IMPROVED CHANNEL EVALUATION USING AUTOMATIC IDENTIFICATION SYSTEM AND HYDROGRAPHIC SURVEY DATA

Lauren M. Dunkin[1], Christina L. Saltus[2], K. Ned Mitchell[3], and Brandan M. Scully[4]

ABSTRACT

The U.S. Army Corps of Engineers maintains hundreds of deep-draft coastal ports and waterways as part of its Navigation mission, which is vital for sustaining maritime commerce and national security. These dredged channels are presently evaluated during the annual Operations and Maintenance budget formulation process in terms of the relative value they bring to the Nation, and this value is weighed against the costs of the regular maintenance dredging required to keep the channels at sufficient depths and widths to enable cost-effective marine transportation. In order to maximize the transportation benefits that can be realized from limited dredging dollars, objective and straightforward methods are needed to evaluate channels and prioritize maintenance dredging work packages. This work employs enterprise datasets to create three-dimensional geospatial layers in order to support objective evaluations of navigation channel functional condition. The availability of time-stamped vessel position reports, broadcast as frequently as every 6 seconds via onboard Automatic Identification System (AIS) transceivers, allows for the vessel dimensions (length, beam, and draft) to be projected for direct, three-dimensional comparisons against the hydrographic surveys of the maintained navigation channel. Recent efforts to use historical hydrographic surveys to determine localized shoaling rates are leveraged to identify shoalest points and other “hot spot” areas of concern relative to the dimensions, positioning within the channel, and transit frequency of calling vessels. After adjusting for tides, the AIS-derived vessel traffic distributions, represented by probabilistic surfaces, are combined with the bathymetric survey data to determine limiting depths along the channel. The goal is to objectively and consistently quantify the relative effectiveness of maintained channel dimensions in supporting the Navigation mission requirement for safe, reliable, and cost-effective marine transportation.

Keywords: Navigation, AIS, shoaling, underkeel clearance.

INTRODUCTION

The U.S. Army Corps of Engineers (USACE) maintains hundreds of deep-draft coastal ports and waterways as part of its Navigation mission which is vital for sustaining maritime commerce and national security. The cost of maintaining the channels and the value they bring to the Nation are evaluated annually as part of the Operations and Maintenance (O&M) budget formulation process. While funding for maintenance dredging has remained fairly flat over the last decade, dredging unit costs and the backlog of deferred maintenance activities have continued to increase (Mitchell et al, 2013).

Enterprise datasets are more frequently available and have been explored in recent literature to support navigation engineering and port operations (Silveira et al., 2017). The standardized Automatic Identification System (AIS) provides time-stamped vessel position reports that are broadcast as frequently as every 6 seconds providing a high density dataset of vessel position (Calder and Schwehr, 2009; USCG, 2012). Hydrographic surveys are also becoming more easily accessible via enterprise services. For example, the USACE uses an enterprise hydrographic survey processing tool (eHydro) to standardize the output files and provide storage of these datasets (Niles, 2013). In addition, the location of the maintained coastal navigation channels are also available through enterprise services (Libeau, 2007). These hydrographic survey data for the USACE maintained navigation channels are used to quantify shoaling rates and volume of material to be removed at various depth increments.

The Corps Shoaling Analysis Tool (CSAT) is a hindcast algorithm that relies on the historical eHydro survey data to determine shoaling conditions (Dunkin and Mitchell, 2015). The pre and post dredging surveys are used to separate dredging events from the survey comparison to determine shoaling rates within the channel.

The shoaling rates are combined with the most recent eHydro survey to provide a prediction of volume of material to be removed at the various depth increments at present condition in addition to six month time intervals to three years. The shoaling forecast are another data layer that supports objective decision making when combined with vessel transit and tonnage data (Dunkin and Mitchell, 2015). The vessel tonnage data is available from the Corps’ Waterborne Commerce Statistics Center (WCSC) and is accessible to Corps personnel for additional query capabilities via the

---

[1] USACE Engineer Research and Development Center, ATTN: CEERD-HN-C 3909 Halls Ferry Rd., Vicksburg, MS, 39180, USA, T: 228-596-4780, Email: lauren.m.dunkin@usace.army.mil.

[2] USACE Engineer Research and Development Center, Christina.L.Saltus@usace.army.mil

[3] USACE Engineer Research and Development Center, Kenneth.n.mitchell@usace.army.mil

[4] USACE Engineer Research and Development Center, Brandan.m.scully@usace.army.mil

DREDGING SUMMIT & EXPO ’18 PROCEEDINGS

Channel Portfolio Tool (CPT), which incorporates the detailed annualized tonnage figures to provide usage statistics at varying depths (Mitchell and Walker, 2009).

The advent of these enterprise datasets provides the means to identify new metrics that will shed additional insight concerning the relative effectiveness of maintained channel dimensions in supporting the Corps’ Navigation mission requirements. By solely relying on enterprise datasets, the methods developed to support the objective channel comparisons are easily transferred to the portfolio of USACE navigation channels. The geospatial layers enable a straightforward approach to a complex problem that leverages the near-real time data collection and storage of these large datasets. The goal is to provide straightforward, objective methods for evaluating channels to prioritize maintenance dredging requirements so as to maximize the cost-effectiveness of limited dredging dollars.

Vessel Dimensions and Underkeel Clearance

AIS vessel transit locations from GPS transponder coordinates are available from the United States Coast Guard’s (USCG) Nationwide Automatic Identification System (NAIS) through a download service developed by the USACE that provides access to a rolling three-year archive of AIS data through a cloud-based platform (Automatic Identification System Analysis Package - AISAP) (AISAP, 2017). The AISAP allows users to query targeted data samples based on geographic location, date, and vessel requirements (dimensions or ship speed), and it has been used in support of several studies seeking objective, quantitative metrics that capture marine vessel activity (Scully and Mitchell, 2017; Mitchell and Scully, 2014; Farhadi, et al., 2016; Touzinsky, et al., 2018; Kruse et al, 2018). For this study, the AIS was constrained to vessels underway and with speeds greater than 3 knots. The three dimensional projection of the vessels are essential in determining limiting depths and sideslope clearances along the channel. The time-stamped AIS data includes latitude/longitude, speed, course over ground, and heading, along with the unique Maritime Mobile Service Identifier (MMSI) for each vessel (ITU, 2010). The vessel record also includes vessel dimension data containing parameters such as vessel length and beam width measurements in addition to design draft. Vessel footprints are created by utilizing the vessel dimension fields within the point feature layer to calculate the XY locations of the outer perimeter vertices of the vessel. The vertices are then connected to create the footprint for each vessel and are stored within an ArcGIS polygon feature layer along with all associated AIS vessel transit data field and vessel dimension field values (Figure 1 - left). The vessel footprint is a three dimensional projection of the transiting vessel (Figure 1 – right top) created from the unique AIS, time-stamped data for the full navigation channel (Figure 1 - right bottom).

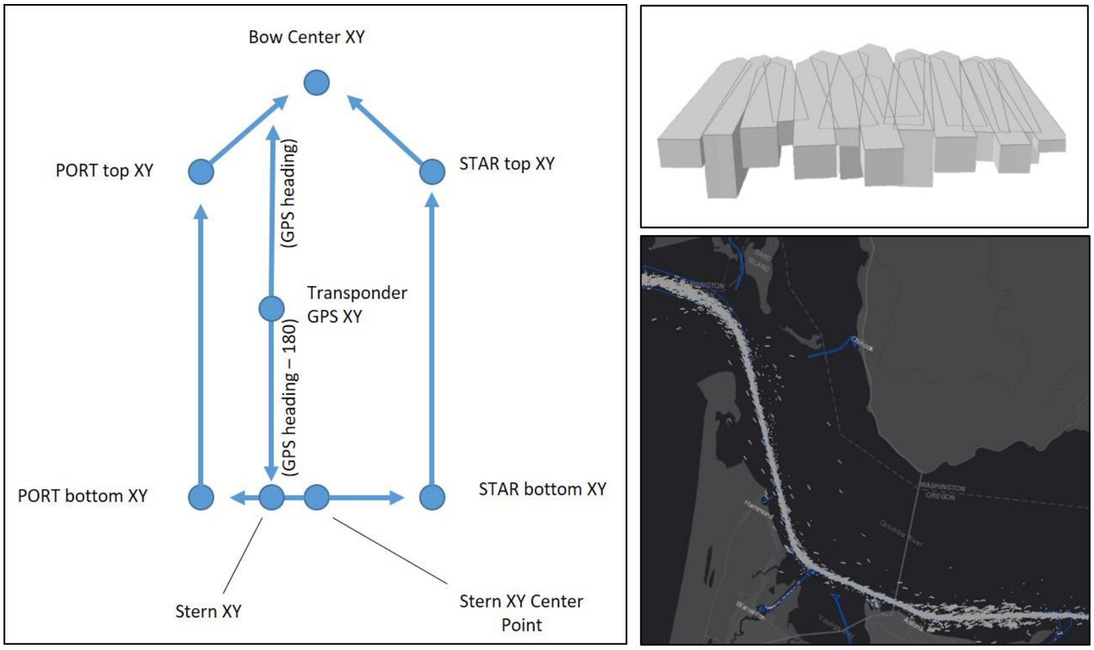

Figure 1. Vessel dimension schematic (left) used to create the vessel footprint (right - top) from the AIS point files for the navigation channel (right – bottom).

DREDGING SUMMIT & EXPO '18 PROCEEDINGS

The underkeel clearance is adjusted by matching the AIS vessel timestamp with the nearest 6-minute tidal data (Scully, 2017). The National Oceanic and Atmospheric Administration (NOAA) tidal stations are queried for proximity to channels and the 6-minute verified water levels are downloaded in monthly batches and combined for the date range specified. The vessel footprint polygon features are matched to water level values at Mean Lower Low Water (MLLW) by selecting features within a 10 mile radius of a NOAA tidal station and linking the vessel transit time to the nearest 6-minute tidal time.

Limiting channel depth includes consideration of the vessel draft after adjusting for varying water level conditions and vessel requirements associated with movement (squat) and loading. Scully and Mitchell (2017) review underkeel clearance in detail comparing the various models that focus on either operational (Silver and Dalzell, 1998; Atkinson & O'Brien, 2008) or channel design (Briggs et al. 2013). Various nuances in each approach exist but are ultimately seeking to reduce occurrences of vessels making contact with the bottom of the channel. For this study, the design draft provided in the AIS vessel dataset is used instead of calculating a sailing draft following the recommendation outlined in Scully and Mitchell (2017) which states that the design draft provides a conservative value for underkeel clearance calculations.

Hydrographic surveys are routinely conducted for the USACE maintained navigation channels and provide channel conditions. The hydrographic surveys are made available through the USACE enterprise hydrographic tool, eHydro, which provides a standard process for survey upload and storage (Niles, 2013). These files are available per channel reach as defined by the National Channel Framework (NCF) and have been combined into a single, nested file structure for each reach with a uniform grid spacing of 10 feet. The X, Y location within the reach is held constant while the bathymetry and timestamp vary. The uniform grid improves efficiencies when comparing the AIS vessel positions to determine the limiting depth directly impacting the space occupied by the vessel footprint.

The AIS data combined with the eHydro surveys and NCF provide the necessary information needed to calculate vessel squat. The increased cost of maintenance dredging and the trend of vessels to transit with limited underkeel clearance necessitates accurate estimation of squat. Vessel squat is the sinkage of the vessel due to the downward displacement as a result of hydrodynamic pressure change along the ship (PIANC, 2014). Vessel squat may be calculated directly using several reported values from AIS, such as the vessel speed and length of the beam and draft, along with the channel dimensions which are available in the NCF. The block coefficient, C_b, is approximated based on the vessel type found in the AIS vessel information and identifying the reported values found in the PIANC guidance (2014). Typical block coefficient values range from 0.85 for the largest bulk carriers to 0.35 for small fishing vessels. The PIANC (2014) definition of restricted channel is assumed for this study since the channels included are all maintained navigation channels that are routinely dredged. The blockage factor, S, is the cross sectional area of the channel that is being occupied by the underwater portion of the vessel (PIANC, 2014). The NCF width is multiplied by the minimum depth as determined for each individual vessel transit by comparing the bathymetric survey that is available from eHydro and the water surface elevation adjustment for tides (Equation 1). The calculated blockage factor is a conservative estimate since there is typically more water outside of the NCF width resulting in less vessel squat. Vessel speed, V_k, is available in the AIS data and may be adjusted for current velocity or approximated based on maximum current speeds in the region of interest. As recommended by Scully and Mitchell (2017), the Barrass (2012) squat equation is used in order to provide a more conservative value and is shown in Equation 2. The total underkeel clearance (TUKC) calculated for this study uses a time stamped sliding window to join the various parameters.

$$S = (\mathit{Draft} * \mathit{Beam}) / ((\mathit{Tide} + \mathit{Minimum\ Depth\ under\ vessel}) * \mathit{NCF\ Width}) \tag{1}$$

$$Squat = \frac{C_b S^{0.81} {V_k}^{2.08}}{20} \tag{2}$$

where

C_b is the block coefficient,

S is the blockage factor, and

DREDGING SUMMIT & EXPO ’18 PROCEEDINGS

V_k is the vessel speed.

Figure 2 shows the schematic of parameters associated with the TUKC that are calculated for the channel reliability model. The water surface elevation varies between locations along the channel and is dependent on the tide fluctuation. The underkeel clearance is adjusted by matching the AIS vessel timestamp with the nearest 6-minute tidal data as reported by the closest NOAA tide station. The vessel draft is the design draft of the specific vessel that is transiting. Hydrostatic effect in freshwater typically accounts for a very small percentage increase in draft on the order of 2-3 percent (PIANC, 2014). Adjustment for hydrostatic effect is not explicitly calculated in the model for the coastal navigation channels included in the study. Wave response is considered in the design depth of navigation channels and is not explicitly calculated for the channel reliability model. The controlling depth for each vessel is the maximum depth below the vessel footprint. By incorporating the tides and bathymetry at the time of transit, the total underkeel clearance provides a snapshot in time of the channel availability associated with the spatial location that is occupied by the transiting vessel. Building these spatial layers to incorporate all of the transits through the channel enables various spatial surfaces to be created, such as total underkeel clearance.

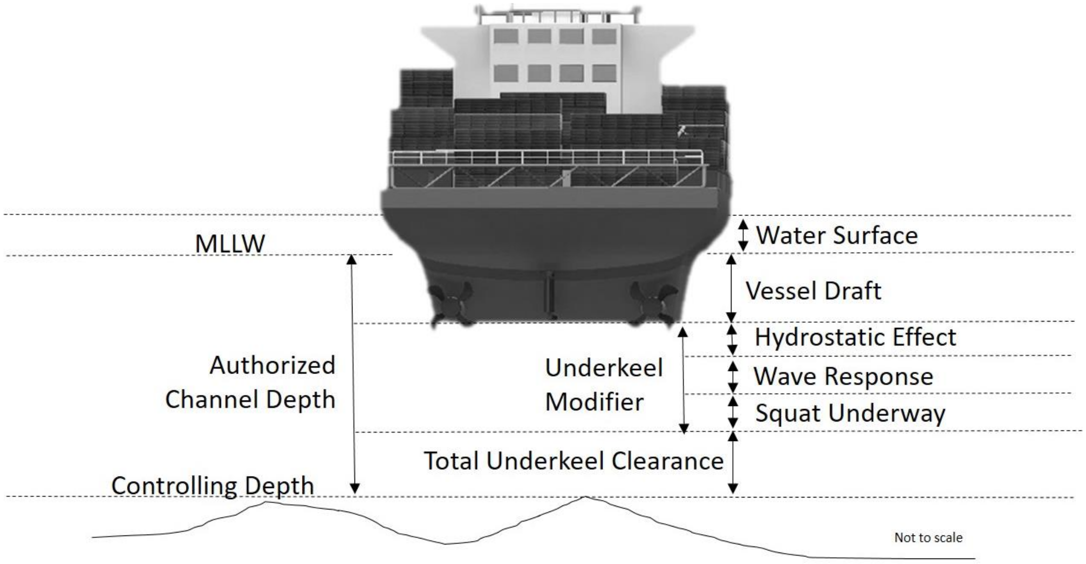

Figure 2. Total underkeel clearance related to the authorized channel depth and vessel draft.

METHODS AND RESULTS

Conceptual Model

The large spatial datasets require custom scripts to merge files and associate the various parameters to the time specific datasets. A conceptual model for the three main data categories includes spatial data, vessel attributes, and vessel position monitoring which are all used to provide input for the Vessel Draft Service Model (Figure 3). The methods developed for the vessel draft service model are scalable and are designed to accommodate vessels at various channels with different temporal frequency. The spatial coverage of the vessel draft service model results are directly influenced by the AIS sampling frequency. The AIS sampling rate used for this study ranged from 30-seconds to 1-minute. The smaller sampling rates generate significantly more data points per time series so understanding the spatial coverage is important before processing the large datasets. Shorter analysis time periods may require the 30-second or less AIS data sampling frequency in order to generate the desired surface coverage. A few example reasons for analyzing shorter time periods may be to focus on a particular bathymetric survey, dredge event, or to represent meteorological events that have impacted the channel region of interest.

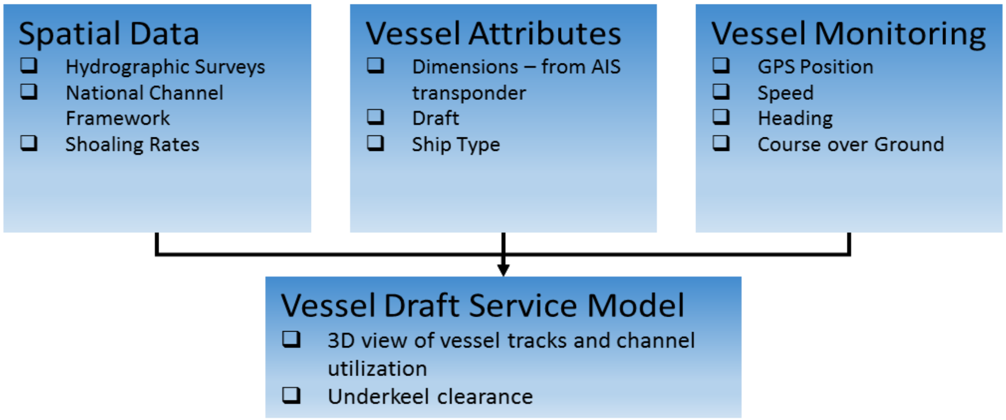

Figure 3. Conceptual model for limiting depth within an authorized navigation channel.

Statistical Surfaces

Once the underkeel clearance of the vessel is quantified, additional statistical surfaces are created to represent the average and minimum total underkeel clearance. As time period increases, multiple vessel surfaces may overlap, creating a stack of vessels with varying total underkeel clearance depths. The statistical surfaces provide a meaningful convention by which to quantify the variability in the vessel traffic through the channel (Figure 4). The average total underkeel clearance represents the mean underkeel clearance for all vessels occupying a specific location in the channel. Therefore, if shallow draft vessels transit a particular section of the channel more frequently, then the average underkeel clearance surface will be skewed to show greater underkeel clearance availability. As such, a statistical surface that captures the minimum underkeel clearance is also considered to account for the deepest drafting vessels transiting the channel, and the points along the channel where vessels come closest to running aground. The minimum underkeel clearance surface provides the most conservative estimate for potential hazards.

DREDGING SUMMIT & EXPO ’18 PROCEEDINGS

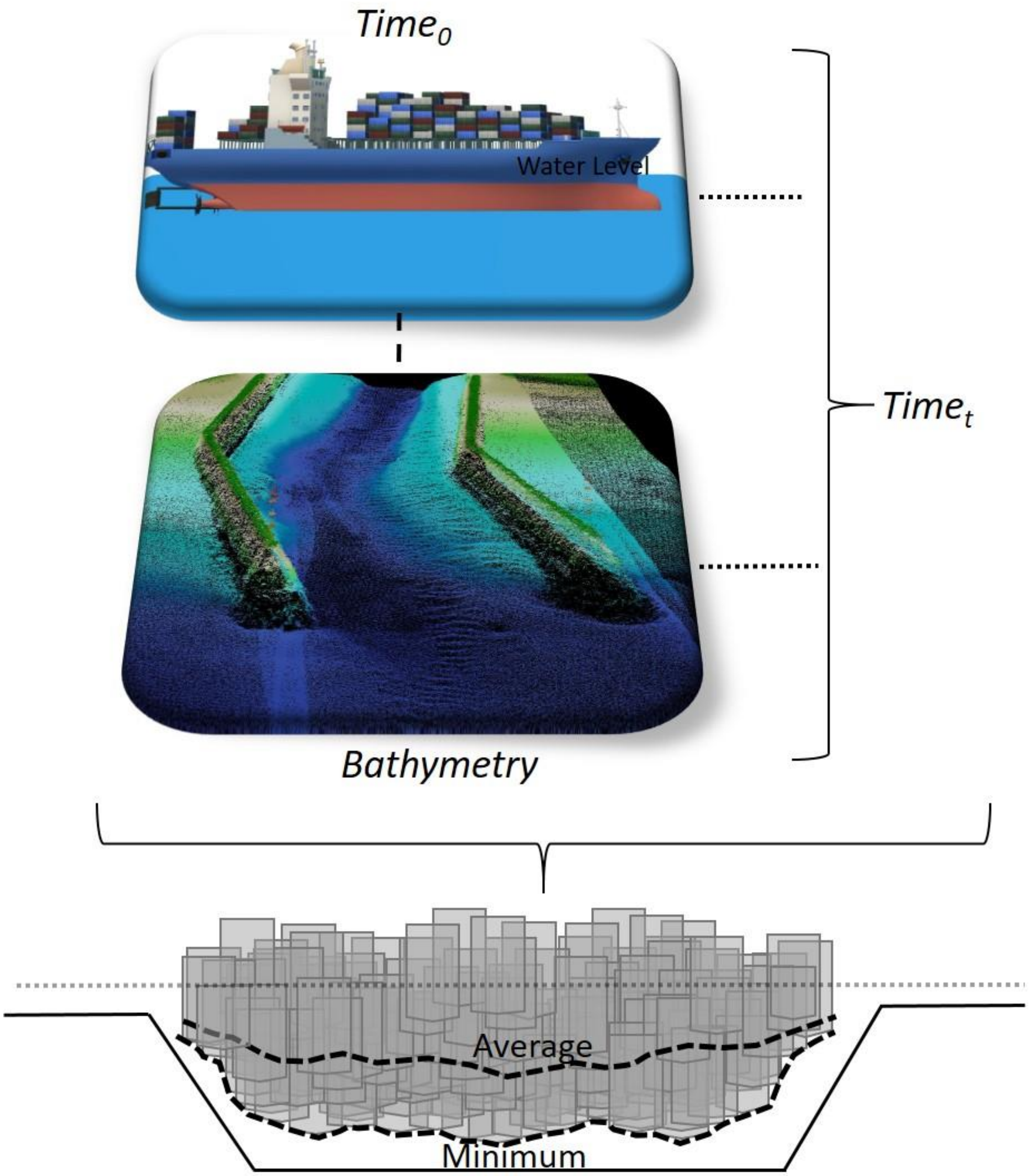

Figure 4. Statistical surface schematic showing average and minimum total underkeel clearance variability as time increases.

Other statistical surfaces are further explored to fully integrate the three dimensional data and extract various metrics that may further provide insight into the limiting channel depths. The surface area of the vessel is compared to the bathymetric surface to quantify the volume available below the vessel plane. Each vessel footprint is compared to the channel bathymetry to provide another metric for quantifying limiting depth for various channels. Similarly to the minimum underkeel surface, the volume surface eliminates any bias that may be present in the average underkeel clearance surface for channels with significantly more shallow draft vessels as compared to the deeper draft vessels.

Additional surfaces for shoaling rates are also available for comparison with the vessel underkeel clearance statistical surfaces. The shoaling rate grids are generated using the CSAT tool which uses available hydrographic surveys to predict shoaling through the channel. These datasets are available for the coastal navigation channels and are well suited to quantify areas of concern, particularly when total underkeel clearance is at a minimum.

DREDGING SUMMIT & EXPO ’18 PROCEEDINGS

By stacking the various spatial layers together, additional metrics may be calculated to better understand the relative effectiveness of maintaining channels at various depths (Figure 5). Figure 5 shows the workflow to create the minimum TUKC statistical surface that begins with the creation of the vessel surface that is next combined with the bathymetry to quantify minimum TUKC. Combining the minimum TUKC statistical surface with the shoaling rate grid in a weighted overlay model is explored as a representation of channel reliability.

The weighted overlay model allows several surfaces to be compared through a multi-criteria analysis. The shoaling rate and minimum TUKC surfaces are represented quantitatively as reliability indices ranging from 0 to 1 (unreliable to highly reliable, respectively). As shoaling increases, the navigation channel reliability decreases. With decreasing minimum TUKC, the channel reliability also decreases.

The weight of influence for each surface may be adjusted to further investigate each individual parameter and the influence associated with limiting depths and developing a channel reliability index. The goals of this study are focused on the GIS applications to create repeatable spatial layers and generate the statistical surfaces used in the multi-criteria, weighted overlay model. Additional work will focus on assigning varying weights of influence to the spatial layers to fine tune the results and develop a national weighting schema for the coastal navigation channels.

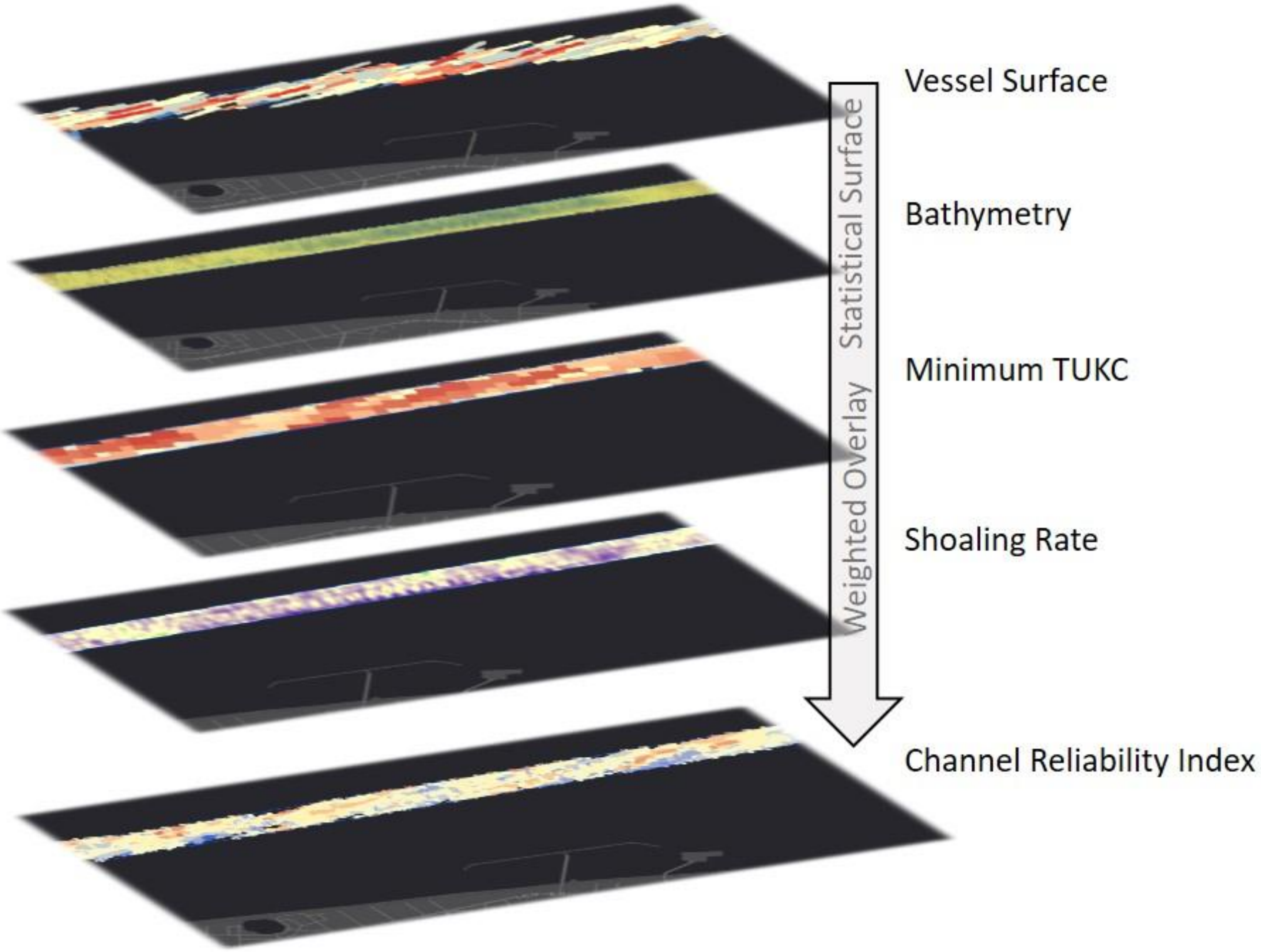

Figure 5. Statistical surface layer stack and weighted overlay surfaces to quantify channel reliability.

DREDGING SUMMIT & EXPO '18 PROCEEDINGS

Columbia River Example

The methods developed for generating the statistical surfaces that are incorporated in the multi-criteria weighted overlay model are shown for a 20 mile stretch of the Columbia River Navigation project (Figure 6).

Figure 6. Columbia River, OR navigation channel with analysis portion highlighted in blue and the red box showing location relative to Portland, OR and Seattle, WA.

The Columbia River is frequently surveyed and also has deep draft vessels transiting. The average vessel draft is 24 feet with a maximum draft of 45 feet reported from the AIS data from January 1, 2015 to December 31, 2015 (Figure 7). During 2015, the Columbia River navigation project was surveyed about every two months. The frequency of surveys provides the near 'real time' bathymetric conditions the vessels transiting the channel encountered. In addition, the AIS data was sampled every 1 minute for the Columbia River region of interest to provide sufficient coverage of the channel and include stacks of vessel transits to create the statistical surfaces.

DREDGING SUMMIT & EXPO '18 PROCEEDINGS

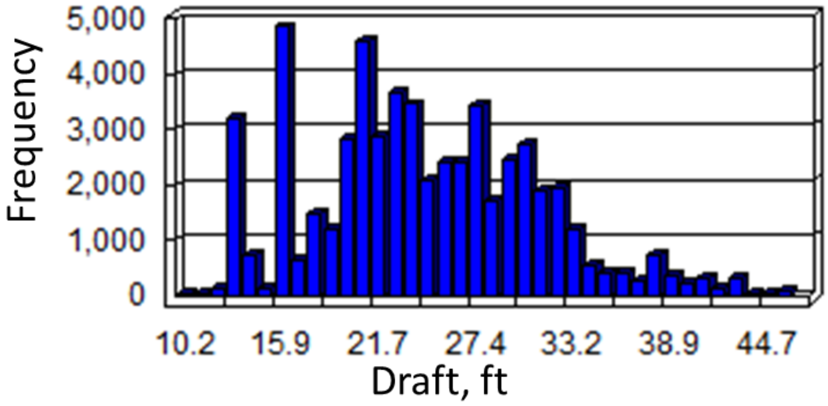

Figure 7. Columbia River, OR draft frequency for the 20 mile region of interest covering the full year in 2015.

The range of depths for the minimum TUKC for the Columbia River region of interest is shown in Table 1. PIANC (2014) recommends 15 percent of the vessel draft for a conservative underkeel clearance threshold. For this region of the Columbia River, the minimum TUKC exceeds the PIANC recommended underkeel clearance for 23 percent of the transiting vessels within the channel. Additionally, the 6.5 feet or less for minimum TUKC is worthy of mention given the average shoaling rate is 1 foot per year.

Table 1. Minimum total underkeel clearance and percent occurrence.

Minimum TUKC, ft	Percent Occurrence
<6.5	23%
6.5 -- 13	39%
>13	38%

The multi-criteria, weighted overlay method provides a representation of the channel reliability as it relates to minimum TUKC and shoaling rates. The channel reliability decreases as shoaling rates increase and minimum TUKC decreases. Applying equal weight of influence for both the shoaling rate and minimum TUKC surfaces qualitatively shows 'hot spot' areas of decreased channel reliability (Figure 8 – red areas). For this study, both surfaces used in the multi-criteria, weighted overlay model had equal influence to determine channel reliability; however, additional analyses should consider varying the influence associated with each surface. Furthermore, incorporating additional surfaces, such as dredging costs and tonnage profile may also provide insight into channel reliability and relative effectiveness of maintained channel dimensions.

DREDGING SUMMIT & EXPO '18 PROCEEDINGS

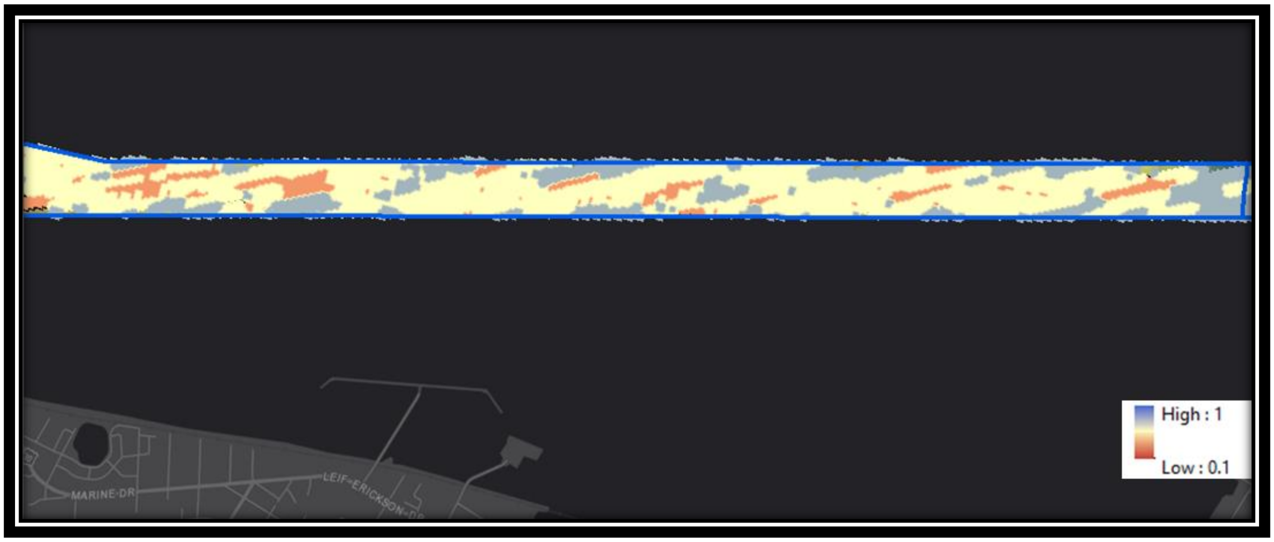

Figure 8. Channel reliability model surface for a reach along the Columbia River, OR showing variation in channel reliability (highly reliable – blue, less reliable – red).

CONCLUSIONS

Enterprise datasets are more easily accessible and are ideal for creating three-dimensional geospatial layers in order to support objective decision making. The availability of time-stamped vessel position reports, broadcast as frequently as every 6 seconds via onboard (AIS) transceivers, allows for the vessel dimensions (length, beam, and draft) to be projected for direct, three-dimensional comparisons against the hydrographic surveys of the maintained navigation channel. Additional surfaces, such as shoaling rates, are used to quantify shoaling hot spot areas and are combined through various weighting schemes with the detailed AIS vessel transit data to further understand limiting depths along the navigation channel. The goal is to quantify the relative effectiveness of maintained channel dimensions in supporting the Navigation mission requirement for safe, reliable, and cost-effective marine transportation.

REFERENCES

AISAP - Automatic Identification System Analysis Package (2017). https://rsm.usace.army.mil/misc/AISAPflyer2017.pdf

Atkinson, E., O'Brien, P. (2008). DUKC in channel design. Proceedings of the 6th IHMA Conference. St. Petersburg, Russia.

Barrass, C. B. and Derrett, D. R. (2012). Ship Stability for Masters and Mates (7th Edition). Elsevier. http://app.knovel.com/hotlink/toc/id:kpSSMME005/ship-stability-masters/ship-stability-masters

Briggs, M. J., Silver, A.L. Kopp, P.J., Santangelo, F.A., Mathis, I.A. (2013). Validation Of A Risk-Based Numerical Model For Predicting Deep-Draft Underkeel Clearance. ASCE Journal of Waterway, Port, Coastal, and Ocean Engineering. Vol 139, No. 4. July 1, 2013. pp. 267-276.

Calder, B. and Schwehr, K. (2009). Traffic Analysis for the Calibration of Risk Assessment Methods. US Hydro 2009. May 11-14, Norfolk, VA.

Dunkin, L.M. and Mitchell, K.N. (2015). Quantitative Approach to Navigation Channels Asset Management. Proceedings of the Western Dredging Association and Texas A&M University Center for Dredging Studies' "Dredging Summit and Expo 2015". Houston, Texas, USA, June 22-25, 2015.

Farhadi, N., Parr, S., Mitchell, K. N., Wolshon, B. (2016). Use of Nationwide Automatic Identification System Data to Quantify Resiliency of Marine Transportation Systems. Transportation Research Record: Journal of the

DREDGING SUMMIT & EXPO ’18 PROCEEDINGS

Transportation Research Board, No. 2549, Transportation Research Board of the National Academies, Washington, D.C. pp. 9-18. DOI: 10.3141/2549-02

International Telecommunication Union (ITU). 2010. *Technical characteristics for an automatic identification system using time-division multiple access in the VHF maritime mobile band*. ITU-R M.1371.4. Geneva, Switzerland.

Kruse, J., Mitchell, K.N., Dijoseph, P.,(2018). Developing and Implementing a Port Fluidity Performance Measurement Methodology Using Automatic Identification System (AIS) Data. Accepted to Transportation Research Record: Journal of the Transportation Research Board. In press. 2018.

Libeau, B.A. C.M. (2007). Partners in Data Management: Creating a National Channel Framework Database by the National Oceanic and Atmospheric Administration and the US Army Corps of Engineers. Marine Technology Society and Institute of Electrical and Electronics Engineers Oceans 2007 conference proceedings.

Mitchell, K. N. and Scully, B. (2014). Waterway Performance Monitoring via Automatic Identification System (AIS) Data. Transportation Research Record: Journal of the Transportation Research Board, No. 2426, Transportation Research Board of the National Academies, Washington, D.C pp. 20–26. DOI: 10.3141/2426-03

Mitchell, K. N., Wang, B. X., and Khodakarami, M. (2013). Selection of Dredging Projects for Maximizing Waterway System Performance. Transportation Research Record: Journal of the Transportation Research Board. No. 2330. pp. 39–46. https://dx.doi.org/10.3141/2330-06.

Mitchell, K. N. (2012). A Review of Coastal Navigation Asset Management Efforts within the Coastal Inlets Research Program (CIRP): Part 2: the Channel Portfolio Tool, ERDC/CHL CHETN-IX-29, U.S. Army Engineer Research and Development Center, Vicksburg, MS. http://chl.erdc.usace.army.mil/chetn

Mitchell, K. N., J. E. Walker. (2009). Depth-Utilization Analysis for Estimating the Economic Activity Supported by Dredging. Western Dredging Association/Texas A&M University Annual Dredging Conference. Phoenix, AZ. http://cirp.usace.army.mil/pubs/pdf/mitchell-walker_WEDA09.pdf

Niles, A.R. (2013). eHydro Navigation Channel Condition Reporting. U.S. Army Engineer Research and Development Center. Coastal and Hydraulics Laboratory.

PIANC. (2014). Harbour Approach Channels Design Guidelines. Report Number 121.

Scully, B., Mitchell, K.N. (2017). Underkeel Clearance Reliability Model for Dredged Navigation Channels. Transportation Research Record: Journal of the Transportation Research Board. No. 2611, Transportation Research Board of the National Academies, Washington, D.C., 2017, pp. 41–49.DOI: 10.3141/2611-05.

Scully, B. M. (2017). Tidal Analysis and Arrival Process Mining Using Automatic Identification System (AIS) Data. ERDC/CHL TR-17-2. U. S. Army Engineer Research and Development Center, Vicksburg, MS.

Silveira, L., Gomes, G., Taiani, L., Pinheiro, V., Benedet, L., Marques, A., and Loureiro, C. (2017). Integrated Method for Optimal Channel Dredging Design. Terra et Aqua, Number 146, March 2017.

Silver, A.L., and Dalzell, J.F. (1998). Risk-Based Decisions for Entrance Channel Operation and Design. International Journal of Offshore and Polar Engineering. Vol. 8, No. 3. Pp. 200-206.

Touzinsky, K., Scully, B., Mitchell, K.N., Kress, M. “Using Empirical Data to Quantify Port Resilience: Hurricane Matthew and the Southeastern Seaboard.” ASCE Journal of Waterway, Port, Coastal, and Ocean Engineering. 2018, 144(4): 05018003.

U.S. Coast Guard (USCG). (2012). Automatic Identification System Encoding Guide. V.2015-05-01. http://www.navcen.uscg.gov/pdf/AIS/AISGuide.pdf

DREDGING SUMMIT & EXPO ’18 PROCEEDINGS

CITATION

Dunkin, L.M., Saltus, C., Mitchell, K.N., and Scully, B.M., “Improved Channel Evaluation Using Automatic Identification System And Hydrographic Survey Data,” *Proceedings of the Western Dredging Association, WEDA, Dredging Summit and Expo, Norfolk, VA*, USA, June 25-29, 2018.