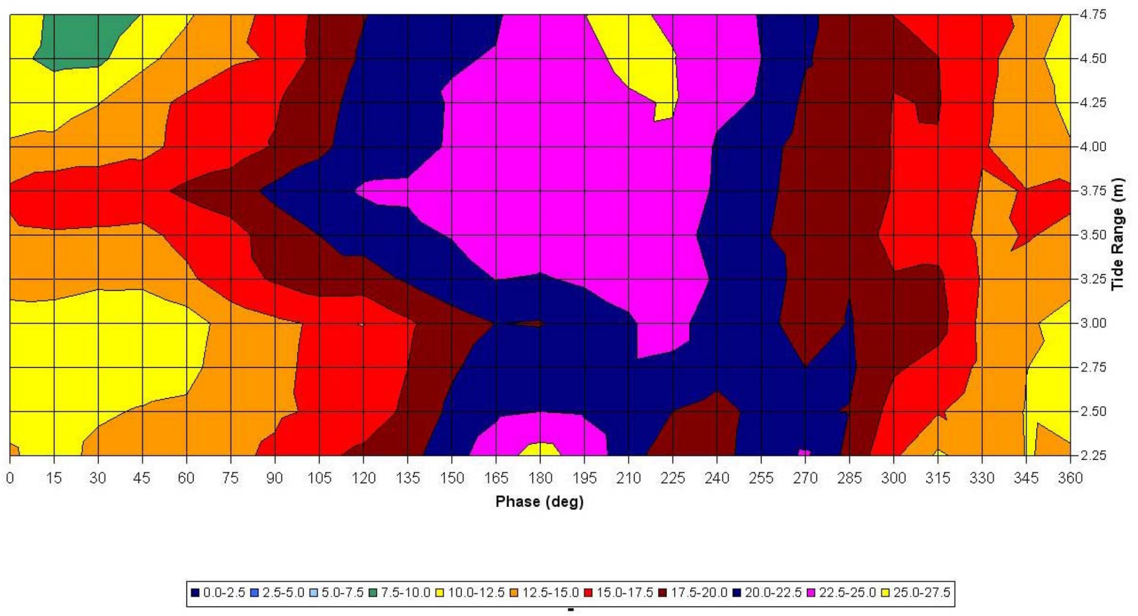

Figure 7: Salinity model implemented at Rechtenfleth.

For predicting currents, an astronomical current prediction model was developed based on historical measurements. This model took the form of a tidal phase prediction similar to the salinity model. Again by combining a series of predictions at various locations the current strength and direction can be predicted for any location and time.

5. RESULTS

5.1 Technical Validation

Before a newly configured DUKC® system is ready for operational trials, the system is validated through Full Scale Vessel Motion Analysis. FSVMA involves placing GPS receivers on the bow and bridge wings of vessel and analysing the combined signals with an external base station to extract the components of UKC experienced by the vessel. OMC and University of Oldenburg performed the measurements (and used previous measurements) to allow the validations of the DUKC® system.

For the Weser River two FSVMA methods were used: the SHIPS method where the base station is situated on a smaller vessel that accompanies the deep draft vessel (the smaller vessel is not susceptible to squat), and the non-SHIPS method where the positions of the GPS receivers were found relative to the German Virtual Reference Station (VRS). In total measurements of 27 transits were obtained, 18 had been collected prior to the development of the DUKC® by the University (12 using the SHIPS method and 6 non-SHIPS method) and 9 new measurements were obtained (using the non-SHIPS method). Of the 27 measurements 17 were of Bulk Carriers and 10 were fine-form vessels (Containers and Car Carriers).

An example of the FSVMA validation of a fine form container vessel is seen in Figure 8. The first point to notice is that the speeds start from zero at KP 73 (Bremerhaven) and rapidly increase to around 13 knots. The divergence between the speed over the ground (SOG) and speed through the water (STW) is due to the vessel travelling with the current. The vessel's squat starts from zero (at rest) and steadily increases with the increasing vessel speed. For this vessel only minimal squat is observed at the bow while over 1.5m of squat is observed at the stern. The forward motion is inducing a trim in addition to the squat. The validation of the squat model is shown by the modelled squat values matching those measured. This result indicates that for container vessels the squat model is well calibrated.

The FSVMA of the bulk carrier (Weser Stahl) is shown in Figure 9 as it transits from the sea into Bremen. Again the speed through the water is lower than speed over ground because the vessel is sailing with the flood tide. The depth plot shows where the depth reduces (around KP 60) as the channel narrows and transforms from an estuary into a river. This can be seen in the measured squat profile where the squat increases although the speed is maintained. Again the predicted squat matches the measured signal well. By performing these measurements OMC was able to verify the system as the prediction incoporates environmental forecasting as well as UKC component modelling.

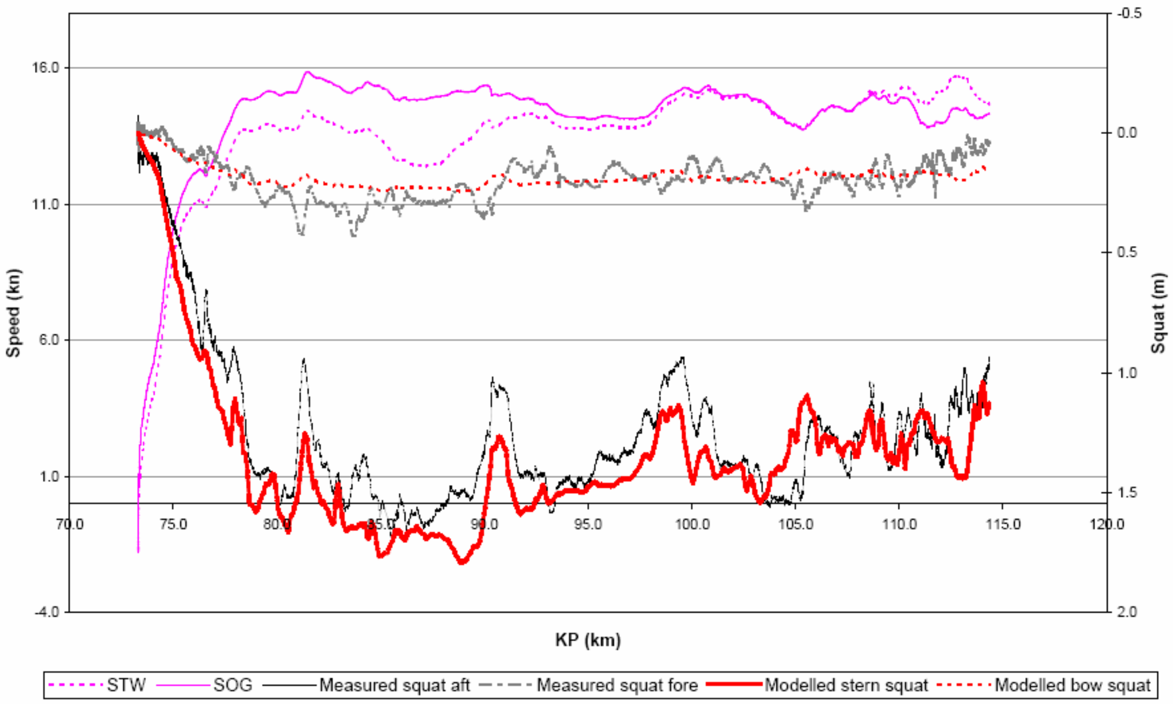

Figure 8: Squat validation results for E-Class Maersk container vessel.

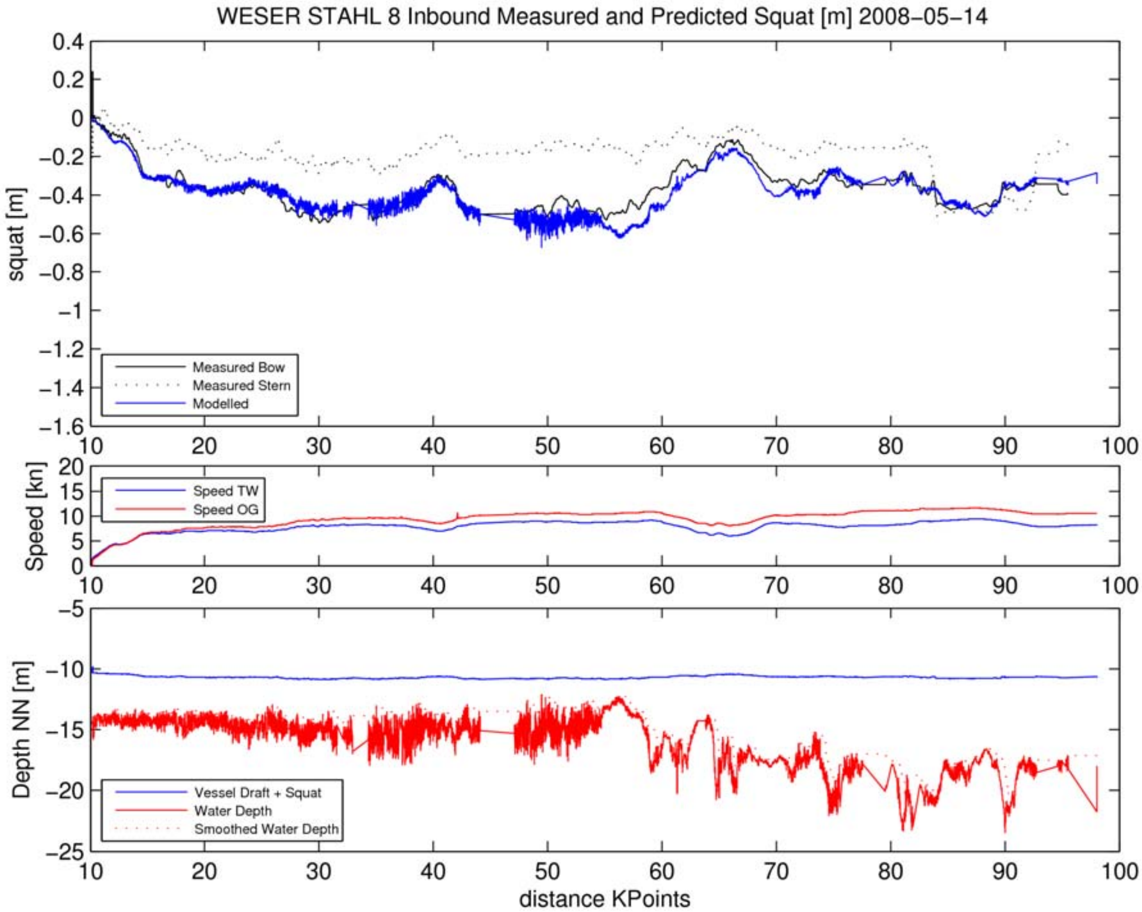

Figure 9: Squat validation results Weser Stahl (LBP ~220, Beam~32)

5.2 Operational Trial

As part of the bedding in process the WSA proposed a 24 month trial of the DUKC® system, which will end in December 2010. During this time as well as trialling the DUKC® system the stakeholders and users are determining how best to incorporate the system into their procedures.

As the purpose of the DUKC® System was to provide advice for when the larger ships (outside existing experience) arrived. It is planned to only run the system for these larger vessel. These larger ships are only run by a few ship lines. As the first step in the DUKC® system is planning, the VTS officers require planned arrival times and DUKC® data regarding the particular vessel from these agents. The required data includes the vessel particulars and stability data.

Using this data the VTS Officer will determine a transit plan for the vessel and use the DUKC® to assess if the UKC requirements of the vessel will be satisfied. The DUKC® result will likely be passed by the VTS officer to the pilot in the pilot house. The pilot house has a 24 hour manned 'VTS lite' system which handles pilot scheduling and receives vessel information from the VTS centre in a read-only form. For inbound vessels, DUKC® results will probably be faxed or emailed to the pilot cutter.

The pilots often work in pairs with one on board, whilst a second sits in a dedicated room connected to the VTS centre and monitors the vessel on the VTS systems. The 'radar' pilot connects with the on-board pilot by radio and is able to communicate relevant information such as traffic information, vessel position, berth availability, etc to the pilot on board. The pilot on board can then adjust his transit based on this information as required. The DUKC® InTransit technology will integrate well with the use of a radar pilot. In adverse conditions the pilot on board can focus on the immediate *tactical* issues, while the radar pilot can focus on the *strategic* issues that include ensuring that any changes to the transit plan do not have an adverse affect of the UKC requirements through the remainder of the transit. The radar pilot is used when weather conditions are very bad or for the very large vessels. It is particularly these latter conditions when the DUKC® is most beneficial.

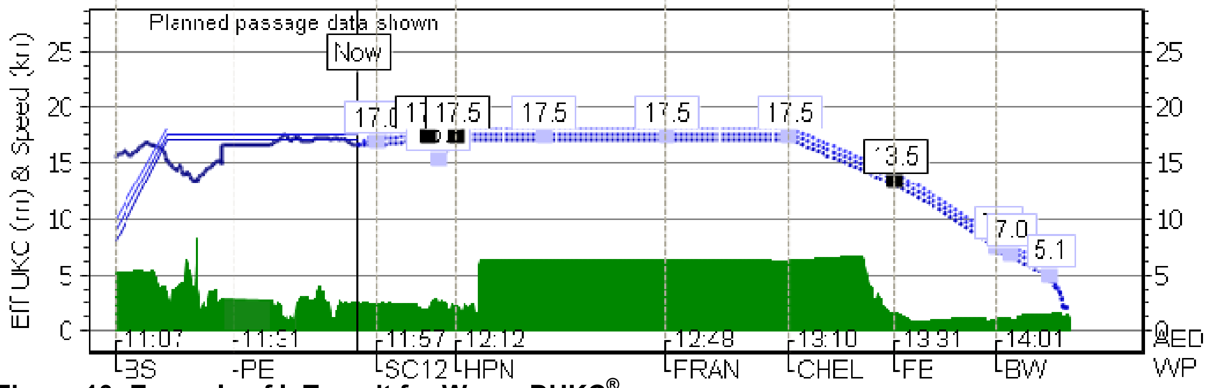

Figure 10: Example of InTransit for Weser DUKC®

Figure 10 illustrates the DUKC® InTransit technology in use. The vertical line with the "Now" label indicates the position of the vessel underway. To the left, the thick solid line indicates the actual speed of the vessel when it passed these locations. To the right, the planned speed for the remainder of the transit is shown. Below, the solid green area indicates the amount of effective UKC. At the moment the InTransit DUKC® indicates that if the pilot maintains the planned speed the vessel will safely transit the waterway. When a negative effective UKC is calculated a red banner appears on the display warning the pilot or VTS operator that action is required to modify the transit to maintain a safe transit.

6. CONCLUSIONS

OMC has successfully delivered the configured Weser DUKC® system, which is currently midway through a two year trial period. Unfortunately the large reduction in shipping and drafts due to the global economic crisis and its impact on trade over the past year have meant that the DUKC® has not been employed to its full potential yet. However, as shipping levels stabilise and start to rise the authorities and pilots of the Weser will be prepared with the system already tested and incorporated into operational procedures.

The implementation of a DUKC® system to the Weser demonstrates that the technology which was originally developed for marine ports has been successfully transferred to riverine waterways. And that the specific need of these ports can be met. Through discussion, planning and technological innovation OMC has met the challenges that were prevalent at the commencement of the project. Through this work the stakeholders in the Weser waterway have been provided with a tool that will enable them to better manage the safety of deep draft vessels, especially as deeper vessels arrive and as dredging plans alter the condition of the waterway.

The issues of navigational safety found in the Weser River are similar to those experienced in other waterways around the world. In South America, the use of DUKC® InTransit technology in the waterways of the Rio de la Plata - Parana system would promise great benefits in regard to navigational safety. By utilizing a scientific method to accurately identify and forecast the relevant UKC components the DUKC® provides assurance that safety of navigation in the Weser follows the highest standards of quality. The introduction of DUKC® technology to the ports and rivers of South America is a logical step in the development of navigational safety in the region.

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