# ESTIMATED GROSS BENEFITS PROVIDED BY NAVIGATIONAL CHARTS IN THE UNITED STATES

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**October 24, 2022**

**Revised January 5, 2024**

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## EXECUTIVE SUMMARY

Marine transportation is essential to the U.S. economy. Over the previous twelve years, total annual international tonnage exceeded 2.0 billion with an associated annual cargo value in excess of $3.5 trillion. ($2021). Waterborne transportation has always dominated total international trade accounting for over 72 percent of tonnage and about 42 percent of cargo value over time.

This analysis contributes to the literature through more comprehensive estimation of the private and societal impacts based on averted or cost reductions across several economic groups including commercial shipping, recreational boating, commercial and recreational fishing. The United Nations specifies the Blue Economy as a range of economic activities related to oceans, seas and coastal areas, and whether these activities are sustainable and socially equitable. An important key point of Blue Economy is sustainable fishing, ocean health, wildlife, mitigating pollution and safe and efficient waterborne transportation. Potential impacts on portions of the $373 billion dollar Blue Economy are addressed.

The value of nautical charts results from several sources. First, without timely, accurate and complete nautical charts the mariner is unable to see below the surface of the water they hence are at risk of being unable to avoid submerged dangers to navigation. Due to averted allisions, collisions and groundings costs associated with vessel and cargo losses, morbidity and mortality and pollution cleanup costs can be minimized or averted. With nautical charts mariners are able to see where navigational dangers are located and enables the ability to plan efficient courses to safety reach the intended destination. Second, with proactive knowledge of channel depths, lowering of private and societal costs can result from reduced fuel and resultant emissions for more efficiently loaded vessels.

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It is recognized that several deliverables and entities (e.g., nautical charts, port pilots, bridge managers, water level measurements (NYLON, PORTS®), etc.) provide essential information that when collectively employed results in significant societal benefits from safe and effective transportation. In this analysis total benefits were parsed among major contributors of supportive information based on their perceived contributions.

### COMMERCIAL SHIPPING

The minimum under keel clearance (distance from the vessel bottom to the sea or lake bottom) is defined by port authorities and the shipping companies. The additional tonnage carried in vessels operating with less than the minimum under keel clearance is cargo that doesn't need to be transported on an additional vessel. By avoiding additional trips, the benefit is the reduced transportation costs such as vessel operational costs and emissions avoided. The total benefit was divided equally between the nautical chart, Water Level data and the expertise of the required pilot.

The benefit derived from use of the nautical chart was $365.6 million ($2017) owing to averted additional vessel transits. Almost 160,000 metric tonnes of emissions, valued at almost $280 million ($2017) are annually avoided owing to the ability to more heavily load vessels. It should also be noted that timely, accurate and complete nautical charts add to societal equity as commercial ports and main waterway channels tend to be in economically distressed less diverse areas of the country. Any reductions in pollutants help improve the environment for those living in proximity to those areas.

### ALLISION AVOIDANCE

The nautical chart is essential for mariners to avoid unseen dangers to navigation. The danger avoidance value of the nautical chart can be calculated from the accidents avoided multiplied by the average cost of a vessel allision with a submerged danger to navigation (DTON). The availability of AIS track data for commercial vessels as well as those commercial fishing vessels and pleasure boats reporting AIS data enabled examination of vessel operations in the vicinity of submerged DTONs.

Avoided accidents were determined by creating a 40-meter danger circle around each charted DTON that are not visible to mariners from the bridge of the ship. Vessels with AIS track lines that intersected a danger circle around a DTON were judged to be sailing dangerously close to a danger and at risk of an allision. Vessel drafts were corrected for squat and compared to the least depth over the DTON corrected for tide/water level and the accuracy of the sounding data. It was also recognized that Vessels track lines operating dangerously close, within 40 meters of a DTON, do not necessarily strike the danger, therefore a simple equation of probability of intersecting the DTON by vessels taking into consideration vessel width and the DTON circle diameter, was developed to better estimate the potential allision. Knowing the width of the vessel the likelihood of an allision was calculated. Finally, to ensure that all the calculated allisions were legitimate, a visual review of all different DTONs involved in expected allisions was conducted to validate dangers to shipping. Vessels with corrected drafts greater than the corrected depth of the DTON were at increased risk of an allision. The number of avoided allisions with DTONS ranged from over 9,300 to just under 22 thousand per year. Recognizing the important combined role of the nautical chart, GPS and the required ship pilot the benefit derived from these avoided allisions was split equally between them. Collectively, based on average costs of an allision, savings from avoided allisions due to nautical charts was estimated to range between $645.5 million to $1,548.6 million ($2017) per year.

## COMMERCIAL FISHING

Nautical charts are essential to the operation of commercial fishing vessels for both safe navigation and planning fishing operations. Between 2004 and 2019, average annual fish catch was about 4.4 million metric tons with an average annual value of nearly more than $5.8 trillion ($2017). Commercial fishermen use electronic charts displayed on various forms of chart viewers and navigation systems. Some commercial fishermen additionally use commercially available electronic detailed seafloor maps with resolution as high as one meter for the planning of fishing operations once the vessel has arrived at the fishing location. The commercial fishing mariners also employed nautical charts to avoid the 71 thousand submerged charted dangers to navigation and for planning safe routes to and from the fishing grounds.

Charts are used in planning fishing operations to set the gear at the proper depth and to avoid operating near dangers to navigation and reefs to avoid damaging fishing gear.
Based on an estimated fleet size of 58 thousand commercial fishing vessels and reported individual self-propelled vessel's willingness to pay an annual benefit of $214.6 million ($2017) for the nautical charts was estimated.

**RECREATIONAL BOATING**

The nautical chart is essential to the recreational boater for safe navigation and route planning and 69 percent of recreational boaters report using nautical charts. Just as with large commercial ships the operators of recreational boats cannot see what lies beneath the water surface and thus cannot avoid dangers to navigation without the use of a nautical chart. There are over 255 thousand charted dangers to navigation (DTONs) 160 thousand of which are within two miles of the shore which is an area most frequented by recreational boaters.

Recreational boaters have a multitude of ways to access nautical chart information. Paper (both print-on-demand and through value added providers), raster chart images (downloaded directly from the National Oceanic and Atmospheric administration's (NOAA) Office of Coast Survey (OCS) site or as part of a large array of chart plotter and navigation systems including inexpensive cell phone app navigation systems, and the information rich vector ENC (electronic navigational chart) available directly from NOAA OCS or from ENC distributors services. Additionally, many recreational boaters rely on their knowledge of familiar boating waters. This includes their examination of nautical charts posted on the walls of their marina, yacht club, fueling site, or even boating supply store. Total recreational boating benefits were estimated to be $92.7 million.

## RECREATIONAL FISHING

Just as with the operators of other recreational boats recreational fishermen cannot see what lies beneath the water and thus cannot avoid dangers to navigation without a nautical chart to aid them in plotting a safe courses. The saltwater recreational fishing industry is sizable. In 2016 there were approximately 10 million saltwater recreational fishermen who took 70 million saltwater fishing trips. These anglers spent $15.4 billion on salt water fishing trips and durable recreational gear expenditures in waters zero to two hundred miles from shore. Recreational fishing also adds a portion to the Blue Economy through coastal and inland state expenditures on both durable and non-durable goods and support services. Employing a Nordhaus approach where a de minimis portion of durable expenditures on fishing trips and durable expenditures was added to the implied value of retained fish catch, an annual value of 138.7 million ($2017) was projected.

## SUMMARY

The nautical chart is essential for all types of mariners to avoid submerged dangers, to plan safe routes, to maximize commercial vessel loading, and aid in operations (e.g. commercial fishing and recreational boating). Nautical charts also benefit the environment and promotes societal equity. Aside from lesser port and channel congestion, the reduced number of vessel trips has a societal benefit from fewer emissions from the burning of vessel fuel. As many ports and vessel transit lanes are located in or adjacent to relatively economically disadvantaged areas, reductions in emissions proportionately assist individuals living in or in proximity to these areas.

In each benefit appraisal, a subjective assessment of the confidence of the estimate was made based on the quality of the underlying data, documented exactness of the relationship between nautical charts and resultant benefits and proximity to previous research findings. Overall, the annual value of nautical charts was estimated to range from $1,457.1 million to $2,360.2 million ($2017).

**ANNUAL VALUE OF NAUTICAL CHARTS**

| BENEFICIARY | ESTIMATED BENEFITS ($ 2017 MILLIONS) | CONFIDENCE LEVEL |
|---|---|---|
| Commercial Shipping | $365.6 | High – Very High |
| Allision Avoidance Tool (DTON) | $645.5 - $1,548.6 | Very High |
| Commercial Fishing | $214.6 | Medium |
| Recreational Boating | $92.7 | Medium |
| Recreational Fishing | $138.7 | Medium |
| **TOTAL** | **$1,457.1 - $2,360.2** | |

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# CHAPTER 1 – BACKGROUND

## I. INTRODUCTION

One of the National Oceanic and Atmospheric Administration (NOAA)'s FY 2022-2026 strategic plan *"is to accelerate growth in an information based blue economy"*.[1] In the mission statement of the plan NOAA

> "*will advance the knowledge-based ocean economy, looking to the ocean for data, information and knowledge that can be applied to innovative and sustainable business development, products and services that support new and established ocean-based sectors."*

Included in this plan is to advance NOAA's contribution to a safe and efficient transportation system as well as expand sustainable marine tourism and recreational opportunities.[2]

Nautical charts have been recognized by many entities as a fundamental tool of marine navigation.

> "*Maps – Humankind's greatest tool"*[3]

> *"Maps and charts throughout history do not just represent the world. They help drive the social and economic growth around the world."*[4]

> *"The nautical chart is essential for safe navigation."*[5]

> *"One of the most important tools for safely navigating waterways is a Nautical Chart."*[6]

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[1] NOAA. 2022. "Building a Climate Ready Nation". NOAA FY22-26 Strategic Plan

[2] Ibid, Page 54

[3] Megan Neal, Popular Mechanics ,July/August 2020, cover

[4] Dawn Forsythe, 2017. "*Nautical Charts Contribute to Economic Growth and National Defense, 1807-1945"*, unpublished white paper, p.5. NOAA, National Ocean Service, Office of Coast Survey, April 20.

[5] https://oceanservice.noaa.gov/facts/nauticl_chart.html

[6] A Boater's Guide to the Federal Requirements for Recreational Boats, United States Coast Guard, p. 45, www.uscgboating.org/images/420.pdf

A nautical chart is a special purpose map specifically designed to meet requirements of vessel navigation. It provides a graphical representation of relevant information to mariners for planning and executing safe navigation making it one of the most fundamental tools available to the mariner. It depicts the configuration of the shoreline and sea floor, provides water depths, locations of dangers to navigation, locations and characteristics of aids to navigation, anchorages, and other features important to a mariner.

Without nautical charts it would be impossible to safely operate ships engaged in the transport of cargo and passengers or those engaged in fishing operations, oil exploration, deep sea mining, scientific research of the ocean, recreational boating or naval defense of our nation. The mariner standing on the bridge of the ship cannot see what lies under the surface of the water and thus cannot see where it is safe to operate. They are completely reliant on the nautical chart.

**Unable to view below the surface of the water the mariner cannot avoid the dangers they cannot see without a nautical chart.**

Even the health of the marine and coastal environments depend on the accuracy and reliability of the nautical chart as they help prevent the marine accidents and the resultant release of hazardous oil and chemical cargoes. And yet rather than the perilous undertaking that sailing on a ship would seem to be it is done now with a minimal risk of grounding with the ocean bottom or allision with another object in large part to the accuracy of the nautical chart. Hundreds of thousands of ships and boats sail in U.S. waters annually with remarkably few accidents related to groundings and allisions. That safety record is due primarily to the accuracy of the nautical chart. While typically thought of as a tool for ships in oceans, nautical charts can be for both fresh and salt water, for ocean and navigable rivers and lakes, anywhere vessels need to navigate. Charts while technically a special type of map are not to be confused with a map typically used on land.

Critical information provides for safe and efficient use of our waterways and for protection of our marine environment. NOAA nautical charts developed by the OCS are mandatory on commercial ships that carry America's foreign commerce. NOAA's charts are also used on every Navy and Coast Guard ship, fishing and passenger vessels, and are widely carried by recreational boaters. Thus, they directly support NOAA's goal to "promote safe navigation" and the Department of Commerce's goal of promoting U.S. competitiveness in the global marketplace.

Detailed accounting of charting benefits has been difficult because they arise from complex behaviors and decisions. Moreover, for a myriad of economic and moral arguments, one cannot suddenly rescind existing navigational charts in order to assess the deleterious impacts of such revocations. Yet such benefit assessments are important for two reasons. First, it helps determine how much charting activities are "worth" which can assist government in determining the priority of these programs in the appropriations process, and the level of investment that best benefits the nation. Second, the ability to measure quantitatively the benefits of nautical charting helps establish an investment strategy that can assist in allocating NOAA's appropriation among different locations, types and granularities of nautical charting activities.

### A. Early Charts

Nautical charts have not always been available. The first marine charts were actually maps with continents and islands located usually inaccurately. There were no chart projections that would enable the accurate depiction of continents and islands and the navigation between ports. There weren't any indications of subsurface features indicating dangers to be avoided. There were no soundings or information on dangers to navigation. All of that would be developed later. An example of one of the earliest nautical charts is the 1339 Dulcert Portolan chart hand drawn on a calf hide velum.[7] (Figure 1)

Enlargement of Dulcert Portolan chart showing in the center, Italy and Sicily, Greece and the Aegean Sea. (Figure 2) A more complete lineage of nautical charts during the last 500 years is provided in Appendix A.

**Figure 1**

**PORTOLAN CHART**
(Attributed to Angelino Dulcert during mid-1300s. Draw on velum)

[7] https://www.bl.uk/collection-items/portolan-chart-attributed-to-angelino-dulcert#

**Figure 2**

**ENLARGEMENT OF DULCERT PORTOLAN CHART**

## B. Evolving With Technology

The ever-growing need for safety and efficiency spurred on the development of technologies to survey the ocean topography more accurately. Nautical charts are also snapshots of advancements made in surveying and mapping technology. New data displayed on today's charts are collected by multibeam and side scan sonar, which provide a comprehensive sweep of the sea bottom that detects obstructions.[8] Older charts (and some of the more remote portions of present charts), on the other hand, were populated with data collected from a number of different sounding technologies including single beam echo sounder, lead-line soundings or readings from casts of a weighted rope. These older technologies do not measure depths or locate obstructions over the entire bottom and are thus inadequate for most modern shipping requirements.

A nautical chart today might carry data from multiple eras, modern and old. The 21st century chart also comes in electronic formats, to meet the needs of mariners operating with the

[8] https://celebrating200years.noaa.gov/foundations/nautical_charts/welcome.html)

latest technology on their ship bridges. These electronic navigational charts enable the mariner to customize what is shown on the screen, and they deliver far more information about chart features than has ever been possible before.

**C. Electronic Navigational Charts**

Up until the early 1990s, mariners relied on paper nautical charts produced by NOAA cartographers using a manual drafting and engraving process. Because it could take up to eight months to revise and print a paper chart, new editions were only released every two or more years, meaning that these static paper versions were essentially only current on the day printed. For chart updates, mariners had to check weekly Local Notices to Mariners published by the U.S. Coast Guard and U.S. Notice to Mariners published by the former Defense Mapping Agency (now the National Geospatial Intelligence Agency). Every Notice to Mariners correction since the print date of the chart would then have to be applied by hand, a process that could take a mariner several hours to update just one chart.

Throughout the 1990s, advancements in technology transformed the appearance, use, and functionality of nautical charts, fueling dramatic improvements in navigational safety. A first step in this transformation was creating digital images of paper nautical charts, called raster charts. Raster charts could be viewed on the bridge of a ship using a simple computer. Raster charts advanced maritime navigation by allowing mariners to quickly observe a vessel's position using global positioning system (GPS) data with charts. However, raster charts do not address all of the limitations associated with paper charts, mainly that they do not provide danger warnings to the mariner.

To address the limitations of paper and raster charts, in 1997, NOAA's Office of Coast Survey started building a vector charting database. A vector chart is a series of points, lines, and polygons that represent features on the chart. Chart information is stored in a database and specific characteristics are identified for each chart feature. For example, database information for a buoy on a chart might include characteristics such as latitude, longitude, color, and number.

### D. The Future of Nautical Charting

Since the introduction of electronic navigational charts (ENCs) the size of commercial vessels has increased four-fold and navigation systems have become more sophisticated. Additionally, there are now over 15 million recreational boat users in the U.S. and many have joined professional mariners in using electronic chart displays and NOAA digital chart products when navigating. User groups of all types are increasingly expecting more precise, higher resolution charts, and greater timeliness and ease-of-access to chart updates.

In November of 2017, the Office of Coast Survey released the National Charting Plan, a strategy to improve NOAA nautical chart coverage, products, and distribution. It outlines actions that will provide the customer with a suite of products that are more useful, up-to-date, and safer to navigate with. It is not a plan for the maintenance of individual charts, but a strategy to improve all charts. It presents strategies to meet the growing demand. The National Charting Plan outlines several improvements to chart content, such as:

- Reducing unwarranted alarms in the electronic chart display and information system (ECDIS) used by large commercial vessels and Improving the differentiation between dangerous and non-dangerous wrecks.
- Resolving uncertainties about ‘reported,’ ‘existence doubtful,’ and ‘position approximate’ dangers (now known as “unverified chart features”).
- Creating an orderly layout for ENC charts that will replace the current set of 1,182 irregularly shaped ENC cells compiled at 131 different scales with a regular gridded framework of cells compiled at a few dozen standard scale.
- Working with the U.S. Coast Guard to develop methods to ingest changes to the database of USCG maintained aids to navigation directly into Coast Survey’s chart production system. This will save time and avoid any chance of data being entered incorrectly by

hand.

- Working with the U.S. Army Corps of Engineers to expedite the provision of minimum channel depths on NOAA products and the Corps' websites.[9]

The nautical chart has many uses but chief among them are safe navigation and voyage planning enabling the mariner to navigate a ship avoiding known dangers that lie invisible beneath the water surface. Without an up-to-date chart the mariner is unable to avoid these dangerous shoals, reefs, rocks, wrecks, and submerged debris lie.

The OCS has a large job to perform. Gonsalves (2017) reports that the U.S. Exclusive Economic Zone is about 3.4 million square nautical miles ($nm^2$). Of this area, about 44,000 $nm^2$ have been surveyed to "modern" standards. Each year, an average of about 3,000 $nm^2$ are surveyed. Of the hundreds of ports in the U.S., the top fifty account for about 97 percent of all import and export activity. Major ports are listed in Appendix B

Each year, OCS receives over 6,000 digital and hardcopy source documents from NOAA's Hydrographic Surveys Division, U.S. Army Corps of Engineers (USACE), NOAA's National Geodetic Survey, and U. S. Coast Guard. Compiling data for updating charts may take as little as six months but can take several years owing to the location, the extent of the surveys required as well as competing requirements (e.g., routine or critical) from other charts.[10] Today, the OCS maintains more than 20 thousand historical nautical charts while maintaining its current suite of over one thousand charts.[11]

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[9] https://nauticalcharts.noaa.gov/news/draft-national-charting-plan.html

[10] Source: https://oceanservice.noaa.gov/facts/chart_produce.html, *"How Long Does It Take to Produce a Nautical Chart?"*

[11] Source: NOAA celebrates 200 Years of Science, Service and Stewardship. https://celebrating200years.noaa.gov/foundations/welcome.html

## II. SCOPE OF ANALYSIS

A benefit-cost analysis was not undertaken owing to the inability to obtain historical and potential future costs of nautical chart new editions. While costs borne by NOAA might be historically reconstructed, they represent only a portion of total costs. For example, while ENCs may be distributed, costs charged from private retailers of such data is not known nor is the cost of vessel Integrated Bridge Management System (IBMS) equipment to receive process and display such data. Hence, only gross benefits were estimated in this analysis. While limited to gross benefits alone, this approach is in keeping with Dorman (1994) who commented:

> *"It is not realistic to encompass all the costs and benefits associated with implementing a project. So long as all the major costs and benefits are considered this should be sufficient to give an estimate of the cost-benefit".*

Following Dorman, all major cost savings benefits related from increased vessel loadings were incorporated into this analysis. As major calculations and results are displayed in a highly transparent nature, readers may develop alternative conclusions when and if additional data or data with enhanced granularity becomes available.

## III. PREVIOUS VALUATION STUDIES

Previous efforts at quantifying the value of hydrographic surveys and nautical charts have largely taken one of several general approaches. Some have researchers, in reviewing the complexity and interrelated nature of charts and other supporting infrastructure, have identified a variety of economic sectors who benefit from charts but did not provide any quantitative estimates of those benefits. In other studies, due to interdependence of factors, only high levels of aggregation were employed to define beneficiary groups (e.g., combining the impacts of nautical charts[12], integrated bridge management systems, PORTS® and other factors.) Still others parsed estimated national total benefits to lower levels of granularity to estimate ENC benefits.

In an early example, Oudet (1972) recounts how the lack of accurate real-time data navigational coupled with inappropriate actions of the captain of the vessel led to the wreck and total loss of the cruise ship *Antilles* in 1971. In his review, no quantitative data was provided.

In a later analysis, Vadus (1996) stated the nautical charts play a significant role in providing safe and effective navigation of vessels involved in commerce, fishery landings, marine recreation, oil spill prevention and remediation and cruises. Other sectors including research and naval operations were also highly dependent on nautical charting. He stated:

> *"Electronic nautical charting systems and related information and databases provide a vital supporting role in ensuring sustainable development of marine transport operations that fulfill national needs that have major economic, social, and environmental implications that equate to hundreds of billions of dollars in the U.S."*[13]

Hecht et al. (2002) followed suit in detailing a wide-variety of benefits due to ENCS beyond marine navigation.

Brinkman et al. (1992) performed a study of The Canadian Hydrographic Service (CHS). He determined benefit-cost ratios ranging between 9.49 and 11.86 resulting from impacts on commercial shipping, accident rates, recreational boating and fishing vessels based on changes in

[12] In this analysis, only the value of charts and underlying chart data developed by NOAA has been estimated. It is recognized that there are also a few open source sources of navigation data supplied by volunteers. The TeamSurv and Open Sea Maps are examples. However, TeamServ notes on its website for mariners not to rely only on these charts for "navigation or any other critical purposes".

[13] Page 33.

consumer and producer surplus[14] and elasticity of transportation demand. Overall, he estimated total benefits from all sources to exceed $473 million (1989 Canadian Dollars) against costs of between $40 to $50 million (1989 Canadian Dollars).[15]

Also in 1992, the Australian Department of Defense Report reviewed the benefits from a number of sectors including: (1) establishment of Australia's exclusive economic zone; (2) mineral exploration; (3) prevention of environmental damage; (4) commercial fishing; (5) safe passage of cargo and passenger vessels; (6) freedom of movement of the fleet; (7) scientific research; (8) complying with Australia's international obligations; and (9) asserting claims to areas of Antarctica. They concluded by stating:

> *"The fact that exact benefit-cost ratios could not be calculated is perhaps not that important as such ratios, even if arrived at objectively, would not tell us the optimum level of activity in any given year. That would require the marginal cost-benefit ratios a far more complex analysis. What is beyond reasonable doubt is that the existence of official up-to-date charts has a benefit to the national economy"*[16]

> *"The Hydrographic Programme is a public good, in the strict economic sense of the word. Such a good or service would, by definition, not be supplied in nationally optimal levels if left to market forces alone. However, there are no theoretical or empirical reasons why more active cost recovery should not be considered, aimed towards carefully targeted groups of beneficiaries."*[17]

> *"Hydrographic activity has traditionally been viewed as a naval activity but this analysis has described, and where possible, analysed its effect on the national economy. The role played*

[14] Producer surplus is measured as the difference between what producers are willing and able to supply a good for and the price they actually receive. Consumer surplus is the difference between the total amount that consumers are willing to pay for a good or a service and the total amount that they actually pay (i.e., the market price).

[15] Total benefits approximate $753 in $2017 U.S. dollars; costs approximate $64 to $80 in $2017 U.S. dollars.

[16] Page 21-3.

[17] Page 22-2.

> *by the Hydrographic Programme is such that it is perhaps time to question whether it should continue to be viewed as a purely military Programme which has benefits to the civil community or whether it should be seen more as a national programme which has both civil and military benefits."*[18]

Fjose et al. (2016) provided a similar list of potential beneficiaries of marine geospatial data and added that *"detailed depth data are the most important component of models that predict ocean currents*"[19]

In investigating nautical charts ad integrated navigation systems, Kite-Powell (1997) estimated that:

> *"Electronic charts and integrated navigation systems at an intermediate level of effectiveness could help avoid 3,000 accidents involving commercial vessels in U.S. waters between 1996 and 2010, assuming no significant changes in underlying casualty rates. The expected overall cost of these accidents is estimate to be about $2.1 billion (1995 dollars)"* [20]

Kite-Powell (2007) employed surveys of both commercial and recreational users of nautical charts.[21] Based on respondents' indication of the "willingness to pay" (WTP) for an "ideal" chart, the value of charts (as measured by consumer surplus) was $15.3 million (2007 dollars) per year for recreational users and $27.5 million for commercial users.[22] He also estimated that the value of producer surplus derived from the activities of value-added resellers

[18] Ibid.

[19] Page 6.

[20] About $3.6 billion in 2017 dollars.

[21] 1,975 surveys were sent to recreational users while 1,000 were sent to commercial users. 406 (20 percent) of recreational users and 138 (14 percent) of commercial users responded.

[22] $17.8 and $31.9 million in $2017 dollars, for recreational and commercial users, respectively .

of charts and data was about $2 million (2007 dollars) per year.[23] He concluded that the lower bound of his total estimate as $44.8 million (2007 dollars) per year.[24]

In 2006, Skjong described the use of formal safety assessment as a non-political approach to rule making by the International Maritime Organization (IMO). He investigated grounding situations across three types of vessels in service outside of the U.S. and concluded the number of grounding incidents and fatalities would be reduced by 36 percent in vessels with ECDIS.[25]

VOLPE (2009) estimated the net benefits from seven areas that included: (1) voyage planning; (2) avoided delays due to PORTS®[26]; (3) PORTS® capacity optimization; (4) averted property damage from grounding; (5) averted spill costs; (6) averted fatalities; and, (7) averted injuries. In these calculations, individual benefits from PORTS® and ENCs were not always clearly delineated. Overall, VOLPE in 2009 estimated total gross benefits of $1.198 billion and government costs of producing National Ocean Service (NOS) products of $48.5 million and calculated a benefit-cost ratio of 24 to 1.[27] Problematic with their estimate was that benefits were accumulated at a societal level while costs were estimated for only NOS production and maintenance of PORTS® and ENCs. This ignored all other costs that must be incurred to get to the societal benefit, such as the purchase of an electronic chart system, training, and maintenance. Additionally, benefits were accrued as marginal benefits of NOS deliverables while costs included fixed costs. Specific monetary benefits associated with voyage planning for

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[23] Producer surplus is the difference between what producers would be willing to accept and the amount they actually receive from selling the product. This is about $2.3 million in $2017 dollars.

[24] This equates to almost 52 million in 2017 dollars.

[25] Bulk carriers (coal), crude tankers and product tankers

[26] In these calculations, benefits from PORTS® and Tides and Current (TC) data were comingled.

[27] This equates to benefits of almost $3.1 billion and costs of over $57 million in 2017 dollars.

commercial vessels ($26.8 million)[28], recreational vessels ($4.2 million)[29] and search and rescue (SAR) officers ($75.5 million)[30]. Collectively they account for a benefit of $106.7 million.[31]

Benefits from averted property damage resulting from groundings or storm-related accidents were estimated for only recreational vessels and SAR vessels. VOLPE found that ENCs and PORTS® were major factors at minimizing risk. Averted damages were placed at $2.9 million (over $3.4 million in 2017 dollars) while increased efficiency of SAR operations were valued at $27.1 million ($32.3 in 2017 dollars). Employing the then value of a human life ($5.8 million), total averted fatalities were estimated to be $449 million with $197 million due to SAR activity ($535 and $2,350 million, respectively in 2017 dollars).

Leveson (2012) provided a highly focused report involving the value of coastal mapping. In his analysis he noted the wide-array of Coastal Mapping Program (CMP) mapping beneficiaries to include: (1) navigation safety; (2) shoreline modification; (3) environmental protection (including precise coordinated of sensitive and protected areas); (4) GIS applications in coastal zone management; (5) on-shore development; (6) recreation; (7) fish habitat mapping; (8) energy exploration and construction; (9) offshore aquaculture; (10) planning and response to natural disasters and environmental emergencies; (11) marine spatial planning; (12) legal and insurance applications; (13) homeland and port security; (14) monitoring sea level change; (15) scientific research; (16) national and international standards: (17) archeology and cultural

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[28] $32 million in $2017
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[29] $5 million in $2017.

[30] $90 million in $2017.

[31] Over $127 million in $2017.

heritage; and (18) military activities.[32] Issues related to inter-state boundaries, resultant taxation issues and international boundaries are additional issues reported by Leveson impacted by the CMP. In his analysis, Leveson estimated total direct, indirect and induced benefits to range between $217.4 and $265.0 million with an overall estimate of $241.4 million (2011 dollars). This would equate to a range between almost $249 and $303 and an overall estimate of almost $277 million in $2017 dollars. (Table 1) In his calculations, economic benefits were delineated as direct, indirect and induced benefits.

**Table 1**

**SUMMARY OF COASTAL MAPPING PROGRAM BENEFITS, $2011**

| AREA | ESTIMATE | RANGE |
|---|---|---|
| Direct Economic Benefits | $100.4 | $90.4 – $110.4 |
| Indirect and Induced Economic Benefits | $100.4 | $90.4 - $110.4 |
| Total Economic Benefits | $200.8 | $180.8 - $220.8 |
| Non-Economic Benefits (not included in Economic Benefits - 10% range (above and below estimate) | $40.6 | $36.5 - $44.7 |
| Total Benefits | $241.4 | $217.4 - $265.0 |

Source: Leveson, Table ES3, Page 7.

Reductions in morbidity and mortality are addressed with respect to natural hazards (e.g., tornados, coastal storms, hurricanes, etc.), as well as commercial and recreational vessels. Levenson assumed that averted morbidity and mortality would have been five to ten percent higher without CMP products. Illustrating the difficulty of such estimations he pointed out that as some of the benefits captured were the result of interdependence among products and that *"emphasis should be placed on the benefit estimates of CMP as a whole rather than individual products",* it is difficult to specifically estimate the precise dollar amount these reductions

[32] Leveson (2012), Page 2.

represent.[33]

Econometrica (2015) performed a recent analysis on the value of charting in 2015. They stated that such estimations were difficult as no empirical data or base case where charting products did not exist could be found. In their study, they determined that the average marine vessel incident type approached $107 thousand (about $119 thousand in 2017 dollars) and that the annual benefit from safety benefits approached $1.13 million (almost $1.20 million in 2017 dollars.) with a "moderate statistical link" but only $195,000 with a "strong statistical link"[34]. Also noted were reductions in travel and delay times that were estimated at $18 per passenger (in terms of passenger travel) and recreational boating user and $46 per hour for commercial vessel crewmember. Finally, they estimated the impact of a one-hour reduction in all waterborne freight travel time at $0.6 million per year.

A more recent study by Wolfe et al. (2020) observed that over 1,200 ENCs across five types of charts or Scale Bands (overview, general, coastal, approach and harbor) were released during the study period. At locations where PORTS® had been installed, a significant portion of allisions, collisions and groundings (ACGs) variation was explained in cases where at least one of each type of ENC had been released during the study period. As the number of ENC releases increased, the accident rates for allisions significantly declined with an annual benefit of between $1.6 and $1.8 million ($2017).

Reductions in allision, collision and grounding rates were also found to be significant in cases where both PORTS® existed and harbor only charts had been updated. Wolfe et al. (2020) also noted with an annual benefit of about $3.1 million ($2017) resulting from grounding

[33] Ibid, Pages 5 and 65.

[34] Econometrica (2015), Pages 3-4, Table 2.

reductions at locations where PORTS® exist and ENCs have been released, it might be inferred that PORTS® contributed about half of that annual total.

## IV. RATIONALE

This report was undertaken for several reasons. First, OCS supports the nation's commerce with information for safe efficient and environmentally sound transportation. The importance of waterborne international trade is reflected in the fact that more than 40 percent of cargo value and 70 percent of cargo weight arrives via water.[35]

Second, the mission of the NOS "*is to provide science-based solutions through collaboration partnerships to address evolving economic, environmental and social pressures on our oceans and coasts"*.[36] One of the recent NOS goals is to *"provide ship managers with up to the minute data and information to maintain reliable safety margins to maximize access to highly trafficked and increasingly space constrained ports."*[37] NOS also understands that among challenges in the future there will be *"increased demands on our marine transportation system"*.[38] To respond to these challenges, NOS cites three major programs: (1) coastal resilience: preparedness, response and recover; (2) coastal intelligence; and, (3) place-based conservation.

Third, the essentiality of NOS products and services supporting transportation is well documented:

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[35] Source: Department of Commerce, USA Trade® Online long run average over the last twenty years.

[36] Refer to "About Us" from http://oceanservice.noaa.gov/about, "Our Mission", accessed February 6, 2017.

[37] NOS Priorities Roadmap. 2016. Such information can help prioritize NOS efforts based on the levels and trends of transportation demand, October, Page 7.

[38] Refer to National Ocean Service. 2016. NOS Priorities Roadmap, October, Page 3.

> *"People in the maritime community rely on coastal intelligence for a range of decisions, from how much cargo to load to choosing the most efficient and safest route between two points. They use coastal intelligence to plan seasonally for ship schedules, mitigate the long-term impacts of sea level rise on port infrastructure and service global trade more efficiently as significantly larger vessels transit through U.S. ports as a result of the Panama Canal expansion. As our economic dependence on the U.S. Maritime Transportation System (MTS) grows, robust coastal intelligence is vital to maintaining MTS resilience, reducing maritime risk and responding to incidents when they occur"*[39]

Fourth, the Office of the Inspector General (OIG) has also stated that the top management challenges facing the DOC include five tasks:[40]

- **TRADE AND INVESTMENT** – Expand the U.S. economy through increased exports and inward foreign investment that lead to more and better American jobs;
- **INNOVATION** - Foster a more innovative economy – one that is better at inventing, improving, and commercializing products and technologies that lead to higher productivity and competitiveness;
- **ENVIRONMENT** – Ensure communities and businesses have the necessary information, products and services to prepare for and prosper in a changing environment;
- **DATA** – Improve government, business and community decisions and knowledge by transforming Department data capabilities and supporting a data-enabled economy; and,
- **OPERATIONAL EXCELLENCE** – Deliver better services, solutions and outcomes that benefit the American People.

Finally, the General Accountability Office (GAO) described performance measurement as *"the ongoing monitoring and reporting of program accomplishments,*

[39] NOS Priorities Roadmap. 2014. *A Guide for Advancing National Ocean Service Priorities over the Next Three to Five Years*, National Oceanic and Atmospheric Administration, National Ocean Service, Silver Spring, Maryland, May, Pages 5 and 11.

[40] United States Department of Commerce. 2014. *Top Management Challenges Facing the Department of Commerce*, Office of the Inspector General, Office of Audit and Evaluation, Final Report NO. OIG-15-002, October 16, pps.1-4.

*particularly toward pre-established goals"*.[41] Begun with the Government Performance and Results Act (GPRA) performance measurement is an assessment of resilience of the initiative or product in terms of its capacity to respond to changing business conditions as well as its ability to recover from adverse events.[42] Comparison of general economic data before and after the activation of a program or service is one method to achieve this assessment goal.

## V. CHART HISTORY

Beginning in 1807 when President Thomas Jefferson signed an "*Act to provide for surveying the coasts of the United States*", the U.S. Coast Survey, later U.S. Coast and Geodetic Survey in 1878 that was subsequently incorporated into NOAA when it was formed in 1970 have created thousands of nautical charts. Today, the OCS maintains more than 20 thousand historical nautical charts while maintaining its current collection of over one Thousand charts.[43] OCS receives over 6,000 digital and hardcopy source documents each year from five main sources account for over 70 percent of all input.[44] These include:

- Water depths and the identification of wrecks, rocks, and other obstructions (Source: NOAA's Hydrographic Surveys Division);
- Depths within federally maintained channels (Source: U.S. Army Corps of Engineers);

[41] United States Government Accounting Office. 1998. *Performance Measurement and Evaluation, Definitions and Relationships*, GAO/GGD-98-26, April.

[42] GPRA, enacted in 1993, required agencies to engage in performance management tasks such as establishing goals, measuring results, and reporting their progress. GPRA, modernized in 2010, required performance assessments of Government programs for purposes of assessing agency performance and improvement.

[43] Source: NOAA celebrates 200 Years of Science, Service and Stewardship. https://celebrating200years.noaa.gov/foundations/welcome.html

[44] https://nauticalcharts.noaa.gov/learn/chart-source-data.html. Remaining source material is provided by a variety of other federal, state and local government agencies, national and international regulatory organizations, private companies, professional organizations, and private citizens.

- Delineation of shoreline (Source: NOAA's National Geodetic Survey);
- Reports of "dangerous to navigation" - wrecks and obstructions (Source: U. S. Coast Guard Notice to Mariners); and,
- Positions, types, and characteristics of aids to navigation including buoys, beacons, and navigational lights (Source: U.S. Coast Guard).

Begun in 1862, paper lithographic nautical charts have been printed by the U.S. government and sold to the public by commercial vendors. Beginning in April of 2014, paper charts were no longer published by the Government owing to declining demand for lithographic charts, the increasing use of digital and electronic charts, and federal budget realities.[45] NOAA continues to develop and maintain Print on Demand (POD) charts which are available from NOAA-certified printing agents.

In essence, raster charts are pictures of paper nautical charts. In raster charts data is a series of pixels (tiny dot of color) that are positionally referenced to that picture only. The raster data is sometimes referred to as "dumb" data because of its lack of useful information.

An ENC (or vector chart) is made of information rich or "smart" data.[46] That is, data each bit of which has positional information (latitude and longitude), as well as, information on what it is (dangerous rock, depth, or navigational light) and its relationship to other data in that feature (depth area, shoreline) in addition to other important meta data.

The real difference between raster charts and ENCs is best demonstrated in their use. Raster charts are used in the same way paper charts have been used for centuries. ENCs can be used to assist mariners in plotting courses to avoid dangerous areas relative to that vessels

[45] Announced October 22, 2013.

[46] Electronic Chart Display Information Service (ECDIS) is a vector-based system that meets the Federal Chart carriage regulations and the highest level of the International Maritime Origination (IMO) standards and requirements.

unique draft and will sound warnings if the vessel is at risk of entering into a dangerous area.[47]

New data for updating charts is prioritized as either “critical” or “routine”. Critical change examples are those that potentially pose dangers to navigation (e.g., changes in position of lights, bacons, buoys, rocks, newly discovered wrecks, shoals or other obstructions). Routine changes involve less critical data such as ordinary shoreline and hydrographic surveys.

**Table 2**

## TYPES OF SURVEYS

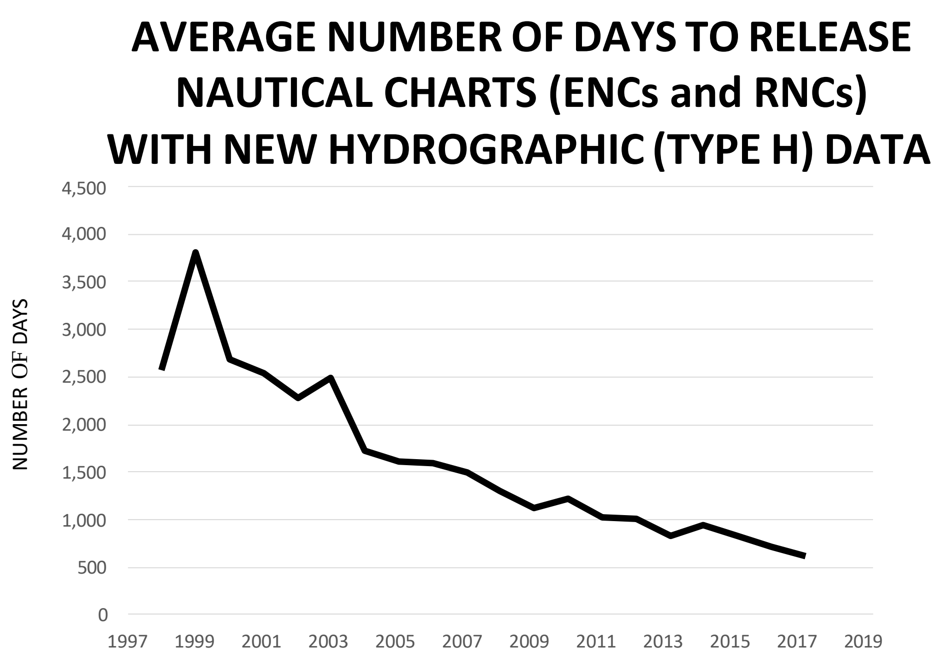
| TYPES OF SURVEYS CONDUCTED | SURVEY CODE | YEARS CONDUCTED (Through the End of 2017) | NUMBER OF SURVEYS PERFORMED |
|---|---|---|---|
| **Hydrographic Exclusive Economic Zone (EEZ) Surveys** Lower-resolution early multi-beam echo sounder surveys. | B | 1984 - 1995 | 290 |
| **Discovery Surveys** Substandard Survey (Special reconnaissance, or evaluation/test surveys). These reconnaissance surveys, often do not meet IHO Order 1 because they may be deep; have inadequate vertical control, inadequate sound velocity control or substandard sounding density. These requirements are intentionally relaxed so that data may be obtained over a larger area either to inform future surveys or to supplement areas of the chart with little to no data. | D | 1977 – 2017 | 112 |
| **Field Examination Surveys** They are item investigations or surveys that cover small areas of specific interest frequently called a smaller scoped version of surveys type H. They may be assigned to prove or disprove dangers or obstructions, to provide data for harbor development, or supplement prior hydrographic surveys. | F | 1934 - 2017 | 614 |
| **Hydrographic Surveys (Basic)** These are the systematic hydrographic surveys, typically meeting IHO Order 1 and adhering to the Coast Survey’s Hydrographic Surveys Specifications (HSSD) and Deliverables Manual. These are the most common commissioned surveys from Coast Survey’s Hydrographic Survey Division (HSD) and Coast Survey’s Navigation Services Division (NSD). | H | 1834 - 2017 | 11,968 |
| **Chart Letter** They cover all types of information (it may or may not pertain to a survey). In the past when OCS did not receive digital data, the source documents were recorded as either letters or blueprints. | L | 1900 - 1975 | 450 |
| **Homeland Security Survey** These surveys are Homeland Security (HLS) and are conducted by | S | 2002 - 2016 | 29 |

[47] Weintrit (2010) notes that raster data is only available in one layer and one format while ENC charts while ENCs contain layered information that allows users to “deselect” certain categories of data that are not required at the time.

| | | | |
|---|---|---|---|
| NOAA ships. They have not been done for a while but the nomenclature are retained in the event there is need to perform HLS surveys again. Typically, HLS surveys were IHO Special Order. | | | |
| **Triangulation Positioning Technique Surveys** In the past, positioning by this method from baseline points onshore was used to position vessels on near-shore projects using generally the azimuth/azimuth method. | T | 1859 - 1860 | 3 |
| **Non-NOS Hydrographic Surveys** These are hydrographic surveys not commissioned by HSD. NSD and are received as externally sourced data, generally by other government agencies (CHS, BA) which are Canada and British Admiralty. They obtain a W registry number once a requirement has been identified to process the data. | W | 2000 - 2017 | 365 |

From 1834 to 2017, OCS and its predecessors completed over 13,831 hydrographic surveys across eight different types of surveys. (Table 2) Of these, the hydrographic surveys (Type H) have accounted for almost 87 percent of all surveys undertaken. If electronic charts are employed, data is updated weekly commensurate with its release. While existing paper charts must be manually updated, newly issued paper charts will contain the most recent updates at the time of compilation.

**Figure 3**



Compiling data for updating charts might take as little as six months but can take several years owing to the location, the extent of the surveys required as well as competing requirements (e.g., routine or critical) from other charts.[48] Since 1998, the average number of days from the time information is initially gathered until the time an ENC is produced has substantially fallen. In 2017, the average days from data to chart was 614. (Figure 3)

## VI. IMPORTANCE OF TRADE TO THE U.S. ECONOMY

International trade allows countries to expand their markets and access goods and services that otherwise may not have been available domestically. As a result of international trade, the market is more competitive. International trade allows countries to expand their markets and access goods and services that otherwise may not have been available domestically. As a result of international trade, the market is more competitive. This ultimately results in more competitive pricing and brings a cheaper product home to the consumer. Among the benefits of international trade are increased revenues. This ultimately results in more competitive pricing and brings a cheaper product home to the consumer.

In 2003, the weight of total U.S. imports exceeded 1.2 billion short tons while U.S. exports account for almost 0.5 billion short tons for a total of over 1.7 billion short tons. Of this, waterborne traffic accounted for over 77 percent of total weight.[49] By 2020, total tonnage had grown to almost 2.2 billion short tons with over 69 percent being handled by water.[50]

Adjusted for inflation, the value of total imports from 2003 to 2020 increased from about

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[48] Source: https://oceanservice.noaa.gov/facts/chart_produce.html, *"How Long Does It Take to Produce A Nautical Chart?"*

[49] Imports accounted for almost 79 percent of all tonnage while exports represented over 74 percent of tonnage handled.

[50] Imports accounted for 60 percent of import tonnage while exports accounted for over 77 percent of export tonnage.

$1.7 trillion to $2.4 trillion while exports increased from $1.0 to $1.4 trillion. Total international traffic cargo value increased from about $2.6 trillion to about 3.8 trillion. Overall, about 44 percent of total cargo value was handled by international vessels.[51] Consequently, charting activities which support safe and effective transportation can provide large amounts of value to the U.S. economy as in addition to primary benefits afforded to the vessels, operators and ports themselves are secondary and tertiary benefits accrued by supporting industries such as railroads, motors carriers, manufacturers, and their suppliers. One study by Wolfe (2019) estimated the value of navigational aids of all types support over $940 million in annual benefits to the railroad and motor carrier industries.

Moreover, the ability to safely navigate ever-larger vessels in U.S. waters reduces the number of vessels required to carry growing traffic levels. This results in lower fuel use, resultant environmental emissions and lower injuries and deaths associated with water-borne transportation.

Major economic sectors and their importance investigated included:

- **Commercial Shipping** – Over 82,000 vessels call on U.S. ports each year; 1.5 billion tons of cargo handled by vessels with a value approaching $1.7 trillion;
- **Recreational Boating** - More than 32.3 million of 118.1 million households (27.3 percent) in the U.S. had at least one member who boated. Over 21.6 million boats of all kinds were used in the U.S.
- **Commercial Fishing** – Since 1950, commercial fish catch has almost doubled from 2.2 to 4.3 million metric tonnes in 2019. [52] During this time, the nominal value of fish catch

[51] Source: U.S. Department of Commerce, USA Trade® Online. It provides current and cumulative U.S. export and import data.

[52] During recessionary 2020, catch value declined almost 15 percent from 2019 levels reflecting a decline in catch weight by over ten percent.

was $5.6 billion in 2019, up from 326 million in 1950.[53]

- **Recreational Fishing -** Saltwater fishing alone draws nearly 21.3 million participants nationwide which accounts for 10.3 percent of the population age 16 or older. During 1999 to 2016, between 7.8 and 14.0 million participated in recreational boating making between 56.9 and 89 million fishing trips

## VII. VALUE OF MAXIMIZING VESSEL CAPACITY

The next generation of ships will require deeper drafts and more costly dredging to maintain coastal entrance channels to insure safe navigation. Minimum Under Keel Clearance (UKC) is the required minimum distance between the ship's keel and the bottom of the channel (Figure 4)

The UKC is a function of the ship size and hydrodynamic characteristics, the channel be cross-section and shape, and the ship speed. Since every inch of added vessel cargo carried represents considerable value, significant savings can be realized if a minimum safe UKC can be reliably determined.[54] Moreover, better utilization of existing channel dimensions reduce the need for dredging costs to expand channels (often costing millions of dollars).

Tables 3 and 4 provide some examples involving imports and exports benefits from the addition of one inch of added vessel displacement.[55] Calculations that are more detailed are listed in Appendix C.

[53] Landings and related catch value declined between 2019 and 2020 owing the February to April recession which represented a -19.2 percent decline in GDP (peak to trough). Refer to https://www.fisheries.noaa.gov/foss/

[54] Refer to United States Army Corps of Engineers at http://chl.erdc.usace.army.mil/chl.aspx?p=s&a=Projects;87

[55] Source: Wolfe, K. Eric. 2011, *"Recommendation for Development of a Nation-Wide System to Assess the Value of NOS Products and Services Resulting From Import and Export Activity*", NOAA, NOS White Paper, July.

**Figure 4**

**UNDER KEEL CLEARANCE**

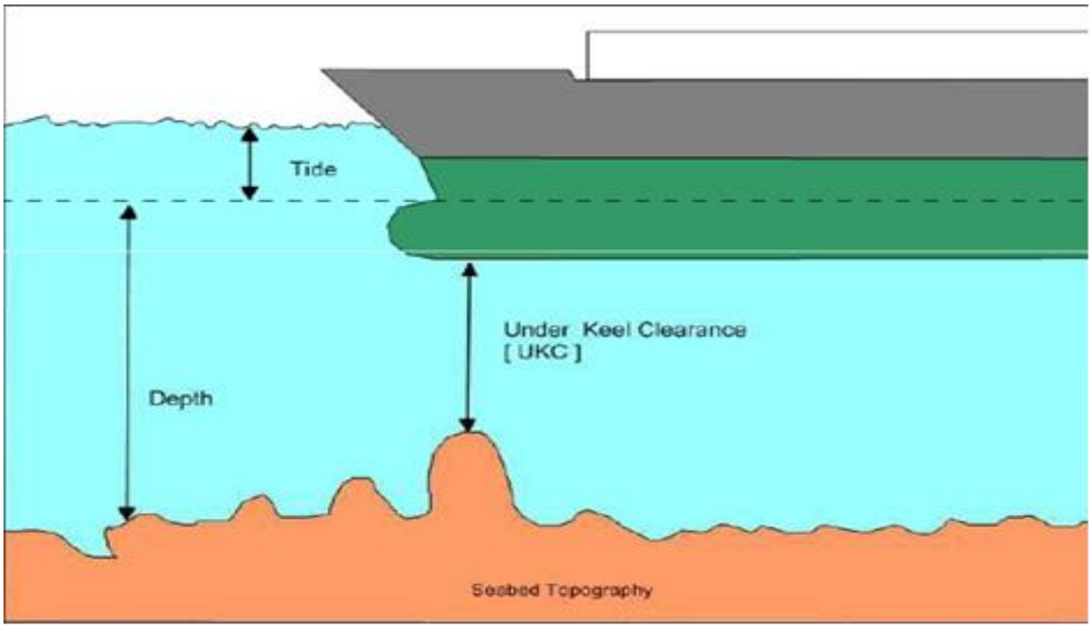



**Table 3**

**SELECTED U.S. EXPORTS**

Impact of an additional 1 inch of vessel draft

| Product | Weight Per Inch of Draft | Value of Product[57] | Vessel Type | Number of Employees |
|---|---|---|---|---|
| Wheat | 358,400 lbs. (162.6 Metric Tons) or 5,973.3 bushels Flour needed to bake 422,535 loaves bread | $39,315 | Bulk Carrier Panamax | U.S. 950,600 producing grain. (2008) |
| Corn | 358,400 lbs. (162.6 Metric Tons) or 6,400 bushels | $48,302 | Bulk Carrier Panamax | U.S. 950,600 producing grain. (2008) |
| Soybeans | 358,400 lbs. (162.6 Metric Tons) or 5,973.3 bushels | $103,193 | Bulk Carrier Panamax | U.S. 950,600 producing grain. (2008) |
| Beef (Choice 1) | 358,400 lbs. | $713,382 | Refrigerated Bulk Carrier Panamax | U.S. 860,600 Animal production (2008) |

[56] Source: KeelClear http://keelclear.com/about-keelclear.html

[57] 2011 dollar quotations converted to 2017 dollars through the Gross Domestic product. Source: Wolfe, K. Eric and David MacFarland, 2013. "An Assessment of the Value of the Physical Oceanographic Real-Time System

(PORTS®) to the U.S. Economy, NOAA, NOS White Paper, September 30.

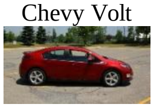
| | | | | |
|---|---|---|---|---|
| Chevy Volt  | 99 | $4,999,313 | Car Carrier | 91,960 North America |
| Ford F150  | 72 | $3,319,666 | Car Carrier | 45,000 in U.S. |
| John Deere 6140D Utility Tractor with cab  | 36 | $3,012,450 | Car Carrier | 55,700 world wide |
| Caterpillar 950H Wheel Loader  | 12 | $3,445,104 | Bulk Carrier Panamax | 43,251 in U.S. |

**Table 4**

## ADDITIONAL SELECTED IMPORT AND EXPORT TRAFFIC

| Cargo | Pounds Per Product / Container | Units / Container | Number Of Containers (if applicable) / 1" Draft | Number Of Units / 1" Draft | Retail Cargo Value[58] |
|---|---|---|---|---|---|
| Athletic Shoes (pairs)  | 11,900 lbs. | 5,292 pairs athletic shoes | 11 containers | 58,212 pairs athletic shoes / inch of draft<br>Enough pairs to enable runners to run 23,284,800 miles, the equivalent distance of 48.7 round trips from the Earth to the Moon. | $6,714,195 |
| Laptop Computers  | 14,176 lbs. | 960 Laptop Computers | 10 containers | 9,600 laptop computers | $10,759,755 |
| Coffee | Dry Bulk Cargo - No Container Required | Dry Bulk Cargo - No Container Required | Dry Bulk Cargo - No Container Required | 358,400 lbs. coffee/ inch of draft<br><br>Enough coffee to make 44,311,268 (6oz) cups of coffee | $955,042 |
| LCD TV 55" Sony  | 23,318 lbs. | 168 TVs | 10 containers | 1,540 55" Sony TVs/ inch of draft | $3,668,307 |
| 2010 Toyota Prius  | 3,042 lbs. | | Individual Units | 88 Vehicles | $2,625,749 |
| 2011 Mercedes-Benz S600  | 4,950 lbs. | | Individual Units | 54 Vehicles | $10,699,953 |

[58] The value of manufactured goods was determined from official company web sites before any discounts. The value of coffee was determined from commodity prices on the New York Mercantile Exchange. 2011 dollar quotations converted to 2017 dollars using the Gross Domestic Product. Refer to: Wolfe, K. Eric and MacFarland, David. 2016. "*A Valuation Analysis of the Physical Oceanographic Real Time System (PORTS®),"* Journal of Ocean and Coastal Economics: Vol. 3, Issue 1, Article 12.

## ESTIMATED GROSS BENEFITS PROVIDED BY NAVIGATIONAL CHARTS IN THE UNITED STATES

### A. Precision Navigation

In addition to these potential savings, many additional benefits could be obtained from improved knowledge of approach, channel and harbor dimensions and conditions. Begun as a pilot program by several NOS offices[59] for the port of Long Beach in 2010, NOAA's Precision Navigation Program (PNP) enlisted existing data and technology to provide vessel operators with better understanding of UKC with respect to the movement of Very Large Crude (oil) Carriers (VLCC)[60]. In essence, PNP represents the ability of a vessel to safely and efficiently navigate and operate in close proximity to the seafloor, narrow channels, other vessels, fixed objects and other hazards.[61] Here, VLCCs were vulnerable to potential groundings when waves arrived in long period swells. Figure 5 depicts the potential problem when a VLCC faces just one degree of pitch. While the Port of Long Beach channel is dredged and maintained at a depth of 76 feet, as a precaution, the port reduced the maximum allowable ship draft to 65 feet. In estimating the benefit of restoring extra draft, for every extra foot of draft, tankers could load 40,000 additional barrels of crude oil, which equates to $2 million of extra cargo value.[62]

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[59] National Geodetic Survey (NGS), Office of Coast Survey (OCS), Center for Operational Oceanographic Products and Services (CO-OPS) and U.S. Integrated Ocean Observing System Program (IOOS) and the National Weather Service (NWS). Refer to: https://nauticalcharts.noaa.gov/learn/precision-navigation.html, as of June 21, 2019.

[60] Oil tankers are categorized into six group or classes based on DWT. VLCC are between 160,000 and 319,999 DTWs. Only Ultra Large Crude Carrier are larger, ranging from 320,000 to 549,999 DWTs. Refer to: Evangelista, Joe (Editor), 2002. *"Scaling the Tanker Market*", Surveyor, American Bureau of Shipping, Winter, pp. 5-9.

[61] Source: NOAA, OCS, https://nauticalcharts.noaa.gov/learn/precision-navigation.html, June 30, 2018.

[62] Ibid; https://nauticalcharts.noaa.gov/learn/docs/precision-navigation/lalbprecisionnav-1pager.pdf. At the time of the initial report in 2010, Wolfe (2015) estimated, employing average oil price expectations from the World Bank that each additional inch of draft carrier by VLCC would translate to almost $150,000 or about $7.1 million per vessel transit.

**Figure 5**

**POTENTIAL PROBLEM WITH VESSEL PITCH**


Source: https://nauticalcharts.noaa.gov/learn/precision-navigation.html, June 30, 2018.

Based on this potential benefit, employing a wide array of data involving weather conditions, forecasts, and additional data in unison with nautical charts NOAA has been refining processes of collecting and integrating data to develop greater accuracy of navigational products to support both real time and planning decision-making process. OCS, working with private industry and across NOAA, developed a precision navigation model for the Port of Long Beach. In this model, observations, forecasts, and foundational data in the model include:

- Nearshore Wave Prediction System (NWPS) for forecasts of wave and swell conditions;
- Water levels for predictions and real-time values available from NOAA's Physical Oceanographic Real Time System (PORTS®);
- Wave buoys for real-time values and 3-hour now-cast short term predictions;
- Lidar for shoreline updates to nautical charts; and,

- Hydrographic surveys and high-resolution bathymetric inland ENC overlays for increased accuracy and resolution over traditional charting products.

Due to the success of the model, several things have happened. First, the U.S. Coast Guard Captain of the Port removed the 65 foot draft restriction. The long-term goal is to achieve 69' draft transits safely, at which time lightering offshore will no longer be required, improving operational efficiencies, safety, and reduce environmental risk. Second, additional PNP benefit studies are being undertaken at several port complex areas (e.g., Lower Mississippi River, Houston/Galveston, Beaumont, TX, New York/New Jersey, Savannah, Columbia River, Port of Virginia, Puget Sound, WA, and San Francisco) to estimate the benefit of additional collaborations.[63]

## VIII. TRENDS IN VESSEL SIZE

Understanding the precise location of a vessel with respect to channel width, depth, side slope and curvature is essential to planning cargo loading and executing a safe passage through reductions of groundings. Such information can also aid in reductions of allisions collisions through support of greater distances between vessels as well as stationary objects. Given ever-increasing international trade, U.S. ports will be increasingly stressed to accommodate larger, heavier vessels making a greater number of port calls each year. This trend has only been enhanced by the 2016 expansion of the Panama Canal.[64]

### A. Economies of Size

New vessel design and construction has followed a trend for years of increasing length,

[63] Source: NOAA, NOS, Precision Marine Navigation Data Dashboard, https://noaa.maps.arcgis.com/apps/dashboards/e791d620047b4de7878c0f44e5d0f288

[64] June 26, 2016.

width or beam, depth or draft and height. While larger vessels can generally be made and operated more efficiently with lower transportation costs, added care must be exercised to ensure timely and safe operation of these vessels. Given cost savings from larger vessels, it is assured that the next generation of ships will require still deeper drafts and more costly dredging to maintain coastal entrance channels to insure safe navigation. In this example, moving up from a small 1,500 TEU container vessel to a previous Panamax vessel containership with 5,000 TEUs could reduce per TEU costs by over 40 percent. Moving up to a larger approximately 14,000 TEU carrier could reduce unit cost almost 62 percent less than the 1,500 TEU vessel. (Figure 6)

Even larger cost per TEU reductions result from employing container vessels over 18,000 TEUs. Although currently restricted from U.S. ports owing to infrastructure limitations, vessels over 22,000 TEUs are already in worldwide service. Other vessel types have also experienced size increases which has resulted in ongoing requests for increases in port depths. Previously authorized by the Congress, deepening the channels for the ports of Miami, Savannah and Charleston[65] illustrate these needs. Overall, waterborne traffic in 2019 represented almost 70 percent of all imported and exported tonnage as well approximately 41 percent of the value of all imported and exported goods.[66]

The evolution of container vessel sizes is depicted in Figure 7. Overall, container traffic has been the fastest growing portion of all vessel traffic in recent years. From 2003 to 2017,

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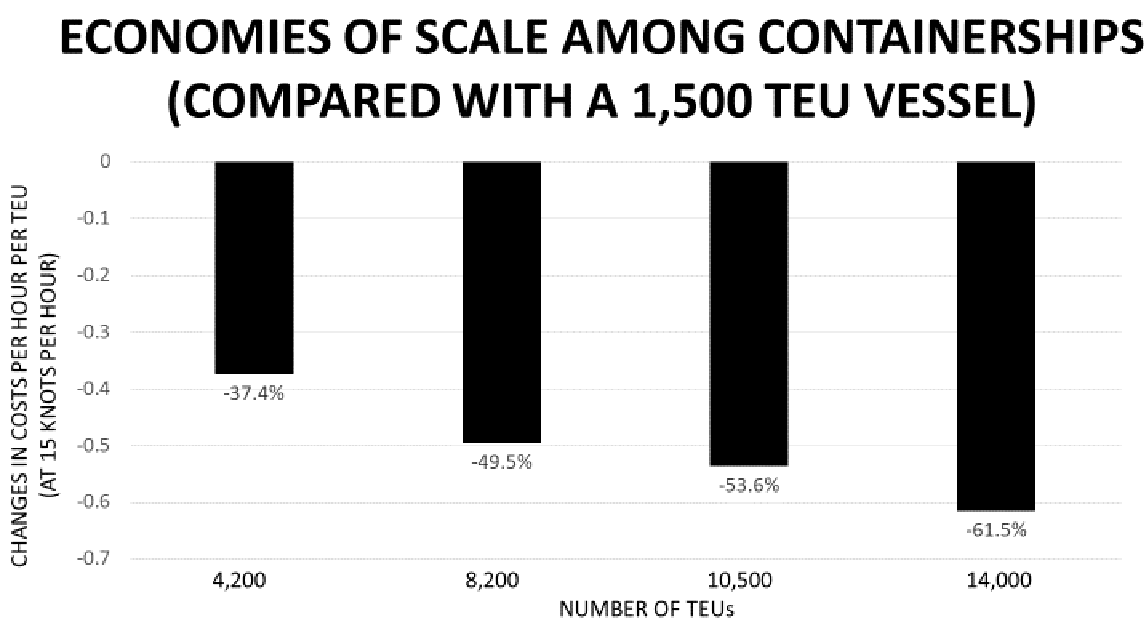
[65] While the Port of Savannah had received a congressional authorization to deepen in 1999, it was not until June 10, 2014 that is deepening to 47 feet at mean low tide was authorized. Refer to: http://savannahnow.com/exchange /2014-06-10/president-signs-water-bill-will-allow-savannah-harbor-deepening-proceed#.U6sSn_ldWSo.

[66] Sources: Sources: Compiled by U.S. Department of Transportation (USDOT), Research and Innovative Technology Administration (RITA), Bureau of Transportation Statistics (BTS). Total, water and air data—U.S. Department of Commerce, U.S. Census Bureau, Foreign Trade Division, *U.S. Exports of Merchandise*, CD-ROM and *U.S. Imports of Merchandise*, Total, truck, rail, pipeline, other and unknown data—USDOT, RITA, BTS, Transborder Surface Freight Data and special calculation and USA Trade On line

while the value of all vessel traffic cargo grew by 98 percent, the value of container traffic cargo grew by 116 percent.[67] At the same time, while total vessel cargo weight increased by 14 percent, container weight increased by 70 percent.

Vessels calls at U.S. ports increased in average vessel size that rose from about 47,000 Dead Weight Tons (DWT) in 2002 to almost 51,000 DWT in 2015 – an 8.2 percent increase.[68] (Table 5)

**Figure 6**

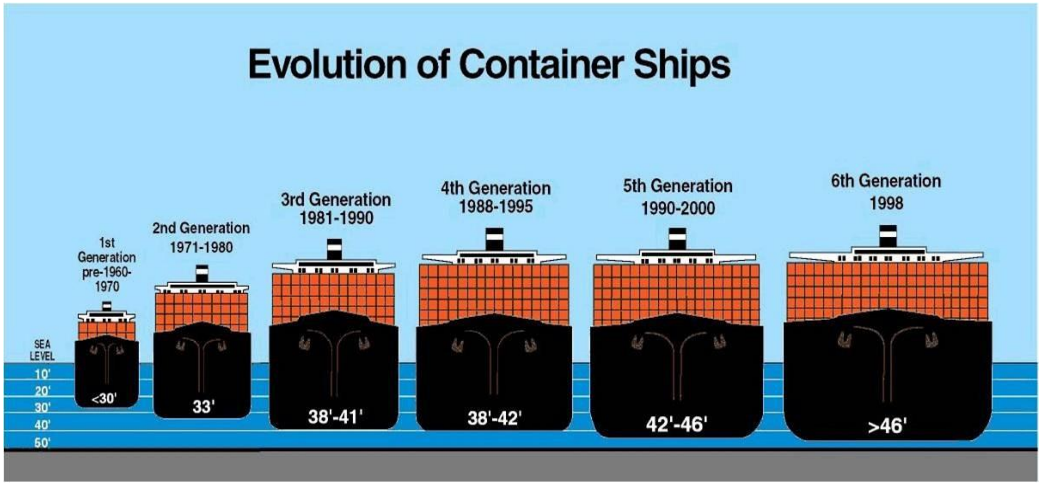



Sources: USACE, NNOMPEAS Database, December, 2020. Hourly costs include vessel capital, administrative overhead, fuel for main propulsion and auxiliary.

67 Ibid.

68 DWT is a measure of how much weight a ship is carrying or can safely carry. It is the sum of the weights of cargo, fuel, fresh water, ballast water, provisions, passengers, and crew. Refer to Turpin and McEwen, pages 14-21, 1980.

**Figure 7**




Source: uniserve.co.uk

**Table 5**

## AVERAGE DEADWEIGHT (DWT) OF VESSEL CALLS AT U.S. PORTS

| TYPE OF VESSEL | 2002 | 2015 | PERCENT CHANGE |
|---|---|---|---|
| **GRAND TOTAL** | **47,026** | **50,877** | **8.2%** |
| CONTAINER | 42,238 | 57,458 | 36.0% |
| DRY BULK | 42,886 | 54,772 | 27.7% |
| GAS (LPG, LNG) | 32,099 | 29,646 | -7.6% |
| GENERAL CARGO | 23,462 | 17,441 | -25.7% |
| RO-RO | 20,381 | 18,128 | -11.1% |
| TANKER | 69,076 | 61,501 | -11.0% |

Source: Department of Transportation, Maritime Administration. *Vessel Calls in U.S. Ports, Terminals and Lightering Areas Report.* 2015 latest year available.

While this figure might initially appear de minimis, closer analysis reveals significantly larger increases. For example, container ship and dry bulk carriers average size rose by 36 percent and 28 percent, respectively.

While many U.S. ports are incapable of handling vessels over 14,000 TEUs, the *OOCL Hong Kong* recently in 2017 was the first ship to carry in excess of 21,000 TEUs.[69] The Mediterranean Shipping Company (MSC) and Hyundai Merchant Marine (HMM) have 11 and 12 vessels under development with maximum 23,000 TEU with late 2019 and 2020 delivery dates, respectively. In fact, the smallest of the 54 new container vessels set for delivery between 2018 and 2020 all exceed 20,000 TEUs.[70] Of the 200 largest container vessels in the world in 2017, only 73 (at less than 14,800 TEUs) are small enough to transit the newly enlarged Panama Canal.[71] (Refer to Appendix D)

While many of the largest vessels (container, tanker, etc.) will not call on many U.S. ports owing to limited channel drafts, more in-depth analysis of recent vessel transits reveals a more compelling account. In the 13 years between 2002 and 2015, the number of total vessel calls at U.S. ports increase by over 48 percent. (Table 6)

**Table 6**

**VESSEL CALLS AT U.S. PORTS**

| TYPE OF VESSEL | 2002 | 2015 | PERCENT CHANGE |
|---|---|---|---|
| **GRAND TOTAL** | **55,342** | **82,044** | **48.2%** |
| CONTAINER | 17,083 | 18,711 | 9.5% |
| DRY BULK | 10,959 | 13,666 | 24.7% |
| GAS (LPG, LNG) | 739 | 1,703 | 130.4% |
| GENERAL CARGO | 3,865 | 7,793 | 101.6% |
| RO-RO | 5,626 | 7,065 | 25.6% |

Source: Department of Transportation, Maritime Administration. *Vessel Calls in U.S. Ports, Terminals and Lightering Areas Report*. 2015 latest year available.

[69] Marine Insight, 2017. *"10 Worlds Biggest Containerships in 2017",* June 14. https://www.marineinsight.com/know-more/10-worlds-biggest-container-ships-2017

[70] https://en.wikipedia.org/wiki/List_of_largest_container_ships, Accessed October 20, 2018.

[71] While the design capacity of the Canal is listed at 14,000 TEUs under which only 13 of the world's largest containerships quality, a total of 73 could make the transit based on recent movements of vessels up to 14,863 TEUs.

**Table 7**

## TOTAL DEADWEIGHT TONNAGE OF VESSELS CALLING AT U.S. PORTS

| TYPE OF VESSEL | 2002 | 2015 | PERCENT CHANGE |
|---|---|---|---|
| GRAND TOTAL | 2,602,524,191 | 4,174,134,138 | 60.4% |
| CONTAINER | 721,547,797 | 1,075,088,868 | 49.0% |
| DRY BULK | 469,983,250 | 748,512,245 | 59.3% |
| GAS (LPG, LNG) | 23,721,306 | 50,487,163 | 112.8% |
| GENERAL CARGO | 90,682,352 | 135,916,711 | 49.9% |
| RO-RO | 114,662,046 | 128,073,195 | 11.7% |
| TANKER | 1,183,198,256 | 2,036,055,956 | 72.1% |

Source: Department of Transportation, Maritime Administration. *Vessel Calls in U.S. Ports, Terminals and Lightering Areas Report.* 2015 latest year available.

Another measure of increase use of U.S. ports involves increased vessel size as measured by total DWT handled. (Table 7) Overall vessel traffic increased by over 60 percent with all vessel types exhibiting gains.

### B. Panama Canal Expansion

When opened in 1914, the Panama Canal provided significant reductions in existing transit times in regards to traffic to and from the Pacific Rim to the gulf and east coast of the U.S. as well as to Europe and Africa. In 2013 vessels unable to use the then existing Panama Canal made up only 16 percent of the world's container fleet but carried 45 percent of the cargo.[72]

[72] Source: The Washington Post, "As Panama Canal grows, so do cargo-hungry ports", January 13, 2013. Page 1.

Additionally, increases in depth recently authorized by the Congress for the ports of Miami, Savannah and Charleston[73] illustrate further traffic increases as micro bridge traffic through a gulf port to east and west coast locations can save time.[74] (Figure 8)

**Figure 8**

**TRAVEL TIME COMPARISONS FROM ASIA TO PACIFIC AND ATLANTIC COAST DESTINATIONS[75]**


[73] While the Port of Savannah had received a congressional authorization to deepen in 1999, it was not until June 10, 2014 that is deepening to 47 feet at mean low tide was authorized.  Refer to: http://savannahnow.com/exchange/2014-06-10/president-signs-water-bill-will-allow-savannah-harbor-deepening-proceed#.U6sSn_ldWSo.

[74] Mini and micro-bridge describe use of the continental U.S. in place of all water movements.  Shippers take advantage of lower costs and quicker shipment times using a combination of drayage motor carriers, line haul motor carriers and railroads in lieu of direct water shipments through the Panama Canal.

[75] Source: Parsons Brinckeroff. 2012. MARAD Panama Canal Expansion, Phase 1 Report

**Table 8**

## COMPARISON OF PANAMA CANAL DIMENSIONS

| PANAMA CANAL DIMENSIONS | PANAMAX LOCK SIZES (4/1/1914 – 6/25/2016) | PANAMAX VESSEL SIZES (4/1/1914 – 6/25/2016) | NEW PANAMAX LOCK SIZES (6/26/2016 to present) | NEW PANAMAX VESSEL SIZES (6/26/2016 to present) |
|---|---|---|---|---|
| Length | 1,050 feet (320.04 meters) | 965 feet (294.13 meters) | 1,400 feet (427.0 meters) | 1,200 feet (366.0 meters) |
| Width | 110 feet (33.53 meters) | 106 feet (32.31 meters) | 180 feet (55.0 meters) | 160.7 feet (49.0 meters) |
| Depth | 41.2 feet (12.56 meters) | 39.5 feet (12.04 meters) | 60.0 feet (18.3 meters) | 49.9 feet (15.2 meters) |
| Number of TEUs[76] | 5,000 | | 14,000 | |

As vessels became larger, it was estimated that only 45 percent of total global traffic could transit the canal. With the expansion of the Canal in 2016, in 2017 it was estimated that the new wider, longer and deeper locks and handle up to 79 percent of total global traffic.[77]

Table 8 provides a comparison of Panama Canal lock sizes and associated limitations of vessel size that can be handled. While initial estimates suggested that 14,000 TEUs were the upper limit of containers that could be handled in the updated Panama Canal, reports of vessels

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[76] Source: http://maritime-connector.com/wiki/panamax/ Prior to June 26 2016, the largest containership that could transverse the Canal ranged between 4,500 and 5,000 TEUs. The new Panamax ships can handle up to 14,000 TEUs. The twenty-foot equivalent unit (often TEU) is an inexact unit of cargo capacity often used to describe the capacity of container ships and container terminals. It is based on the volume of a 20-foot-long (6.1 m) intermodal container, a standard-sized metal box that can be easily transferred between different modes of transportation, such as ships, trains and trucks. Refer to Rowlett et al. (2000) *"How Many, A Dictionary of Units of Measurement",* University of North Carolina, Chapel Hill. There is a lack of standardization in regard to height, ranging between 4 feet 3 inches (1.30 m) and 9 feet 6 inches (2.90 m), with the most common height being 8 feet 6 inches (2.59 m). Also, it is common to designate 45-foot (13.7 m) containers as 2 TEU, rather than 2.25 TEU. Refer to: http://en.wikipedia.org/wiki/Twenty-foot_equivalent_unit. The first 24,004 TEU vessel was delivered in June 2022 with an addition 13 ships planned for construction. https://gcaptain.com/china-delivers-first-24000-teu-containership-ever-alot/?subscriber=true&goal=0_f50174ef03-fb1e2157ce-170456695&mc_cid=fb1e2157ce&mc_eid=e60e1bda50

[77] Refer to: https://www.washingtontimes.com/news/2017/jan/24/navigating-the-panama-canal-expansion/

with a Total TEU Allowance (TTA) of 14,863 have traversed the Canal.[78]

## IX. DATA EMPLOYED

In an ideal world, data involving the size and scope of major economic sectors supported by marine transportation would be readily available and detail a wide-variety of costs which could be avoided due to the presence of nautical charts. As such unified data repositories do not exist, they were created for this study by integrating a series of independent data sources. Access to several of these are restricted to Federal government personnel (listed in bold). These included:

- United States Department of Commerce, Census Bureau's USA Trade® Online;
- United States Department of Transportation's Maritime Administration (MARAD);
- **United States Army Corps of Engineers' (USACE) National Navigation Operation and Maintenance Performance Evaluation and Assessment System (NNOMPEAS);**
- United State Coast Guard's Automatic Identification System (AIS) network;
- United States Department of Commerce, Bureau of Economic Analysis Gross Domestic Product (GDP) Deflator;
- **United States Army Corps of Engineers' (USACE Channel Portfolio Tool (CPT);**
- **United States Coast Guard's Boating Accident Report Data Base (BARD);**
- **United States Coast Guard's Marine Information for Safety and Law Enforcement (MISLE);**
- National Oceanic and Atmospheric Administration's, Office of Coast Survey Dangers to Navigation; and,

[78] https://micanaldepanama.com/expansion/2017/08/panama-canal-welcomes-second-more-than-14000-teus-container-vessel-through-expanded-locks/

- NOAA's National Marine Fisheries Service Reports.

Joining selective portions of the aforementioned data bases, the size and relative importance of the economic sectors investigated were estimated as were the avoidance of costs (i.e., estimated benefits). Probable changes in vessel operating costs involving such things as ship type, speed, cargo weight, cargo type, engine size and other engineering attributes (e.g., hull dimensions, propeller size, fuel type, etc.) were developed. Appendix E provides detailed explanations of the data bases and data tools employed in this study. As deaths and injuries are a part of maritime transportation, highly granular estimates of societal costs resulting from marine accidents were also calculated through merger of several data sources. A complete description of the process to estimate mortality and morbidity costs is provided in Appendix F.

# CHAPTER 2 – COMMERCIAL SHIPPING

## I. INTRODUCTION

As a member of the Maritime Domain Awareness Steering Committee, NOAA representing the Department of Commerce, has been tasked with carrying out the National Strategy for Maritime Security as well as Presidential Policy Directive: Maritime Security.[79] Over $5.4 trillion in economic activity is generated by U.S. seaports annually.

Safe and efficient marine transportation essential to the U.S. economy has long been recognized by NOAA as a fundamental goal. The 2016 NOS Priorities Roadmap provides a guide over the next three to five years for advancing NOS recognized essentiality of transportation to the economy of the United States. It stated:

> *"**Increased demands on our marine transportation system.** U.S. commercial ports directly support more than 13 million jobs. The demand for safe, effective and resilient marine infrastructure and transportation continues to grow."*[80]

The essentiality of NOS products and services supporting transportation is well documented:

> *"People in the maritime community rely on coastal intelligence for a range of decisions, from how much cargo to load to choosing the most efficient and safest route between two points. They use coastal intelligence to plan seasonally for ship schedules, mitigate the long-term impacts of sea level rise on port infrastructure and service global trade more efficiently as significantly larger vessels transit through U.S. ports as a result of the Panama Canal*

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[79] Refer to https://www.noaa.gov/media-release/noaa-joins-federal-maritime-security-team-to-support-american-blue-economy, August 28, 2020.

[80] *NOS Priorities Roadmap, A Guide for Advancing National Ocean Service Priorities over the Next Three to Five Years*, National Oceanic and Atmospheric Administration, National Ocean Service, Silver Spring, Maryland, October, 2016

> *expansion. As our economic dependence on the U.S. Maritime Transportation System (MTS) grows, robust coastal intelligence is vital to maintaining MTS resilience, reducing maritime risk and responding to incidents when they occur"*[81]

NOS' Coastal Intelligence Outcome 1 recognizes that:

> *"integrated decision support tools safely enable expanded waterborne commerce in busy ports".*[82]

In short, to paraphrase the NOS Ocean Service website, NOAA's NOS has been characterized as "Americas Ocean and Coastal Agency" whose mission is to provide science-based solutions through collaborative partnerships to address evolving economic, environmental and social pressures on the oceans and coasts.[83]

> *"**Safe and Efficient Transportation and Commerce** - Ships move $1.5 trillion worth of products in and out of U.S. ports every year. Every ship moving in and out of U.S. ports relies on navigation charts and water level information that NOS alone provides. All mapping, charting, and transportation activities and infrastructure are founded on a reliable, accurate national coordinate system. NOS is solely responsible for maintaining that system, which provides more than $2.4 billion in potential annual benefits to the U.S. economy. Businesses in the maritime community rely on NOS for a range of decisions, from how much cargo to load to choosing the safest and most efficient route between two points. They use NOS data, tools, and services to plan seasonally for ship schedules to service global trade more safely and efficiently as significantly larger vessels transit through U.S. ports as a result of the Panama Canal expansion."*[84]

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[81] Ibid, Page 7.

[82] Ibid.

[83] Refer to: http://oceanservice.noaa.gov/about

[84] Ibid.

More recently, in 2018, president Trump illustrated the importance of ocean policy in an Executive Order.

> *"Section 1. Purpose. The ocean, coastal, and Great Lakes waters of the United States are foundational to the economy, security, global competitiveness, and well-being of the United States. Ocean industries employ millions of Americans and support a strong national economy."*[85]

Overall, transportation and warehousing at $25 billion represents 6.7 percent of the Blue Economy.[86]

### A. Requirements for Chart Carriage

The U.S. Coast Guard responsible for maritime safety in the United States exercises oversight of all marine transportation activities in U.S. waters recognizes the critical importance of nautical charts to the safety of commercial shipping by establishing regulations for all shipping both foreign and domestic to abide by. They require that each vessel must have marine charts of the area to be transited.[87]

## II. WATERBORNE TRAFFIC TRENDS

Between 2003 and 2019, total waterborne tonnage of imported and exported traffic grew over 16 percent while international container traffic measured by tonnage grew by 78 percent.[88] (Table 1). Major changes were led by exports and a shift away from imported crude oil traffic.

During the same timeframe, the nominal value of cargo increased by over two-fold, again

[85] Executive Order 13840, Ocean Policy to Advance the Economic, Security and Environmental Interests of the United States, June 19, 2018.

[86] Refer to: https://www.noaa.gov/media-release/marine-economy-in-2018-grew-faster-than-us-overall.

[87] Code of Federal Regulations (CFR) Title 33: Navigation and Navigable Waters Subsection Part 164 Navigation Safety Regulations, updated to January 15, 2021.

[88] Source: USA Trade® Online: U.S. Import and Export merchandise statistics.

lead by exports. Depressed imported crude oil costs beginning in late 2014 has helped depress total import cargo value. (Table 2)

**Table 1**

**CHANGES IN IMPORT AND EXPORT CARGO WEIGHT (RATIO BETWEEN 2003[89] to 2019)**

| TYPE OF TRAFFIC | WATERBORNE CARGO WEIGHT | CONTAINER CARGO WEIGHT |
|---|---|---|
| EXPORT | 2.410 | 2.268 |
| IMPORT | 0.696 | 1.536 |
| TOTAL | 1.163 | 1.780 |

Source: U.S. Census Bureau: Foreign Trade Division, USA Trade® Online: U.S. Import and Export merchandise statistics. Downloaded November 25, 2020.

**Table 2**

**CHANGES IN IMPORT AND EXPORT CARGO VALUE (NOMINAL DOLLARS – RATIO BETWEEN 2003[90] to 2019)**

| TYPE OF TRAFFIC | WATERBORNE CARGO VALUE | CONTAINER CARGO VALUE |
|---|---|---|
| EXPORT | 2.862 | 2.552 |
| IMPORT | 1.848 | 2.223 |
| TOTAL | 2.233 | 2.301 |

Source: U.S. Census Bureau: Foreign Trade Division, USA Trade® Online: U.S. Import and Export merchandise statistics. Downloaded November 25, 2020.

Total international trade represents a significant portion of the economy of the United States. In 2019, the Gross Domestic Product (GDP) of the United States approached $21.4 trillion.[91] The value of total imported and exported goods during that period exceeded $4.1

[89] Ibid. 2003 was first year that container traffic data was available.

[90] 2003 was first year that container traffic was available.

[91] Source: U.S. Department of Commerce, Bureau of Economic Analysis, Gross domestic product (GDP) is the market value of all officially recognized final goods and services produced within a country in a given period. GDP per capita is often considered an indicator of a country's standard of living.

trillion that equates to about 19.3 percent of GDP.[92] In 2000, this figure was 19.5 percent of GDP reflecting continued interdependency of the U.S. and world economies.[93]

Of all international trade, the Marine Transportation System (MTS) remains essential to the commerce of this county. Waterborne traffic represented 72.4 percent of all imported and exported tonnage as well as 41.9 percent of the value of all imported and exported goods in 2018. When international waterborne traffic is further examined, containerized freight, the fast growing segment of international trade, represented 26.2 percent of total cargo value and 15.8 percent of total cargo weight.[94] Since 2003 total tonnage of imported and exported goods grew by 16.3 percent while international container traffic as measured by tonnage grew by 78.0 percent.

Based on interviews with more than 10,000 firms providing services to the cargo and vessels handled at the U.S. deep water ports, Martin estimated that deep-draft seaports and seaport-related businesses in the United Stated generated approximately 13.3 million jobs and added nearly $3.15 trillion to the economy. (Martin, 2007)[95]

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[92] As GDP is calculated as the sum of private consumption, gross investment, government spending plus the net of total exports less imports, both imports and exports impact the level of demand for domestic railroad and motor carrier transportation services.

[93] 2000 nominal GDP was about $10.3 trillion with exported and imported goods valued at $0.8 and $1.2 billion, respectively. Source: U.S. Department of Commerce, Bureau of Economic Analysis, U.S. Census Bureau, Foreign Trade Division.

[94] U.S. Census Bureau, Foreign Trade Division, USA Trade Online, U.S. Import and Export Merchandise Statistics.

[95] In updating an earlier study from 2000, Martin investigated additions from direct jobs (firms providing support services to the sea port), induced jobs (local and national jobs from the purchase of goods and services by those directly employed), indirect jobs (national jobs generated as a result of local purchases by firms dependent upon seaport activity) and related jobs (manufacturing and distribution benefiting from deep-water ports). Special care was exercised to avoid double counting.

Martin (2015) updated his data by estimating that in 2014 deep-draft seaports and seaport-related businesses in the United Stated generated approximately 23.1 million jobs and added nearly $4.6 trillion to the economy that represented 26 percent of the GDP.[96]

In 2000, there were almost 28.2 million containers (TEU equivalent) in worldwide service. This had increased to 34 million in 2020.[97] While world GDP is forecast to increase two to three percent annual rate in the near future, container growth is forecast to increase by 4.7 percent annual growth rate.[98] Consequently, future near-term TEU increases in the major container ports of Los Angeles / Long Beach and New York/New Jersey traffic levels seem all but certain.

## III. NAUTICAL CHARTING ACCURACY

The International Hydrographic Organization (2020) states that

> "*the primary purpose of nautical charts is to provide the information required safe navigation.*[1] *The mariner has a need for appropriate, relevant, accurate and unambiguous information*."[99]

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[96] Ibid, Page 6.

[97] https://www.worldshipping.org/about-the-industry/containers

[98] Refer to: Source: Container through put growth is outperforming world GDP forecast. Source: : http://www.statista.com/statistics/253931/global-container-market-demand-growth/; Downloaded February 2019.

[99] Page 2.

**Table 3**

## ZONES OF CONFIDENCE (ZOC) CATEGORIES[100]

| ZOC CATEGORY | POSITION ACCURACY | DEPTH ACCURACY | | SEAFLOOR COVERAGE | TYPICAL SURVEY CHARACTERISTICS |
|---|---|---|---|---|---|
| A1 | ± 5 m + 5% depth | =0.50 + 1%d | | Full area search undertaken. Significant seafloor features detected and depths measured. | Controlled, systematic survey high position and depth accuracy achieved using DGPS and a multi-beam, channel or mechanical sweep system. |
| | | Depth (m) 10<br>30<br>100<br>1000 | Accuracy (m)<br>± 0.6<br>± 0.8<br>± 1.5<br>± 10.5 | | |
| A2 | ± 20 m | = 1.00 + 2%d | | Full area search undertaken. Significant seafloor features detected and depths measured. | Controlled, systematic survey achieving position and depth accuracy less than ZOC A1 and using a modern survey echo-sounder and a sonar or mechanical sweep system. |
| | | Depth (m) 10<br>30<br>100<br>1000 | Accuracy (m)<br>± 1.2<br>± 1.6<br>± 3.0<br>± 21.0 | | |
| B | ± 50 m | = 1.00 + 2%d | | Full area search not achieved; uncharted features, hazardous to surface navigation are not expected but may exist. | Controlled, systematic survey achieving similar depth but lesser position accuracies than ZOC A2, using a modern survey echo-sounder, but no sonar or mechanical sweep system. |
| | | Depth (m) 10<br>30<br>100<br>1000 | Accuracy (m)<br>± 1.2<br>± 1.6<br>± 3.0<br>± 21.0 | | |
| C | ± 500 m | = 2.00 + 5%d | | Full area search not achieved; depth anomalies may be expected. | Low accuracy survey or data collected on an opportunity basis such as soundings on passage. |
| | | Depth (m) 10<br>30<br>100<br>1000 | Accuracy (m)<br>± 2.5<br>± 3.5<br>± 7.0<br>± 52.0 | | |
| D | Worse than ZOC C | Worse than ZOC C[101] | | Full area search not achieved; large depth anomalies may be expected. | Poor quality data or data that cannot be quality assessed due to lack of information. |
| U | Unassessed - The quality of the bathymetric data has yet to be assessed[102] | | | | |

Source: International Hydrographic Organization (IHO) S-57 Ed3.1 Supp 3 (Jun 2014), pp. 13-14

They summarize charting activities as navigational tools that promote safe transit for all

[100] International Hydrographic Organization, Annex A, Table A-1, Page 19.

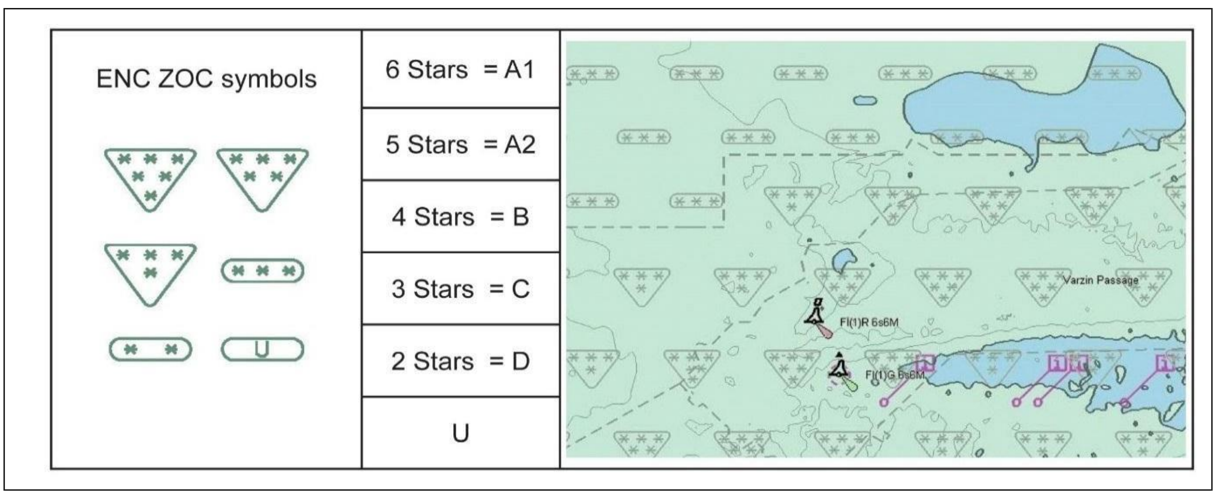
[101] While not officially established, in this analysis, locations with ZOC D ratings were defined as 3.0 meters +/- 8 percent of depth.

[102] In this analysis, ports with a "U" rating were assigned the same accuracy as those with a "D" rating (i.e., 3.0 meters +/- 8 percent of depth.)

classes of vessels from the smallest to the largest in both coastal waters and major ports. As mariners use navigational charts for a variety of operational activities (e.g., overall, general, coastal, approach, harbor and berthing), the need to know the adequacy and accuracy of depth information is critical to the both the planning and execution of the voyage. By 2016 the Office of Coast Survey was adding Category Zone of Confidence (CATZOC) to the Electronic Navigational Charts (ENC) to highlight the accuracy and reliability of the data presented on the charts. The Zone of Confidence (ZOC) has six categories named A1, A2, B, C, D and U based

**Table 4**

**STAR INDICATORS OF CATZOC VALUE**




Source: International Hydrographic Organization, Figure 5-1 Page 13.

on a minimum set of criteria for position, depth accuracy and seafloor coverage.[103] (Table 3) CATZOC on the ENC in simple terms refers to the Quality and Accuracy of survey data and the applicable error in chart datum that sometimes can greatly affect vessel's Under Keel Clearance (UKC) calculations.[104] The number of stars on the chart is an indication of the CATZOC value.

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[103] Admiralty Marine Data Solutions, Category Zones of Confidence (CATZOC) dispelling the myths, March 16, 2017. Downloaded February 2, 2021.

[104] UKC is the difference between the keel of the vessel and bottom depth.

(Table 4) Bridge watchkeepers should be aware of the Electronic Chart Display and Information System (ECDIS) function to activate the CATZOC symbol on the Electronic Navigational Charts (ENC).[105] This data may be used to ascertain the contour settings on the chart. For example – if the data is unreliable, the vessel may need to keep a larger safety contour margin.

CATZOC designation can greatly affect the vessel's ultimate UKC calculation and must be considered where the depths are shallow. As a basic rule of thumb the Master should plan vessel's passage by keeping the vessel in areas shown by the triangles with CATZOC – A1, A2 and B designations and staying away from the areas covered by rectangles in areas of CATZOC-C, D and U designation.

Where the vessel can't keep clear from passing close to the rectangles, cautions notes should be posted on the ENC using the User Maps option instructing the navigator to "Keep Echo Sounder "on" and "Monitor UKC Continuously". Ship's staff should factor in the value associated with these categories. This can be seen in the example below:

If the depth marked on ENC is 3 meters, the actual depth of that area may differ depending upon the CATZOC shown on ENC.

- For area with CATZOC A1, Actual depth may be as shallow as: 3 - (0.5 + 0.1) = 2.4 meters.
- For area with CATZOC A2, Actual depth may be as shallow as: 3 - (1.0 + 0.2) = 1.8 meters[106].
- For area with CATZOC B, Actual depth may be as shallow as: 3 - (1.0 + 0.2) = 1.8 meters.
- For area with CATZOC C, Actual depth may be as shallow as: 3 - (2.0 + 0.5) = 0.5 meters

[105] The North of England P&I Association. 2017. *"Loss Prevention Briefing*", May.

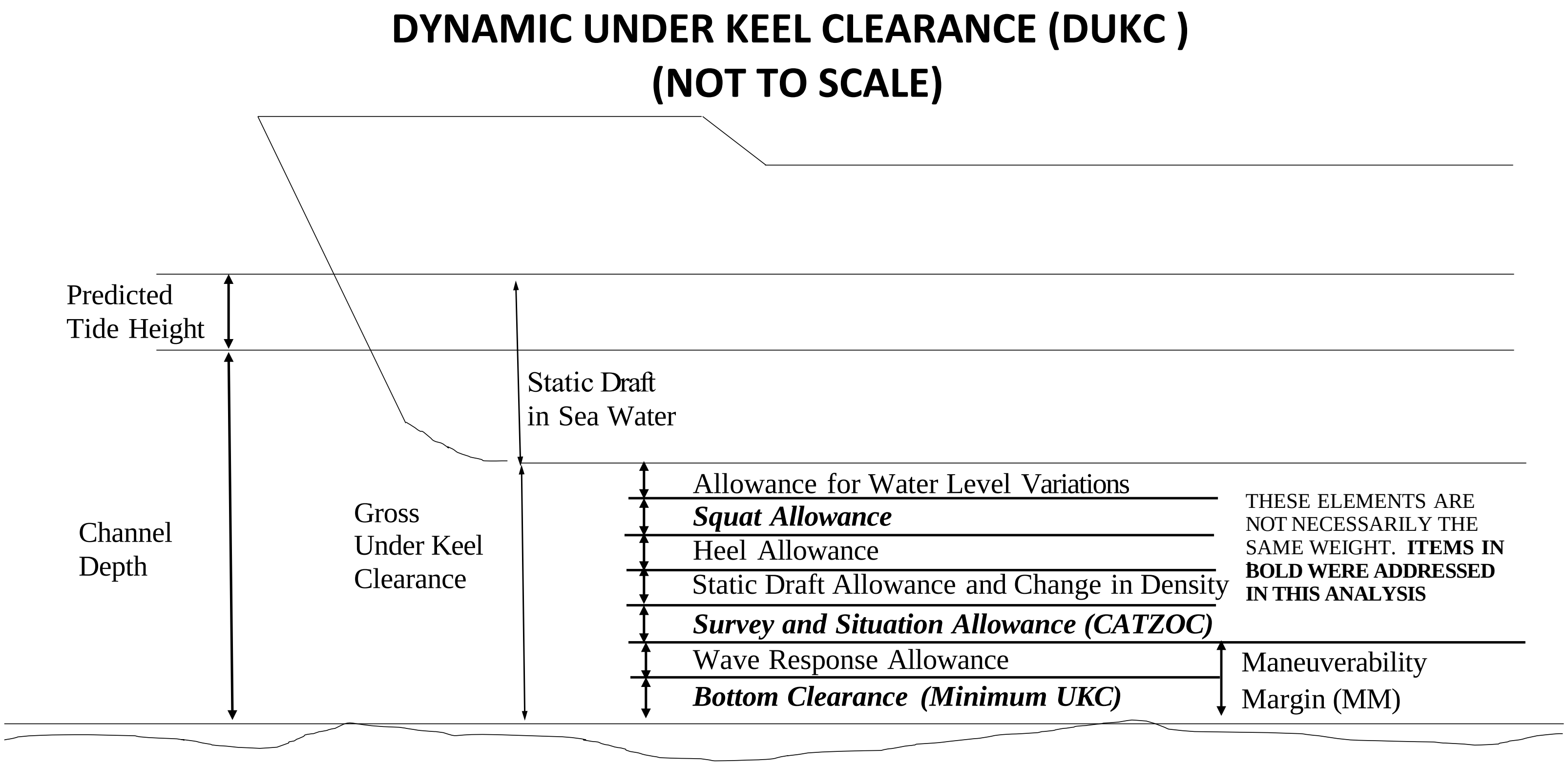
[106] Although A2 and B have the same depth accuracy what differs is the positional accuracy.

For areas with CATZOC – D and U the error is not specified or unassessed and should therefore be avoided as far as possible specially when in shallow waters. While the correction to the depth is + /- (i.e., it can also assist by providing a greater depth), it is prudent for the Master to calculate for shallower depth by using "-" accuracy to err on the safer side.

Several years ago the director of the Office of Coast Survey made the decision that United States Army Corps of Engineers (USACE) surveys be given a CATZOC of "B" until adequate data is provided to warrant a more accurate rating (where B indicates not full coverage and a depth accuracy of plus or minus 1.2 meters.[107]There are still some areas that are rated "U" or unassessed. While specialized work has been done with the USACE to reduce inaccuracy (e.g., raising San Francisco Bay's Pinole Shoal

[107] Personal communication between Rear Admiral Shep Smith (NOAA) and Denise LaDue U.S. Army Corps of Engineers, September 8, 2016.

**Figure 1**




Source: Port Taranaki, OMC International, Figure 1, Page 2

Channel CATZOC to A1) 99 percent of all channels are rated as “B”.[108]

## IV. UNDER KEEL CLEARANCE (UKC)

Ports exhibit a wide-variety of physical characteristics. While some ports may have rocky bottoms, others have a softer silty or muddy bottom. Likewise, while tides are not a factor in the Great Lakes, in coastal areas large differences in tides may exist across ports which need to be taken into account to help ensure that UKC requirements are met. Based on the physical characteristics of a port, its management may dictate standards for minimum UKC. measurements.

Following Regulation 19 involving preventing the release of oil, double bottom hulls of tanker vessels are mandated for those of 5,000 or more deadweight tonnes and above delivered on or after July 6, 1996.[109] Vessel owners and operators may also establish UKC limits to mitigate liability issues especially in the case movements of petroleum products.

Overall, the minimum UKC represents a safety factor that the operators of the vessel, pilots for the port, and perhaps U.S. Coast Guard and port authority feel is necessary to account for the variability and potential error in measuring all the components of the UKC depth. As the environment is dynamic, to ensure UKC standards are met several elements must be concurrently understood and accounted for. These factors include:[110] (Figure 1)

- **Allowance for Tide Level Variations** – Leeway for tides
- **Squat Allowance**- approximately proportional to the square of the vessel’s speed, squat is the hydrodynamic phenomenon that is associated with a vessel moving quickly through shallow water. This creates an area of lower pressure that results in the vessel being

[108] A1 ratings expire after two years and must be reexamined to retain that rating.

[109] http://www.marpoltraining.com/MMSKOREAN/MARPOL/Annex_I/r19.htm.

[110] https://knowledgeofsea.com/under-keel-clearance/; Updated March 29, 2021

drawn closer to the seabed than otherwise would have been expected.

- **Heel Allowance** – the temporary inclination of a vessel from external forces including waves, winds, or during the ship's turn.
- **Static Draft Allowance and Change in Density** – static draft is the draft (depth) of the vessel when it stationary or subject to sea and swell influences. Water density alters statis draft as it changes with temperature.
- **Survey and Situational Allowance** – nautical chart itself to include the CATZOC depth variability. The variability should always be applied by subtracting the variability from the charted sounding this being the most conservative and thus safest practice.
- **Wave Response Allowance** – A factor employed in determining bottom clearance that accounts for vessel motions induced by sea and swell waves
- **Bottom Clearance** - Measurement of distance between lowest point of vessel's keel and the bottom of seabed.

Gourlay (2007) reviewed these considerations and placed them into the following formula: *UKC = Chart datum depth + tide – static draft – (squat, heel and response).*

Because pilots and vessel operators do not have perfect knowledge each port usually has a "rule-of-thumb" safety factor for minimum UKC to ensure a safe passage to and from the port. In some cases like California the minimum UKC is published but in others this may be known only by pilots, the Coast Guard Captain of the Port, port operational personnel and vessel operators. (Refer to Appendix G and H) Some ports may call for added depth (Washington ones) reflecting the need for greater caution. Since ports usually compete with each other for business this number may be considered a bit proprietary. While a number of factors are the basis for estimation of UKC, water depths provided by ENCs provide the basis for subsequent calculations.

Channel depths were identified for each port and differences between reported vessel draft and channel depth were calculated. Total vessel tonnages and cargo values were identified by vessel type and region by summation of reported vessel transits.

## V. MAJOR PORT CAPABILITIES

Detailed vessel movement data for 2016, the latest year available, was obtained from the USACE's Channel Portfolio Tool (CPT) database for the largest ports in the Great Lakes and U.S. coastal ports. A complete description of the CPT database is provided in Appendix I

A total of 55 Great Lakes ports were identified while an additional 84 coastal locations were investigated. (Tables 5 and 6) Collectively, these 139 locations represented almost 94 percent of total tonnage transported via water in 2016 and 84 percent of total vessel transits.[111]

Taylor et al. (2007) reports vessels on the Great Lakes capable of traversing the locks of the St. Lawrence Seaway are called Seawaymax. They measure 225.6 meters (740 feet) in length, 23.8 meters (78 feet) wide and have a draft of 8.08 meters (26.5 feet) with a height above the waterline of 116 feet. Coastal vessel sizes for container, dry bulk and tankers were estimated based on overall average vessel size, measured by Dead Weight Tonnage (DWT) [112] reported by the Maritime Administration (MARAD).[113]

[111] 3,394,037 vessel transits in the studied ports compared with 3,991,481 total vessel transits in 2016. Source: USACE, CPT.

[112] DWT refers to the entire weight of the ship including its lading, fuel, ballast, crew, etc.

[113] 2015 Vessel Calls in U.S. Ports (latest available)

**Table 5**

## UNDER KEEL CLEARANCES AT MAJOR COASTAL PORTS[114]

| PORT | CATZOC RATING (MAINTAINED CHANNELS) | CATZOC RATING (NATURAL CHANNELS) | UNDER KEEL CLEARANCE REQUIRED (Feet)[115] | CHARTED CHANNEL CONTROLLING DEPTH[116] (Feet) |
|---|---|---|---|---|
| Aberdeen, MD | | C | 2 | 6 |
| Aberdeen, WA | B | | 1 | 36 |
| Albany, NY | B | | 2 | 11.6 |
| Anacortes, WA | | A1 | 10% / 3 | 34 |
| Anchorage, AK | | B | 10% / 3 | 35 |
| Baltimore, MD | B | | 2 | 50 |
| Baton Rouge, LA | B | | 2 | 45 |
| Beaufort, NC | B | | 10% | 15 |
| Beaumont, TX | B | | 2 | 40 |
| Bellingham, WA | B | | 10% / 3 | 32 |
| Boston, MA | A2 | | 10% / 2 | 45 |
| Brownsville, TX | B | | 2 | 42 |
| Brunswick, GA | B | | 10% | 36 |
| Calcasieu River, LA | B | | 2 | 40 |
| Canaveral, FL | B | | 2.5 | 44 |
| Carquinez Strait, CA | A1 | B | 2 | 51 |
| Charleston, SC | B | | 10% | 45 |
| Chester River, DE | A2 | | 2 | 45 |
| Chester, PA | A2 | | 2 | 45 |
| Coos Bay, OR | B | | 10% / 3 | 37 |
| Corpus Christi, TX | B | | 2 | 47 |
| Eastport, ME | A1 | | 2 | 45 |
| El Segundo, CA | | A1 | 2 | 43 |
| Everett, WA | B | | 10% / 3 | 45 |
| Fernandina, FL | B | | 20% | 36 |
| Freeport, TX | B | | 2 | 45 |
| Galveston, TX | B | | 2 | 45 |

[114] Voted on and approved by the Harbor Safety Committee of the San Francisco Bay Region June 14, 2012. Pursuant to the California Oil Spill and Prevention Act of 1990. Submitted by the Harbor Safety Committee of the San Francisco Bay Region.

[115] Numbers alone indicate the UKC recommendation in feet. Percentages alone indicate the UKC based on the depth of the vessel (e.g., a 40 foot vessel depth in a port with 10 percent UKC suggests a UKC of four feet). In cases where both a percentage and number appear, the lower of the two numbers is used. Numbers in italics were estimated based on similar ports in adjacent geographic areas. Most of the values for under keel clearance came from personal communications with the Office of Coast Survey Navigation Managers.

[116] USACE, Soundings from USACE project reports. Charted controlling depth. Refer to: (https://nauticalcharts.noaa.gov/rnconline/rnconline.html)

| | | | | |
|---|---|---|---|---|
| Gloucester City, NJ | A2 | | 2 | 42 |
| Gloucester, NJ | A2 | | 2 | 45 |
| Gramercy, LA | B | | 2 | 81 |
| Gulfport, MS | B | | 3 | 36 |
| Honolulu, HI | A1 | | 2 | 41 |
| Houston, TX | B | | 2 | 45 |
| Jacksonville, FL | B | | 20% | 40 |
| Juneau, AK | | B | 10% / 3 | 25 |
| Kalama, WA | B | | 3 | 43 |
| Ketchikan, AK | | A1 | 10% / 3 | 35 |
| Lake Charles, LA | B | | 2 | 40 |
| Long Beach, CA | A1 | | 10% | 80 |
| Longview, WA | B | | 3 | 43 |
| Los Angeles, CA | A1 | | 10% | 53 |
| Manatee, FL | B | | 2 | 40 |
| Miami, FL | B | | 2 | 50 |
| Mobile, AL | B | | 2 | 45 |
| Morgan City, LA | B | B | 2 | 20 |
| New Haven, CT | B | | 10% | 35 |
| New London, CT | B | | 10% | 40 |
| New Orleans, LA | B | | 2 | 50 |
| New York, NY | A1 | | 2 | 50 |
| Newark, NJ | B | | 2 | 50 |
| Norfolk, VA | B | | 2 | 50 |
| Oakland, CA | B | | 2 | 50 |
| Olympia, WA | B | | 10% / 3 | 30 |
| Palm Beach, FL | B | | 2 | 36 |
| Panama City, FL | B | | 3 | 36 |
| Pascagoula, MS | U | | 3 | 42 |
| Pensacola, FL | B | | 2 | 33 |
| Perth Amboy, NJ | B | | 2 | 35 |
| Philadelphia, PA | A2 | | 2 | 45 |
| Port Arthur, TX | B | | 2 | 40 |
| Port Everglades, FL | B | | 2 | 42 |
| Port Hueneme, CA | B | | 3.5 | 36 |
| Port Lavaca, TX | B | | 2 | 36 |
| Portland, ME | B | | 10% / 3 | 45 |
| Portland, OR | B | | 3 | 43 |
| Portsmouth, NH | A1 | | 10% / 3 | 35 |
| Providence, RI | B | | 10% | 40 |
| Richmond, CA | B | | 2 | 46 |
| Richmond, VA | B | | 2 | 25 |
| Sabine Pass, TX | B | | 2 | 40 |
| San Diego, CA | B | | 1 | 42 |
| San Francisco, CA | | B | 2 | 43 |
| San Joaquin, CA | B | | 2 | 37 |
| San Juan, PR | B | | 3 | 40 |
| San Pablo Bay, CA | A1 | | 2 | 40 |
| Savannah, GA | B | | 10% | 42 |
| Searsport, ME | A1 | | 10% / 3 | 35 |
| Seattle, WA | B | A1 | 10% / 3 | 60 |
| Skagway, AK | | A1 | 10% / 3 | 96 |
| Tacoma, WA | B | | 10% / 3 | 51 |

| | | | | |
|---|---|---|---|---|
| Tampa, FL | B | | 2 | 43 |
| Texas City, TX | B | | 2 | 45 |
| Vancouver, WA | B | | 3 | 40 |
| Wilmington, DE | A2 | | 2 | 42 |
| Wilmington, NC | B | | 10% | 42 |

Sources: Voted on and approved by the Harbor Safety Committee of the San Francisco Bay Region June 14, 2012 Pursuant to the California Oil Spill and Prevention Act of 1990. Updates from 2021 NOAA navigation manager input.

UKC in the Great Lakes is not normally referenced by port. Instead, UKC is determined by the level of experience and responsibility of the individual managing the vessel. While companies set their own policies for minimum UKC clearance a set of common posted requirements is: if a port pilot is in charge, a UKC of 0.3 meters is recommended while if a vessel master, a one meter UKC is advocated and if the third mate is in charge, a three meter UKC is suggested.[117]

**Table 6**

## UNDER KEEL CLEARANCES AT MAJOR GREAT LAKES PORTS

| PORT | CATZOC RATING (MAINTAINED CHANNELS) | CATZOC RATING (NATURAL CHANNELS) | CHARTED CHANNEL CONTROLLING DEPTH[118] (Feet) |
|---|---|---|---|
| Alpena, MI | B | | 24 |
| Ashland, WI | B | | 25 |
| Ashtabula, OH | B | | 27 |
| Bay City, MI | B | | 25 |
| Buffalo, NY | B | | 23 |
| Burns Harbor, IN | | B | 30 |
| Calumet, IL | B | | 28 |
| Cedarville, MI | B | | 28 |
| Charlevoix, MI | B | | 18 |
| Cheboygan, MI | B | | 21 |
| Chicago, IL | B | | 29 |
| Cleveland, OH | B | | 29 |
| Conneaut, OH | B | | 28 |

[117] Source: LCDR Charles Wisotzkey, NOAA, Personal communication, January 27, 2021.

[118] Soundings from USACE project reports. Charted controlling depth. Refer to: (https://nauticalcharts.noaa.gov/rnconline/rnconline.html)

| | | | |
|---|---|---|---|
| Detroit, MI | B | | 29 |
| Duluth Superior, MN | B | | 32 |
| Erie, PA | B | | 28 |
| Escanaba, MI | | D | 22.5 |
| Essexville, MI | B | | 27 |
| Fairport, OH | B | | 25 |
| Gary, IN | | B | 30 |
| Gladstone, MI | B | | 22 |
| Grand Haven, MI | B | | 21 |
| Green Bay, WI | B | | 26 |
| Harbor Beach, MI | B | | 16 |
| Holland, MI | B | | 17.5 |
| Huron, OH | B | | 29 |
| Indiana Harbor, IN | B | | 29 |
| Kelly's Island, OH | B | | 17 |
| Lorain, OH | B | | 26.3 |
| Ludington, MI | B | | 30 |
| Mackinaw City, MI | | B | 19 |
| Manistee, MI | B | | 25 |
| Manitowoc, WI | B | | 25 |
| Marblehead, OH | | B | 26 |
| Marquette, MI | B | | 27 |
| Marysville, MI | B | | 28 |
| Menominee, WI | B | | 24 |
| Milwaukee, WI | B | | 30 |
| Monroe, MI | B | | 21 |
| Muskegon, MI | B | | 29 |
| Oswego, NY | B | | 27 |
| Presque Isle, MI | B | | 30 |
| Rochester, NY | B | | 20 |
| Rouge River, MI | B | | 25 |
| Saginaw, MI | B | | 27 |
| Sandusky, OH | B | | 26 |
| Silver Bay, MN | | D | 28 |
| St. Clair, MI | B | | 30 |
| St. Josephs, MI | B | | 21 |
| Taconite Harbor, MN | | D | 30 |
| Toledo, OH | B | | 28 |
| Traverse City, MI | | C | 23 |
| Two Harbors, MN | | B | 30 |
| Washburn, WI | | D | 19 |
| Wyandotte, MI | B | | 28 |

Medley (2018) wrote

> "*The U.S. federal channel in the Delaware Bay is vital to maritime commerce, leading deep draft vessel traffic to and from the major ports of Wilmington, Delaware, Philadelphia, Pennsylvania, and Camden, New Jersey. To navigate this federally maintained waterway safely and efficiently, mariners rely on the surveyed depths*

*displayed on nautical charts. The U.S. Army Corps of Engineers (USACE) Philadelphia District regularly surveys this area, utilizing sophisticated techniques and equipment to map the depths of the seafloor. NOAA's Office of Coast Survey, in turn, adds quality classifications to these channel depths and displays them on the nautical chart."*

*"The portion of the federal channel from Newbold Channel Range down to the mouth of the Delaware Bay is the first waterway in the U.S. to have an improved quality classification assigned to USACE survey data—category of zone of confidence (CATZOC) A2. Improving survey quality and upgrading the CATZOC classification allows operators to accommodate smaller margins of error while still ensuring that navigating maritime approaches and constrained environments remain safe. These decreased tolerances allow ships to maximize their loads, ultimately increasing inbound and outbound cargoes."*[119]

The value of added vessel draft has long been recognized. Senator Coons reported

*"This is a huge leap forward toward the sophistication of nautical charts, and will help the maritime sector along the Delaware River. I want to commend the men and women at NOAA's Office of Coast Survey and the Army Corps of Engineers District Philadelphia for working together to provide safer timely high-quality data for maritime commerce. I applaud Commerce Secretary Ross for recognizing the vital role that NOAA's Coast Survey provides to the maritime industry and thank him for this outcome. This synergy between NOAA and the Army Corps is exciting to see, and I support efforts to replicate this pilot project in other ports and waterways around the country."*[120]

## VI. COMPONENTS OF WATER COLUMN MEASUREMENT ACCURACY

In essence, CATZOC provides a level of confidence that the mariner has with respect to

[119] Medley, Rachel. 2018. "First U.S. Federal Channel Using USACE Survey Data Receives Improved Quality Classification From NOAA", News and Updates, Office of Coast Survey, NOAA website, Posted May 18.

[120] U.S. Senator Chris Coons (D-DE), 2018

the depth of water under their vessel at a particular location for each maintained and natural channel. The range of these intervals is dependent upon the depth of the vessel passing in that area and the rating given to that location. As CATZOC designations rise, (e.g., B to A1, A2 to A1) the level of uncertainty declines in both depth and position accuracies. For example, if the CATZOC rating for a position advances from a "B" to an "A1" the uncertainty of depth is reduced by 0.5 meters plus 1 percent of the position's depth.

The value of enhanced CATZOC designations is the ability to safely and efficiently transport vessels with greater loads. Such enhancements can reduce the number of vessel transits required to transport the same level of lading. With fewer vessel transits, vessel fuel use for both main propulsion and auxiliary systems would decline along with resultant environmental emissions. In addition, with fewer transits, the incidence of vessel collisions, allisions and groundings would also be expected to decline as would port congestion. As current traffic levels do not make use of the total theoretical potential value of enhanced CATZOC designations, they are explored in theory and not monetized in this study. The demand for transportation is derived as vessel cargo represents a series of services (e.g., location, condition, storage, etc.) that support other industries rather than the waterborne commerce industry in and of itself. In essence, the demand for vessel transportation depends on the demand for goods that it transports. The selection and use of specific vessel types and sizes is dependent on many factors which include the underlying derived demand function, characteristics of the commodity transported, vessel availability, port congestion and supportive infrastructure capabilities (e.g., highway, rail access) etc.

Analyzing each of the 84 coastal and 55 Great Lakes port locations studied, two methods were employed to provide an assessment of the potential of heightened nautical chart accuracy as measured by changes in CATZOC ratings. In each evaluation, it must be stressed that both these calculations are theoretical, based on the assumption that sufficient traffic became available to make use of the added confidence supplied by heightened CATCOZ ratings and that no changes in channel depths are made – only reductions in existing depth uncertainty. In short, this investigates the theoretical maximum potential value that could result without addition channel improvements by the USACE.

### A. Value of Advancing All Current CATCOZ Designations to "A1"

In 2015, the Department of Transportation's Maritime Administration (MARAD) reported that over 82,000 vessel calls had been made at U.S. coastal ports.[121] Using the lower level of CATZOC port accuracy reported between maintained and natural channels, potential added vessel displacement from coastal ports was estimated by calculating the increase in vessel displacement which could be facilitated if all current CATZOC port location ratings were upgraded to A1. This was calculated by vessel type and reported vessel displacement by port. In turn, this figure for each port-vessel type-depth calculation grouping was multiplied by the number of reported trips for that grouping.[122] (Table 7) In essence, this approach estimated the theoretical amount of additional tonnage that could have been carried due to increased certainty of underwater depth had sufficient demand been present.

This calculation suggests a theoretical potential of over 825 million additional tons could be handled at coastal ports through handling the movement of an additional 8,476 vessels if

[121] U.S. Department of Transportation, Maritime Administration. 2015. "Vessel Calls in U.S. Ports, Selected Terminals and Lightering Areas".

[122] Vessel trips and depths were obtained from the USACE's Channel Portfolio Tool for 2016.

sufficient traffic demand was present. Based on reported 2015 MARAD data this would represent over a ten percent increase over 2015 levels.

**Table 7**

**ESTIMATE OF MAXIMUM ADDED VESSEL TONNAGE AND TRANSITS (UPGRADE CURRENT CATZOC PORT RATINGS TO "A1")**

| VESSEL TYPE | POTENTIAL ADDED TONNAGE (THOUSANDS) | TYPICAL LADING PER VESSEL (TONS)[123] | NUMBER OF ADDED VESSEL TRANSITS |
|---|---|---|---|
| Container | 264,659 | 108,877 | 2,431 |
| Tank | 265,633 | 97,524 | 2,724 |
| Bulk | 294,877 | 88,872 | 3,321 |
| Total Coastal | 825,170 | | 8,476 |
| | | | |
| Great Lakes | 10,848 | 63,817 | 170 |
| Grand Total (All Areas) | 836,018 | | 8,646 |

Upgrading all ports in the Great Lakes from their current CATZOC assignment levels to "A1" suggest a theoretical potential to carry an added 11 million tons by 170 vessels should sufficient traffic demand be present.[124] Upgrading all ports in coastal states from their current CATZOC assignment levels to "A1" suggest a theoretical potential to carry an added 825 million tons by 8,476 vessels should sufficient traffic demand be present. Together, this represents a potential increase of over 836 million tons across an additional 8,646 vessels. To place this into perspective, the ability to safely handle an additional 836 million tons could increase waterborne

[123] Based on ninety percent of DWT is attributable to cargo. The remaining ten percent accounts for weight of stores, crew, fuel, etc.

[124] 93.3 percent of all Great Lakes tonnage and cargo value was carried in dry bulk vessels.

tonnage from 1,527 million tons to 2,363 million tons – a 54.7 percent increase in 2017.

The theoretical value of advancing all coastal and Great Lakes locations to "A1" status is reflected in the added tonnage which theoretically could be transported without the need to invest additional monies by the USACE to enhance or augment channel depths. This potential is presented to only illustrate a theoretical potential future monetary benefit which could present as use of larger, more economic vessels. As no traffic is currently present to take advantage of this potential benefit, no current dollar value has been calculated at this time.

### B. Value of Water Column Depth Measurement

The value of the ability to more fully load and safely operate vessels represent collective benefits from several groups. If depth accuracy was in question, vessels would probably have to be more lightly loaded to ensure safe passage.[125] Given ongoing demand for vessel transportation service, the forgone opportunity to transport additional cargo would ultimately result in the use of extra vessels to transport the same level of lading.

Those costs, saved owing to heavier vessel loadings, are a measure of the value of NWLON, PORTS®, charts and the expertise of vessel pilots and bridge managers. Benefits from averted vessel movements include: (1) vessel capital cost; (2) administrative overhead; (3) main propulsion fuel use; (4) auxiliary fuel use; (5) societal costs from added environmental emissions; (6) added property damages from accidents; (7) augmented morbidity and mortality from increased exposure; (8) heightened property damages (e.g., vessel, cargo) for added

[125] This may occur in one of two ways. First, the vessel may be loaded at its point of origin to less than design capacity to ensure adequate underwater clearance. Alternatively, the vessel may be directed to a lightering location where "extra" cargo is transferred to another vessel to lessen the depth of the vessel. In either event, added costs for the movement would be increased. Both situations would result in the required use of additional vessels to transport the same amount of cargo. In turn this would result in added vessel capital costs, fuel use, and resultant societal emission costs.

allisions, collisions and groundings; and, (9) vessel handling fees.

### C. Licensed Pilots and Vessel Navigation in Pilotage Waters

Vessel pilots are expert mariners in their geographic area. They combine all available information with their extensive experience to guide vessels safely through the waters of their pilotage license. As part of obtaining their license they are required to memorize the nautical charts for their area of operation. The exam requires them to reproduce the cart accurately given only the shoreline. All other charted features are hand drawn from memory. They maintain this level of knowledge by studying the new chart editions and corrections from the Notices to Mariners. Their knowledge goes well beyond the cartographic aspects of the nautical chart. They synthesize all available data to provide the most knowledgeable shipping navigation in their pilotage waters. They know what the area looks like in daylight and at night, in good weather and bad. They understand the effect wind speed and direction has on water level and on local water currents. They know where the safe water is and pilot their ship to stay in the channels and avoid dangers to navigation. They do not traditionally track the vessels course through traditional navigation techniques but rather mentally track and direct the vessel relying on their image of the nautical chart and their knowledge of all aspects of the water and weather in their area.

While a licensed pilot provides expert assistance in the movements of vessels it is still the responsibility of the vessel master to ensure the safety of the vessel. It is prudent for the bridge watch to maintain a navigation backup using their ECDIS (Electronic Chart Display and Information System) using the most up-to-date Electronic Navigation Chart (ENC) and the ships GPS for accurate vessel positioning.

### D. Assignment of Benefits to Benefit Providers

While useful in providing warnings of areas with potentially shallow channel depths, CATZOC was not designed to make specific situational assessments if water column depths can safely support transit of more heavily loaded vessels. Instead, three instrumentalities work together to enable safe and efficient transit of vessels when their DUK is less than what is nominally required.

- **Nautical Charts** – The depth of the water column measured during a time of Mean Lower Low Water (MLLW) provided as a static measure.[126]
- **NWLON and PORTS®**– Managed by the National Ocean Service's Center for Operational Oceanographic Products and Services (CO-OPs) Office, the National Water Level Observation Network (NWLON) and Physical Oceanographic Real-Time System (PORTS®) provides real time information on water levels, winds, temperature, salinity, waves, etc. which affect static water column depths.
- **Pilots and Bridge Managers** – While NWLON, PORTS® and charts provide data, it is ultimately the vessel master that makes the final decision conforming to instructions from the shipping company by merging real time data with extensive local and situational experience to safely and efficiently direct the vessel's track.

Vessels are required to have and use up-to-date nautical charts and water level information for the areas to be transited, and to utilize the services of a licensed pilot with expert local knowledge. As a requirement for their licensing Pilots are required to memorize the nautical charts for their area of expertise and reproduce them accurately from memory during the pilot exam. All three of these sources of information are critical for the safe transit of the vessel. For the purposes of this analysis, the benefits to heavily laden vessels were apportioned

[126] Mean lower low water (MLLW) is the average height of the lowest tide recorded at a tide station each day during a 19-year recording period, known as the National Tidal Datum Epoch as used by NOAA.

accordingly: (1) Charts - 30% of total; (2) NWLON & PORTS® - 40% of total; and, (3) Pilots - 30% of total.

## VII. OPERATION, RESPONSIBILITIES AND UKC MANAGEMENT

The management of a safe under keel clearance for a vessel remains the responsibility of the vessel Master. Vessel groundings over the past years have resulted in loss of cargo and damage to vessel but more significantly has been the large losses that have resulted from the release of fuel oil or oil and chemical cargo. The value of cleanup and punitive damages levied by Federal, state and local authorities can be overwhelming to insurance and shipping companies. As a result, shipping companies often set minimum under keel clearance standards that they require their vessel masters to comply with.

Because of these large risks not only shipping companies but marine insurers and P & I Clubs, shipping trade associations, port authorities, Harbor Safety Committees, and even state governments have developed recommendations for safe under keel clearance standards.[127] Refer to Appendix G and H.

### A. Ship Passage Plan – Ship Master and Company Operations Manager

Prior to berthing to a port facility with the assistance of a port pilot the shipmaster is required by the shipping company to plan the ship's passage using the Company's written guidance and estimate the anticipated under keel clearance.[128]

INTERTANKO (the International Association of Independent Tanker Owners) has been

[127] A P&I Club (Protection and Indemnity) is a mutual insurance association that provides risk pooling, information and representation for its members.

[128] Draft Guidelines (for mariners) on determination (estimation) of vessel's safe under keel clearance, Helsinki Commission – Expert Working Group on Transit Routing, 13th Meeting, Helsinki, Finland, 7-8 October 2008 Agenda Item 2.

active in addressing the development of minimum under keel clearance. They state that ZOC (Zone of Confidence) depth uncertainty should be addressed during passage planning, taking into account the UKC policy of the Company and the ZOC data of the chart.

In determining the ship's UKC, the following variables need to be accounted for:

- Ship's static draft
- Squat based on the vessels' speed through water
- Wave and swell height
- Predicted tide
- Effect of wind speed and direction on water level
- Nature of bottom (e.g. rock, silt, sand waves, etc.)
- Reliability of ship's draft measurement
- Increase in draft from heel during turns
- Accuracy/reliability of chart depth data
- Company minimum under keel clearance requirement

The company mandated minimum under keel clearance was designed as a safety factor to account for anything not previously included. It was not intended to account for any of the above factors."[129]

INTERTANKO wrote referring to the use of CATZOC in transiting port channels,

> *"Tankers determine the maximum draft allowed for a vessel during transits of waterways in US ports, adding a margin of error to the draft for safety. In some cases, a safety margin of 25-30% may be added, ultimately resulting in dollars lost for the shipping and terminal operators, not to mention negating the expense and time involved in dredging a channel. The navigational tolerances are determined using guidelines that include the known quality of survey data in a particular waterway. The better the quality of the survey, the lower the*

[129] Guide to Safe Navigation (Including ECDIS), 1st Edition 2017, INTERTANKO.

> *risk associated with the ship transit, resulting in additional cargo loading per transit."*[130]

In port when navigating within a port or secured to a berth, it is recommended the UKC is never less than 2 feet (0.6m); unless under extenuating circumstances, when the Master, with concurrence from the shipping company, may allow for the reduced UKC provided considered safe. In case a UKC of 2 feet cannot be maintained circumstances do not apply; the Master must advise and consult with the Company to seek further guidance.[131] Note the INTERTANKO specified use of CATZOC (ZOC) in planning the voyage UKC in channel.

The Helsinki Commission addressed the need for the vessel master to determine the under keel clearance for the entire transit of the vessel.

> *"The master is responsible for estimating the minimum under keel clearance along the whole transit route of the vessel, including the port facility or anchorage. To assist the master with this requirement, the vessel's Company should provide the master with written under keel clearance guidance. Vessel draft, controlling depth of the port, and the impact of weather and other environmental conditions such as sea conditions and vessel traffic must be addressed in written guidance. If conditions which mandate when the Company must be contacted should be prescribed in writing and provide the master with direct authority to delay the transit to take any action necessary to ensure the vessel's safe navigation."*[132]

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[130] INTERTANKO newsletter, week of February 3, 2019

[131] Helsinki Commission – Expert Working Group on Transit Routing

[132] Ibid.

## B. Role of the Ship Master and Pilot

Vessel pilots are an important part of the vessel team. They are engaged and used as required by law to be employed anytime a vessel enters pilotage waters, moves through the port or departs the port. Pilots are engaged:

- For their expertise in navigating in close proximity to land in narrow channels.
- For their ability to anticipate accurately the effects of currents and tidal influences.
- For their understanding of local traffic.
- For their ability to work effectively with the local VTS.
- For their language ability when dealing with shore services.
- For their expertise in handling tugs and linesmen.
- To support Master and relieve fatigue.
- To provide an extra person or persons on the bridge to assist with navigating the ship.

Overall, a Pilot onboard improves both the safety and efficiency of operation.

In U.S. ports the ship's master retains control and responsibility for the navigation of the ship at all times. Pilots when employed advise the Master on the movement of the ship in a pilotage area. While the Master may allow the pilot to direct bridge crew in course and speed the Master retains responsibility and is required to countermand the orders of the pilot if the Master considers them unsafe. If, in the master's opinion, the situation developing is obviously dangerous, it is his duty to draw the pilot's attention to the risk and, if necessary in his judgment, take over the conduct of the vessel.[133] The shipmaster and the relevant pilot shall discuss and agree the transit plan including the anticipated under keel clearance.

## C. Considerations in Deviating From Company Mandated Minimum UKC

While all ship masters try to comply with the standard for under keel clearance defined

[133] https://cultofsea.com/navigation/master-pilot-exchange-duties-responsibilities-and-elements-of-effective-relationship/

by their company and the relevant port authorities there can be occasions when it is worth considering whether these standards could be relaxed for a specific instance. If the vessel is slightly overloaded and either the cost of lightering or the delay caused by lightering would result in a ship missing its docking schedule it is occasionally worth considering the option of operating with a lesser under keel clearance minimum. Information that could indicate a passage should be safe even at a reduced minimum under keel clearance would include:

- The availability of higher than expected real-time water level information either from a NOAA PORTS (physical oceanographic real-time system), a NOAA hydrodynamic model, or even NOAA real-time water level information from the National Water Level Observation Network (NWLON) stations in the port.
- The accuracy of the nautical chart especially the sounding data is of such quality that water shallower than what is charted would not be expected.
- The Harbor pilot believes that in their expert opinion considering all information that a safe passage can be expected.

It is recognized that there are cases where operating with a lesser under keel clearance is justified. These cases require the vessel master to discuss the matter with the vessel pilot and with the concurrence of the vessel company such a passage may be undertaken. The vessel master retains responsibility for the consequences of any such action.

## VIII. ADDED VESSEL UTILIZATION

While improvements in CATZOC port ratings provide theoretical benefits from enhanced port performance without the need for added investments for deepening of channels, reliance on existing ENC reported water depth provides a number of benefits from the ability to more heavily load vessels. An existing benefit of nautical charts results from the ability of vessels to more efficiently and safety travel into and from ports. These result from the ability to load existing vessels to a greater extent or negate the need to lighter existing vessels which reduces the total number of vessel transits required to transport the same amount of cargo.

While individual ports have established recommended UKC high levels of nautical chart accuracy coupled with knowledge of near real-time water levels can facilitate the movement of vessels with lower than recommended UKCs. To estimate these benefits, the cost of vessel operations was developed through a bottom-up approach were components are individually estimated later summed. Components of vessel costs were individually developed.

### A. Vessel Immersion

In order to assess the value of additional cargo that might be transported by vessels it is necessary to assess its displacement in light of its water plane or "footprint" in water. Displacement is a function of the water plane of the vessel where:[134]

A = area
L = length
B = Width or Beam
F = Fineness of the water plane ($C_b$ coefficient)[135]

W = Volume in cubic feet of one ton of sea water (35)
I = Inches per foot (12)

**Tons Per Inch of Immersion (TPII) A = (L * B * F) / (W * I)**

Hypothetical example: Coastal oil tanker vessel

Length = 674 feet
Beam = 104.4 feet
Fineness ($C_b$) = 0.8 (Typical $C_b$ coefficients are listed in Table 8.)

A = (674*104.4*0.8) = 56,292

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[134] Sources: Hughes, Charles H., 1917, *Handbook of Ship Calculations Construction and Operation*, D. Appleton and Company, New York, Pages 170 – 178; Gillmer, Thomas C. and Bruce Johnson, 1982, *Introduction to Naval Architecture*, United States Naval Institute, Annapolis, MD, Page 55.

[135] Fineness has been defined as the ratio of the area of the immersed midship section to the area of its circumscribing rectangle or the ratio of the immersed volume of a vessel to the product of its immersed draft, length and beam. In essence this measures the degree to which a ship's profile differs from a pure rectangle.

TPII = A / (W * I)
TPII = 56,292 / (35 * 12) = 134.1

**Table 8**

**Typical $C_b$ values at fully loaded drafts**

| Ship Type | Typical $C_b$ Fully Loaded | Ship Type | Typical $C_b$ Fully Loaded |
|---|---|---|---|
| ULCC | 0.850 | General cargo ship | 0.700 |
| Supertanker | 0.825 | Passenger liner | 0.575–0.625 |
| Oil tanker | 0.800 | Container ship | 0.575 |
| Bulk carrier | 0.775–0.825 | Coastal tug | 0.500 |

Medium-form ships ($C_b$ approx. 0.700), full-form ships ($C_b > 0.700$), fine-form ships ($C_b < 0.700$).

Based on the USACE's National Navigation Operation and Maintenance Performance Evaluation and Assessment System (NNOMPEAS), a series of steps was undertaken to estimate added vessel operating costs.

**Table 9**

**ESTIMATED TONS CARRIED PER INCH OF VESSEL DISPLACEMENT**

| STUDY AREA | VESSEL TYPE | LENGTH / BEAM (FEET) | VESSEL DWT (METRIC TONS)[136] | METRIC TONS PER INCH OF DISPLACEMENT |
|---|---|---|---|---|
| Great Lakes | Dry Bulk | 759.6 / 105.8 | 70,908 | 153.1 |
| Coastal | Dry Bulk | 814.3 / 132.2 | 98,647 | 205.0 |
| Coastal | Tanker | 808.3 / 137.6 | 108,360 | 211.9 |
| Coastal | Container | 1,182.8 / 158.0 | 120,974[137] | 255.9 |

[136] Source: USACE, NNOMPEAS database

[137] Handling an estimated 12,500 TEUs.

Employing vessel dimensions from the USACE's NNOMPEAS database in conjunction with estimated fineness ($C_b$) numbers[138], tons per inch of immersion were calculated based on the average vessel sizes reported by the Maritime Administration. (Tables 8 and 9) While shippers would probably want to utilize the largest ships available under UKC constraints to take advantage of economies of size, it is unlikely that there would be sufficient supply in the short-run. This would result in use of even smaller ships with larger operating costs per ton-mile. Although the Great Lakes are fresh water and consequently less dense, the linear formula for TPII would tend to slightly overstate the capacity of vessels and hence understate the number of added vessels required to ensure vessel clearance.

An additional adjustment was made to account for the portion of DWT attributable to cargo as it is a measure of how much a vessel can carry including the weights of cargo, fuel, fresh water, ballast water, provisions, passengers, crew and stores. As vessel size becomes larger a smaller proportion is represented by non-cargo weight (e.g., stores, fresh water, fuel, crew, etc.) Adjustments were made to each vessel groups average carrying capacity to reflect the portion of DWT attributed to cargo alone.

**B. Squat**

Squat is the hydrodynamic phenomenon by which a vessel moving through shallow water creates an area of reduced pressure that causes the ship to increase its draft and thereby be closer to the seabed than would otherwise be expected. It is impacted by the fineness of the vessel's hull and the speed of the vessel. It is calculated by the fineness coefficient times the speed of the vessel squared divided by 100. This was added to reported vessel drafts to estimate total vessel

[138] Source: https://cultofsea.com/ship-stability/coefficients-of-form-ships-waterplane-block-midship-and-prismatic-coefficient/

draft. Not knowing the precise speed of the vessel in channels, average trip speeds were utilized.[139]

### C. Travel Distances

In keeping with the conservative approach of this study average length of haul was estimated to be 850 Nautical Miles[140] on the Great Lakes.[141] Distances for coastal movements were estimated to be 1,500 nautical miles for dry bulk and tank vessels and 6,000 nautical miles for container movements.[142]

## IX. DEVELOPMENT OF VESSEL COSTS

Costs resulting from operation of additional vessels are estimated from the addition of major vessel cost categories calculated on a per vessel trip basis based summation of vessel and port costs. These categories included: (1) hourly vessel capital cost; (2) hourly administrative overhead; (3) hourly main propulsion fuel use; (4) hourly auxiliary fuel use, and (5) hourly societal costs from added main propulsion and auxiliary environmental emissions. Per trip costs from (1) added property damages from accidents; (2) augmented morbidity and mortality from

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[139] As the vessel approached the dock, vessel speeds would undoubtedly decline and hence reductions in DUK due to squat.

[140] 850 miles was selected as a conservative estimate given dominate traffic flows. National distance examples include; Chicago to Detroit (633 miles); Milwaukee, WI and Erie, PA (759 miles); Buffalo to Milwaukee (828 miles); Duluth to Ashtabula (876 miles), Duluth, MN to Ogdensburg, NY (1,218 miles) Source: U.S. Department of Commerce, NOAA, NOS. 2019 “Distances Between United States Ports”, 13th Edition, Page 34.

[141] Iron ore is the dominate commodity carried representing 47 percent of total traffic. Coal represents 21 percent of traffic while limestone accounts for 21 percent. Salt and cement account for 8 and 2 percent, respectively. In 2012 a total of 132.0 million short tons were transported. Source: Figures extracted from Lake carriers Association 2012 Statistical Annual Report, U.S.-Flag Share of Major Commodities: 1993–2012, 2012. U.S. Flag carries handled 71 percent of total lake traffic in 2012.

[142] 6,000 miles was selected as a conservative estimate given dominate traffic flows. International distance examples include: Hong Kong China to Long Beach – 6,323 nautical miles; Rotterdam to New York – 3,161 nautical miles; Singapore to New York (8,284 nautical miles); Singapore to Tacoma, U.S. (7,013 nautical miles and San Francisco to Melbourne (6,837 nautical miles).

increased vessel trips; and, (3) vessel port handling fees were added to total hourly costs to form total per trip cost estimates. Employing operational demographics from vessels typically operating on the Great Lakes and coastal regions obtained from the USACE's National Navigation Operation and Maintenance Performance Evaluation and Assessment System (NNOMPEAS) cost and emission volumes were estimated.

Inventory carrying costs (ICC), the total of all expenses related to storing unsold goods including intangibles such as depreciation and lost opportunity costs were not included in this analysis. As ICC may have been initially reduced due to lighter vessel loadings maintain UKC levels, ultimate carriage of this traffic on added vessel trips would offset any savings. In essence, in this analysis approach, ICC is cost neutral.[143]

**A. Fuel Cost**

Bialystocki et al. (2016) related that fuel on vessels (referred to as "bunkers") accounts for almost 50 percent of voyage cost.[144] Wijnolst et al. (2009) reported with energy representing a significant portion of deep-sea vessel operating costs interest in designing more fuel efficient vessels is linearly related to fuel prices.

**1. Changes in vessel emission regulations**

Noted by GardAS in 2009[145] various international regulations and Emission Control Areas (ECA) have been in force since 2005 to mitigate vessel emissions.[146] New and stricter

[143] This assumes equal transit times, cargo values and interest rates between the original and added vessel movements.

[144] Also refer to M. Stopford, *Maritime Economics*, Third Edition, 2009.

[145] Refer to: http://www.gard.no/ikbViewer/Content/134078/No%2015-09%20Low%20sulphur%20fuel%20changeover.pdf

[146] Under MARPOL Annex VI, Regulations for the Prevention of Air Pollution from Ships, countries can apply to set up Emission Control Areas (ECA). More information about ECA areas is available at:

fuel sulphur content regulations promulgated by the European Union (EU) and California were earlier implemented.[147] The Californian Air Resource Board (CARB) has since July 1, 2009 enforced the use of marine diesel oils (MDO) or marine gasoils (MGO)[148] in Californian waters.[149] Reported by the Energy, Finance and Future Weekly, heavy fuel oil (HFO), also referred as "Bunker C" while relatively inexpensive and used extensively, was responsible for 15 percent of global sulphur dioxide ($SO_2$) emissions.[150] They reported:

> *"The International Maritime Organization (IMO), the governing body of international shipping, decided to diversify the industry away from HFO into cleaner fuels with fewer side effects on the environment and human health. Effective in 2015, ships operated within the Emission Control Areas (ECAs)covering the Economic Exclusive Zone of North America, Baltic Sea, North Sea, and English Channel will begin to use Marine Gas Oil (MGO) with the sulphur level up to 1,000 ppm. Starting from 2020, ships sailing outside ECAs will switch to Marine Diesel Oil (MDO) with the sulphur level up to 5,000 ppm.[151]"*

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http://i.pmcdn.net/p/ss/library/docs/subscriber/ECAs_2009.pdf.

147 CARB, "Marine Notice 2009-2, Regulations on Fuel Sulphur and other Operational Requirements for Ocean-Going Vessels within California Waters and 24 NM of the California Baseline", 7 May 2009; EU Directive 2005/33/EC, "Amendment of the EU Low Sulphur Directive"

148 Marine gasoil describes marine fuels that consist exclusively of distillates. Similar to diesel fuel MGO has a higher density. It does not have to be heated during storage as does Heavy Fuel Oil (HFO).

149 The following regulations are in force when operating within the 24 nautical mile regulatory zone off the California Coastline: From 1 July 2009, Marine gas oil (MGO) at or below 1.5% Sulphur content, or Marine diesel oil (MDO) at or below 0.5% Sulphur content. From 1 January 2012, Marine gas oil (MGO) or Marine diesel oil (MDO) at or below 0.1% Sulphur content.

150 Source: https://lookbackatchina.wordpress.com/2014/07/09/the-end-of-the-era-of-heavy-fuel-oil-in-maritime-shipping/; July 9, 2014 by Haifeng; downloaded May 14, 2015.

151 Implementation of this last requirement was subject to a review of fuel availability to be completed by 2016.

**Table 10**

## MARINE FUELS

| FUEL TYPE | DESCRIPTION | SULPHUR CONTENT |
|---|---|---|
| VLSFO | IMO 2020 grade bunkers | Maximum 0.5% sulphur |
| LSMGO | Compliant with 2015 Emission Control Areas (ECA) regulations[152] | Maximum 0.1% sulphur |
| HFO | Heavy Fuel Oil[153] | Cap of 3.5% Sulphur<br>Most common 2.5% sulphur[154] |
| MGO | Marine Gasoil | Maximum 1.5% sulphur |
| LS-MGO | Low Sulphur Marine Gasoil | Maximum 0.1% sulphur |

Paris (2019) later opined that 13 percent of world-wide sulphur-dioxide emissions came from shipping. Due to the level of pollutants. especially $SO_x$ and related emissions, The International Maritime Organization (IMO) issued new ship emission regulations (IMO 2020) that requires vessels use lower-sulphur bunkering fuel effective January 1, 2020.[155] Under the IMO 2020 standard, in addition to the 0.5 percent Very Low Sulphur Fuel Oil (VLSFO), shippers can employ Low Sulphur Marine Gas Oil (LSMGO) with a sulphur content of 0.1

[152] Emission Control Areas (ECAs) also referred to as Sulphur Emission Control Areas (SECAs), are areas of the sea where stricter controls were established to minimize airborne emissions from ships as defined by Annex VI of the 1997 Maritime Pollution (MARPOL) Protocol. Regulations on these emissions (SOx; NOx; Ozone Depletion (ODs); and, (4) Volatile Organic Compounds (VOCs) began in May 2005. Beginning in July 2010, a more stringent version of Annex VI was enforced in the ECAs with significantly lowered emission limits. As of 2011 there were four existing ECAs: the Baltic Sea, the North Sea, the North American ECA, including most of U.S. and Canadian coast[5] and the U.S. Caribbean ECA.

[153] Source: U.S. Energy Information Administration (August 2019, 2020)

[154] https://www.exxonmobil.com/en/marine/technicalresource/news-resources/imo-sulphur-cap-and-mgo-hfo#:~:text=The%20current%20global%20sulphur%20cap,today%20%2D%20is%20around%202.7%25.

[155] Emission control areas include: (1) The Baltic Sea Area; (2) the North Sea Area; (3) the United States; (4) Canada; and the United States Caribbean Sea area.

percent to replace the currently used High Sulphur Fuel Oil (HSFO) that contains up to 3.5 percent sulphur content.[156] (Table 10) Also impacting the decision of what fuel to burn is the question of the "open" versus "closed" loop scrubbers. An open loop scrubber utilizes sea water to lower the sulphur content of the exhaust gases to an equivalent of 0.1 percent. The seawater can then be discharged in open sea in compliance with IMO 2020 regulations. Several countries have already banned open-loop systems and discharge wash water in their port and emission control areas (e.g., Singapore, China, etc.)[157] In closed systems, the wash water is held in holding tanks and off loaded at appropriate facilities.[158]

Before the Covid-19 pandemic, experts were in general agreement that 2020 would see the greatest impact on prices as the oil industry ramps up production to meet demand. However, since the pandemic, reduced demand for transportation has depressed world energy prices.

**2. Emissions impact**

Paris (2019) reported that the new fuel guidelines are estimated to impact at least 60,000 vessels. At the time of this statement, industry executives estimated that they would have to pay

[156] The term HVO (Heavy Viscosity Oil) often used interchangeably with HFO (Heavy Fuel Oil). This is as opposed to IFO (Intermediate Fuel Oil) and the more refined distillates of MDO (Marine Diesel Oil) and MGO (Marine Gas Oil). HVO or HFO is what is often referred to as residual oil, bunker C oil or bunker number 6 (and sometimes bunker number 5) fuel oils. IFO is usually a blending of HVO and MDO (traditionally about 10 percent give or take though not sure if this specification has changed as IFO is not as commonly used anymore for shipping). The ranges in viscosity for these four basic classes of fuel are based on ranges for centistoke-equivalent with the heaviest fuels approaching or exceeding 380 Ct. and with IFO being in the range of between 180 Ct. and 380 Ct. with the vast majority being closer to 180 Ct.. Most of these fuels now have low sulfur designations or variants as well and usually will employ the "LS" to indicate as such in respective labeling (i.e., LSHVO, LSHFO, LS+380, LS-C, etc.).

[157] As of May 28, 2020, California and Massachusetts have banned open-loop scrubber discharge. Source: https://www.shipandoffshore.net/fileadmin/pdf_Fachartikel/Sulphurcapspo119.pdf

[158] A third type of wet scrubber (hybrid) makes use of sea water or a combination of sea water and fresh water running operations. Dry scrubbers make use of lime granulates in place of water.

a 25 to 40 percent premium on fuel. With fuel then costing about $440 per metric ton, this would place future costs between $550 and $616 per metric ton. Their estimates appear high as of July 2020 prices of low-sulphur fuels was about $317 to $369 per metric ton.

The International Shipping News (2019) estimated that up to six percent of the global vessel fleet will employ scrubbers by the end of 2020.[159] One year before implementation of the new fuel standard Gelder (2019) reported that vessel owners are now heavily investing in scrubbers. They stated that there were over 2,000 scrubbers on order mostly designed for long-distance vessels. Given the global shipping fleet exceeds 90,000 vessels, this seems as a slow start. Later, Blackmon (2020) reported that the majority of shippers had chosen to use lower-sulphur fuel. Ewing-Chow (2019) reported that the Caribbean Shipping Association predicted the new IMO fuel standard will increase operating costs by three percent and that 80 percent of vessel owners will switch to the lower sulphur, more costly fuel what the remaining 20 percent are expected to retrofit their vessels with scrubbers. Macleod (2019) stated that scrubbers cost his firm between two and four million dollars per vessel with an expected payback of between none to 18 months.[160]

Drewry (2019) has urged containership owners planning to scrap older vessels this year to "get a move on".[161] They noted that the number of vessels scrapped last year fell to an eight-year low, adding to the overcapacity issues blighting the liner industry and the maritime

[159] Shipyards were reported an inability to keep up with the demand for retrofitting ships with scrubbers. https://www.universalcargo.com/world-fleet-does-not-seem-ready-for-imo-2020/

[160] Robert Macleod, CEO, Frontline Management A/S, a Norway-based tanker firm in The Wall Street Journal's *"Maritime Emissions Rule Triggers Split in Shipping Costs*", December 20, 2019. Story by Costas Paris.

[161] Refer to: https://gcaptain.com/drewry-containership-scrapping-rebalance/; May 19, 2019

consultant said: *"It would certainly help the supply-demand balance if more at the top end of the age range were to be demolished."* It was reported that 85% of the current global cellular fleet is less than 15 years old and only five percent are over 20. Drewry anticipated that the 2020 IMO low-sulphur regulations would accelerate the scrapping of the older, so-called 'dirty', containerships, given the quest for fuel-efficient or scrubber-fitted tonnage.

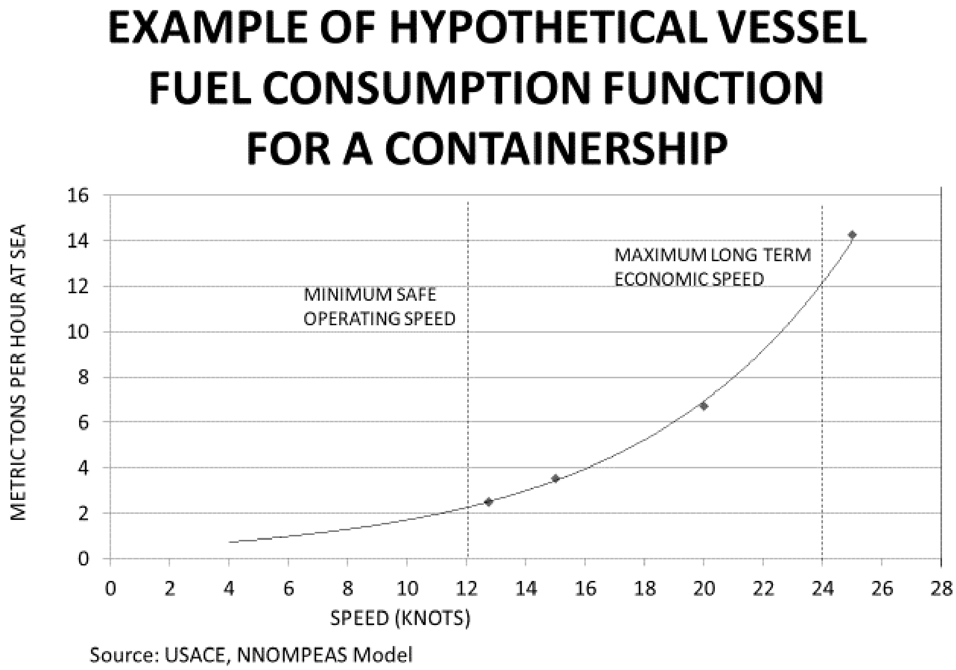
Last year carriers such as the Mediterranean Shipping Company (MSC), Evergreen and Hyundai Merchant Marine (HMM), agreed to add extra hire charges for long-term charters of scrubber-fitted ships that could see them enjoy cost savings over competitors unable to bunker with cheaper heavy fuel oil (HFO). However, it would probably be uneconomic for older containerships to consider installing scrubber systems, given the estimated five million dollars per unit being quoted.

In this study, a three year average of fuel costs (2017 – 2019) used by the USACE in their analyses were employed to represent a more accurate assessment of long-term fuel cost. MGO average costs were $648 per tonne while HFO costs were $351 per tonne. Main bunkerage costs were based on a weighted average of two- thirds HFO and one-third (MGO) was employed ($449 per tonne). Auxiliary power configurations were assumed to use a mix of HFO and MGO fuel ($500 per tonne).

**B. Vessel Fuel Costs**

Traditionally, fuel usage use has represented a dominant portion of total vessel operational costs. Fuel utilization for main propulsion is highly variable and a function of transit speed while fuel employed to run auxiliary systems (i.e., electrical power) are uniform with little if any changes over the speed and draft range of the vessel.

**Figure 2**




In the case of main propulsion, fuel use estimates were based on approximately 400 combinations of vessel speed and displacement depth for each vessel size and type. From these numerous point estimates, continuous fuel cost functions were developed for operations at sea for each vessel type and size combination. Coefficients of determination ($R^2$) developed for all fuel use estimations exceeded 0.99. A hypothetical example is provided as Figure 2.[162] Employing "x" as the speed of the vessel a "small" containership with a design displacement of 50,400 DWT moving at 14 knots would consume 1,692 kilograms per hour/ (1.7 metric tonnes).

[162] While propulsion engines use fuel at exponential rates based on vessel speed, auxiliary engines which are used to provide electrical power for non-propulsion systems such as air conditioning, are independent of vessel speed and highly linear. Often there will be two or three auxiliary engines on a diesel-mechanical vessel and four to six on a diesel electric vessel and can represent up to 15 percent of total vessel fuel consumption. Refer to: Global Maritime Energy Efficient partnerships. https://glomeep.imo.org/technology/improved-auxiliary-engine-load/

**Table 11**

**VESSEL FUEL USE ASSUMPTIONS**

| LOCATION / VESSEL TYPE | VESSEL SPEED (Knots) | VESSEL SIZE[163] (Metric Tons) | FUEL USE – MAIN PROPULSION (Metric Tons / Hour) | FUEL USE - AUXILIARY (Metric Tons / Hour) |
|---|---|---|---|---|
| Great Lakes / Dry Bulk | 12 | 70,908 | 0.651 | 0.154 |
| Coast / Dry Bulk | 11 | 98,647 | 0.763 | 0.159 |
| Coast / Tank | 12 | 108,360 | 0.988 | 0.171 |
| Coast / Container | 15 | 120,974[164] | 2.481 | 1.360 |

In this analysis fuel use for both main propulsion and auxiliary power were estimated based on kilograms of fuel used at a constant speed for one hour. Vessel speed and size assumptions are listed in Table 11.

## C. Societal Cost of Emissions

As emissions are a reflection of fuel utilization, they are calculated in a method similar to the methods employed to estimate fuel use. For each of the 400 or so point estimates for fuel use based on vessel type, speed and depth, resultant levels of emissions were calculated. From these point estimates, continuous functions were developed.[165] The vast majority of these equations were exponential with the remainder polynomial in nature. Coefficients of determination ($R^2$) developed for emission estimations equaled or exceeded 0.90. Based on estimated tonnage

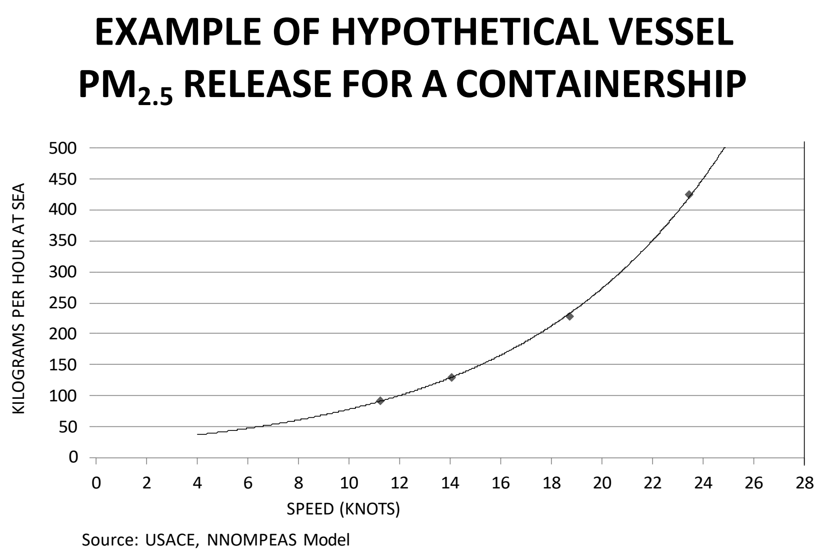
[163] Nearest vessel size (in DWT) reported in NNOMPEAS based on averages listed by the Maritime Administration for 2015 transits (latest available).

[164] With a capacity of 12,500 TEUs

[165] It should also be noted that NNOMPEAS model emission estimation volumes have been reviewed by the Environmental Protection Agency (EPA).

released societal costs were estimated based on costs per tonne provided by several sources (e.g., Shindell (2015), Muller et al. 2006, 2007, 2011) (Figure 3)

**Figure 3**




There have been a large number of models and estimations of monetary and societal impact of pollutants. They often take one of two general formats. The first involves measurement of damages that result from pollutants. Wang (1994) explains that requires: (1) identification of emission sources; (2) emission amounts; (3) simulations of air pollutant concentrations; (4) exposure by humans and objects to air pollution; (5) identification of air pollution effects on humans and objects; and, (6) economic valuation of air pollution effects. While a sound analytical approach it often requires many assumptions and simplifications. Table 12 compares estimated damages across several pollutants.

The second involves estimation of control costs. Wang (1994) explains:

> *"The control cost estimating method is based on the presumption that emission standards or air quality standards are established at the ideal level - where the marginal damage of air pollution is equal to the marginal control cost. In this approach, it is assumed that the cost required to meet predetermined air quality standards imposed by legislators "reveals" the value society places on the emissions being controlled (the method is sometimes called the "revealed preference method"). Therefore, the estimated marginal control cost to meet air quality standards represents the marginal damage value of air pollution when air quality standards are met." Wang p. 20*

> *"Calculation of control costs in dollars per ton of emissions controlled requires information on the cost and emission reduction of the control measure over its lifetime. Cost estimation must include initial capital cost, operation and maintenance costs, and other pollutant-specific cost components. Estimates of emission reductions need to account for emission control deterioration over the lifetime of the equipment. If a control measure reduces emissions of more than one pollutant, the cost of the technology needs to be allocated among the reduced pollutants to obtain a dollars-per-ton cost for each pollutant. Obtaining the detailed information necessary for control cost estimates can be resource intensive. Assumptions often have to be made for certain components." Wang pp. 21-22*

> *"However, we do not take the position that emission damage values are accurately represented by the estimated emission control costs. In many cases, emission damage values can differ significantly from control costs. Thus, control costs cannot represent damage values" (Wang p. 3)*

The Interagency Working Group on Social Cost of Carbon (2010) determined the cost of $CO_2$ was $65 per ton in 2007. This equates to about $75 per ton in $2017.[166] Muller et al. (2006, 2011) reported results from the Air Pollution Emissions Experiments and Policy Analysis

[166] Page 33.

(APEEP) model. They reported the cost per ton of particulate matter ($PM_{2.5}$) was over $52,000 ($2017) in San Francisco.[167] It is designed to estimate the marginal epidemiological, value of human health effects and concentration damages of emissions in almost 10,000 districts in the contiguous U.S. Environ (2007) estimated the cost to control highly reactive volatile organic compounds (HRVOC) at between $14,774 and $17,778 per ton ($17,096 and $22,146 per ton $2017).

**Table 12**

## EXAMPLES OF SOCIETAL EMISSION DAMAGE ESTIMATES

| SELECTED EMISSIONS (EMISSION ABBREVIATION) | DAMAGES PER METRIC TON ADJUSTED TO ($2017 DOLLARS)[168] | GLOBAL MEAN SURFACE TEMPERATURE IMPACT[169] | PATHWAY TO COMPOSITION – HEALTH IMPACTS |
|---|---|---|---|
| Carbon Monoxide (CO) | $731 | Warming | Surface Ozone |
| Carbon Dioxide ($CO_2$) | $97 | Warming | None |
| Nitrogen Oxide ($NO_x$)[170] | $77,700 | Cooling | Surface $PM_{2.5}$ and ozone |
| Sulphur Dioxide ($SO_2$) | $48,707 | Cooling | Surface $PM_{2.5}$ |
| Methane ($CH_4$) | $5,335 | Warming | Surface Ozone |
| Ammonia ($NH_3$) | $28,992 | Cooling | Surface $PM_{2.5}$ |
| Black Carbon (BC) | $313,118 | Warming | Surface $PM_{2.5}$ |

Source: Shindell, Table 1 and Table 2

[167] Particulate matter inhaled emissions are deposited throughout the human airways. The smaller the particle, the more likely it is to travel farther into the lung. Such particles can induce tissue damage and lung inflammation such as acute or chronic bronchitis, asthma attacks, etc.

[168] Refer to: Shindell (2015) Table 2, Median Total (3% discount rate), page 319.

[169] From Shindell. (2015) Table 1 “The global mean surface temperature impact is also a proxy for the many additional climate impacts that occur alongside global mean temperature change, including changes in sea-level, rainfall, heatwaves, etc.” page 315.

[170] Ibid, Table 1

Marten et al. (2015) estimated the 2007 cost per ton of carbon monoxide, methane, and nitrogen oxides ranged from $12 to $123, $540 to $3,200 and $4,700 to $39,000. These equate to $14 to $142, $625 to $3,703 and $5,439 to $45,129, respectively in $2017. Shindell (2015) estimated monetary damages across a number of pollutants. (Table 12)

**D. Vessel Capital and Administrative Cost**

Annual capital costs were developed by the USACE based on vessel DWT weight. First, annual vessel 2019 replacement less scrap costs for each vessel group were calculated based on the assumptions that the vessel was foreign flag (flag of convenience)[171], employed the use of high sulfur Heavy Viscosity Oil (HVO) fuel with scrubbers and had a 25-year economic life.[172] It was additionally assumed that 12 days of downtime due to annual maintenance would be allotted for establishing the length of an operational year for vessels. Hourly vessel operating costs from insurance, maintenance, depreciation, stores, crew wages, insurance, etc. for each vessel type were also developed.[173]

**E. Safety**

With additional vessel transits to transport materials, additional accidents can be expected.

[171] The Institute of Shipping Economics and Logistics (2010) estimated that 86 percent of tonnage attributed to North American shipping companies was operated by foreign flag carriers. This number has undoubtedly increased as the DOT reported in 2010 the U.S. fleet represented 0.7 percent of the oceangoing self-propelled cargo carrying vessels of 1,000 or more tons declined to 0.4 percent in 2019. In addition, a 14.1 percent decline in the total DWT capacity of U.S. vessels occurred (4,584 to 3,939 thousand) tons during the 2010 to 2019 period.

[172] Costs were based on a five year average (2016-2020) with an average year of build was considered to be 2018. These costs include closed loop and hybrid scrubbers based on costs to retrofit existing vessels and cost of inclusion at the time of new construction.

[173] As capital costs for TEUs are already taken into account, their transfer to another vessel does not result in additional TEU costs.

### 1. Property damages

The United States Coast Guard (USCG's) Marine Casualty and Pollution Database contains data related to commercial marine casualty investigations reportable under 46 C.F.R. 4.03 and pollution investigations reportable under 33 C.F.R. 153.203.[174] An incident must be filed if: (1) a person dies; (2) a person disappears from the vessel under circumstances that indicate death or injury; (3) a person is injured and requires medical treatment beyond first aid; (4) damage to vessels and other property totals $2,000[175] or more; and, or (5) the vessel is destroyed.

While data is available for 2003 and 2004 the number of reported ACGs incidents are significantly lower than the long-term average of over 1,424 events per year during the latter 2005 to 2017 period.[176] During the earlier period of time in reporting it appears that, "no consequence" incidents including "touch and go" groundings and "bump and go" allisions that did not result in any damages were not uniformly reported.[177] A comparison of 2005-2017 ACG reports with earlier 2003-2004 ACG reports showed reported events doubling in later years. Consequently, examination of ACGs was based on more complete and representative data from 2005 to 2017.

With each vessel trip, there is a possibility of an accident where loss of life, injury and

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[174] Any person in charge of a vessel or of an onshore or offshore facility shall, as soon as they have knowledge of any discharge of oil or a hazardous substance from such vessel or facility in violation of section 311(b)(3) of the Act, immediately notify the Commandant (CG-MER-3).

[175] Losses include the vessel itself, its cargo, damage to facilities (e.g., docks) and other.

[176] In 2003 and 2004 an average of 724 ACG events reported each year. During the 2005 to 2017 period, an annual average of 1,424 ACG events were reported.

[177] The U.S. Coast Guard transitioned from the Marine Safety Information System (MSIS) to the Marine Information for Safety and Law Enforcement (MISLE) information system in December 2001.

property damages may result. Three types of commercial shipping accidents occurring between 2005 and 2017 were employed in this analysis.[178] Allisions, Collisions, and Groundings (ACG) were defined as:

- Collisions – the striking of a (moving) vessel upon another (moving) vessel;
- Allisions[179] – the striking of a moving vessel with a stationary object (another vessel, bridge, dock, obstructions, etc.); and,
- Groundings – the impact of a vessel on the seabed or waterway side (within or outside of the channel).[180]

**Table 13**

## COSTS FROM VESSEL ACCIDENTS

| ACCIDENT TYPE | EVENT RATE PER VESSEL TRIP | COST PER INCIDENT ($2017) | EXPECTED COST PER VESSEL TRIP |
|---|---|---|---|
| Allisions | 0.00463% | $215,694 | $9.99 |
| Collisions | 0.00148% | $237,689 | $3.52 |
| Groundings | 0.00314% | $54,383 | $1.71 |
| All Accidents | 0.00925% | $154,417 | $14.28 |

Wolfe et al. (2020) reported marine accidents are relatively rare events. Expected property losses from vessel, cargo, facility and other property exceeded $14 per vessel transit. (Table 13)

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[178] This included all reported coastal accidents where nautical charts had been released. Anecdotal evidence from earlier 2003 to 2004 suggests that, “no consequence” incidents including "touch and go" groundings and "bump and go" allisions that did not result in any damages were not uniformly reported. Beginning in 2005 this changed as witnessed by the 80 percent (2003 to 2004) and 30 percent (2004 to 2005) increases in reported year-to-year increases in total ACGs. Source: USCG MISLE data.

[179] The movement of objects involved in accidents is a critical decision factor is assignment of the type of accident. For example, if a bridge were stuck while in motion (e.g., a drawbridge in the process of opening for vessel passage). the accident would be classified as a collision rather than an allision.

[180] Includes instances reported as “aground” in addition to “grounding”.

### 2. Morbidity and mortality

With an increased number of accidents from additional vessel movements, the incidence of both mortality and morbidity increase. Like property damages, death and injury losses are relatively rare but highly costly. In this analysis, 2017 costs employed by Wolfe et. al (2020) were employed. (Table 14). Overall, the average cost of deaths and injuries per vessel movement approached $3,400.

**Table 14**

**MORBIDITY AND MORTALITY COSTS FROM VESSEL ACCIDENTS**

| TYPE OF ACCIDENT | EVENT RATE PER VESSEL TRIP | COST PER INCIDENT ($2017) | EXPECTED COST PER VESSEL TRIP |
|---|---|---|---|
| Mortality | 0.00021% | $9,800,000 | $2,058 |
| Morbidity | 0.00169% | $789,233 | $1,334 |
| Total | | | **$3,392** |

### F. Port Costs

Commensurate with an increase in the number of vessels transits are port costs associated with port calls. Reported by Wolfe et al. (2016) a survey of the ports of Norfolk, Miami, New Orleans, Houston, Long Beach, and Seattle was conducted September 13, 2013 the USACE to determine typical port costs that a vessel would expect to incur when calling on a port to load or unload cargo. Most of the ports were unwilling to supply values for all the types of costs claiming that it was proprietary information. However enough information was obtained to enable the researchers to develop a composite set of port costs for a typical coastal port and make an educated estimate of the port costs for a Great Lakes port. Where multiple responses were received for a cost category an average was used for the composite typical coastal port. It is believed that these costs are typically low especially for the pilotage fees. All costs were update to $2017.

**Table 15**

**ADDITIONAL MARINE TRANSPORTATION COSTS OWING TO ADDED VESSEL TRANSITS**

| COST CATEGORY (Per Trip) | COASTAL PORT ASSUMPTIONS | COSTS[181] ($2017) | GREAT LAKES PORT ASSUMPTIONS | COSTS[182] ($2017) |
|---|---|---|---|---|
| Tug Fees | 2 tugs, 2 hours each | $6,105 | 2 tugs, 1 hour each | $2,200 |
| Pilotage Fees | Average 2 hour trip | $2,613 | Average 2 hour trip | $0[183]<br>$2,613 if not |
| Stevedore Line Handling Dees | Average of survey data | $614 | Average of survey data | $614 |
| TOTAL Round Trip (arrival and departure) | | $18,663 | | $5,628 |
| Dockage Fee | 800' vessel<br>2 day stay at dock | $10,715 | Estimate based on Houston which was the smallest encountered in this survey. Fees in Great Lakes are typically small | $1,900 |
| Fresh Water | Average of survey data | $101 | Average of survey data | $101 |
| Administrative | Average of survey data | $427 | Average of survey data | $427 |
| TOTAL Costs for Round Trip | | $29,906 | | $8,055 |

Fees associated with cargo handling (removal and loading), storage, and moving away from the port facility were not considered in these costs. The rational for this was that only the numbers of ship transits were changing in this analysis and not the amount of cargo. (Table 15)

181 Updated from Wolfe et at. study (2016) using GDP.

182 Ibid.

183 Vessel Masters usually have their pilotage license

## X. WATER LEVEL CALCULATIONS

Dusek (2019) reports that ocean tides fluctuate between two and six feet with two high and two low tides each day at six hour intervals.[184] NOAA bases its nautical charts on the water depth determined at the Mean Lower Low Water measurement (MLLW) which is the average height of the lowest tide recorded at a tide station each day during the recording period.

Much smaller than oceans, the gravitational pull from the sun and the moon is not as strong on the Great Lakes. Consequently, water levels may change a few centimeters per day in these areas but are essentially considered non-tidal. That does not mean that water levels do not change over time. Both ocean and Great Lakes water levels are subject to non-tidal fluctuations, due to atmospheric conditions (e.g., barometric pressure, wind speed and direction), as well as river and storm runoff.

To make maximum use of vessel capacity, it is not uncommon for operators to navigate heavily laden ships into channels and ports where the vessel's displacement would initially appear to exceed the depth of the port's channel. In this analysis, allowances were made in Great Lakes and coastal vessel transits to reflect the impact of ocean tides and changes in Great Lakes vertical datums (due to changes in the earth's crust) which can facilitate an operational procedure often referred to as "riding the high water". In these cases, heavily laden vessels may safely and efficiently approach and dock at otherwise limited channel and port locations.

### A. Great Lakes

Vessel types were evaluated and data revealed that over 93 percent of all cargo tonnage and cargo value was categorized as dry bulk. The remaining seven percent of traffic was made up of tankers, liquid barges and miscellaneous craft (e.g., cranes). This analysis focused on dry

[184] Comments of Gregory Dusek, Oceanographer, NOAA, reported in https://www.cleveland.com/news/2019

bulk given their preponderance of the Great Lakes.

The International Great Lakes Datum (IGLD) (1992) reports that the elevation reference system employed to define reference water levels within the Great Lakes and St. Lawrence River System is adjusted every 25 to 30 years to reflect movement of the earth's crust.[185] The last datum determination was created in 1985 and implemented in January, 1992.

Great Lakes companies often set their own guidelines with respect to UKC but can deviate from them.[186] Pilots on Lake Superior, Michigan, Huron, and Erie can load to the maximum allowed at the locks on the St. Lawrence (8.08 meters or 26.5 feet). Lakers often load to the maximum depth of the interconnecting (lake to lake) waterways such as the St. Mary's River, which flows from Lake Superior to Lake Huron, the Niagara River connecting Lake Erie to Lake Ontario and the narrow Straits of Mackinac, joining Lake Michigan and Lake Huron.

A set of commonly posted requirements for UKC in the Great Lakes are referenced to the level of experience for the bridge officer: (three meters UKC for 3rd mate; (2) one meter for Master on Bridge; and, (3) 0.3 meters for Pilot on Bridge. The rule of thumb for pilots on the Great Lakes managing ocean bulk carriers is to expect squat of 1.3 meters. In this analysis, the value of the chart is reflected in the volume of tonnage for both pilots and masters on the bridge that were carried at UKC levels less than those recommended (0.3 and 1 foot, respectively).

### B. Coastal Movements

UKCs for ports were calculated based on guidelines from individual coastal ports. In instances where an estimate of footage was provided as a number alone (e.g., two or three), the

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185 The zero reference point for the IGLD is set in Rimouske, Quebec.

186 LCDR Charles Wisotzkey, NOAA, Personal communication with Captain MacFarland, January 27, 2021.

number was interpreted as the depth of UKC recommended by the port. In instances where a percentage alone was listed (e.g. 10 or 20 percent), the recommended UKC was calculated by multiplying reported vessel depth times the stipulated percentage. In cases were both a percent and number are provided (e.g., 10% / 2), the greater of the UKCs calculated by comparing the single digit UKC with the percentage of reported vessel depth was taken as the UKC for that location. Additionally, assuming average transit speeds and vessel fineness, vessel squat was added to reported drafts to estimate effective draft. (Table 8) For each coastal port location, charted controlling depth and squat (the latter based on the vessel's typical block coefficient and estimated speed) were summed to estimate the UKC.

Potential maximum depths were then compared with reported vessel transit depths where these trips exceeded the recommended UKC. In those cases, the amount of cargo weight that was carried to depress the vessel's depth below the UKC was calculated.

In an example of this process a bulk vessel reporting a 39 foot draft would be 1.03 feet UKC or 0.97 feet under the recommended UKC at their port location were analyzed.[187] If this vessel's lading had been reduced to achieve the requested two foot DUK, the vessel's load would have had to be reduced by 23,862 tons.[188] If four vessels were in this depth category, a total of almost 96 thousand tons would require the use of one additional vessel to transport. The ability to avoid added vessel transits represents the benefits provided by NYLON/PORTS®, pilots and bridge management and nautical charts.

The estimated portion of averted vessels transits was then summed across all ports at all reported vessel depths by vessel type. Hourly costs (vessel, overhead, fuel, mortality, morbidity,

[187] Vessel draft was increased by an estimate of squat.

[188] Refer to Table 9. It was calculated that average coastal bulk carrier displacement was 205.0 short tons per inch of displacement.

property, environmental and port handling) were estimated by the multiplication of vessel transit hours by hourly costs. (Table 16)

**Table 16**

**SUMMARY OF AVOIDED VESSEL TRANSITS DUE TO NWLON/PORTS®, CHARTS AND PILOTS**

| LOCATION | VESSEL TYPE | ESTIMATED TRIP LENGTH | TOTAL COST PER TRIP (Millions $2017) | METRIC TONS TRANSPORTED IN VESSELS IN EXCESS OF DUK RECOMMENDATIONS (Millions) | AVERTED VESSEL TRIPS |
|---|---|---|---|---|---|
| COASTAL | CONTAINER | 5,000 | $2.7 | 19.5 | 189 |
| COASTAL | BULK | 1,500 | $0.9 | 32.1 | 382 |
| COASTAL | TANK | 1,500 | $0.9 | 28.0 | 341 |
| GREAT LAKES | BULK | 850 | $0.5 | 6.9 | 114 |
| TOTAL | | | | 86.4 | 1,026 |

Due to the information provided by NYLON/PORTS®, the skills of pilots and nautical chart accuracy, 1,026 fewer vessels are required to transport current traffic levels (over 86 million metric tons) which results in lower costs and emissions from a number of sources including: (1) vessel capital cost; (2) fuel use; (3) morbidity and mortality; (4) dockage fees; (5) property damage; and, (6) environmental emissions. (Table 16) This suggests that about 3.7 percent of all vessel arrivals at U.S. coastal ports and 1.2 percent at U.S. Great Lakes ports occurred at UKCs less than desired. Together, 3.4 percent vessels at all U.S. ports transited with DUKs less than specified. (Table 17)

**Table 17**

**VESSEL TRANSITS WITH DEPTHS UNDER KEEL LESS THAN RECOMMENDED**

| LOCATION | TOTAL TRIPS OVER DUK[189] | PERCENT OF TOTAL DOMESTIC AND FOREIGN TRIPS OVER DUK RECOMMENDATIONS |
|---|---|---|
| COASTAL - CONTAINER | 2,814 | 5.8% |
| COASTAL – BULK | 3,757 | 2.2% |
| COASTAL – TANK | 3,914 | 6.2% |
| COASTAL – TOTAL | 10,484 | 3.7% |
| | | |
| GREAT LAKES | 496 | 1.2% |
| | | |
| GRAND TOTAL - ALL AREAS | 10,981 | 3.4% |

## XI. CONCLUSIONS

Overall, about three percent of all vessel transits occur with DUKs less than those recommended. The combination of NWLON/PORTS®, pilot and bridge management personnel and reliable nautical charts enable the safe movement of almost 11 thousand vessel transits that result in total annual savings from the averted vessel transits by more than $1.2 billion. (Table 18) Overall, annual benefits from NWLON/ PORTS® were estimated to approach $488 million while annual benefits from pilot and bridge management personnel and nautical charts approached $366 million each. Total added container costs per trip were highest due to longer lengths of transit assumptions, higher vessel capital and administrative costs, greater fuel use and resultant emissions.

[189] Includes all vessels (e.g., self-propelled vessels, barges, etc.)

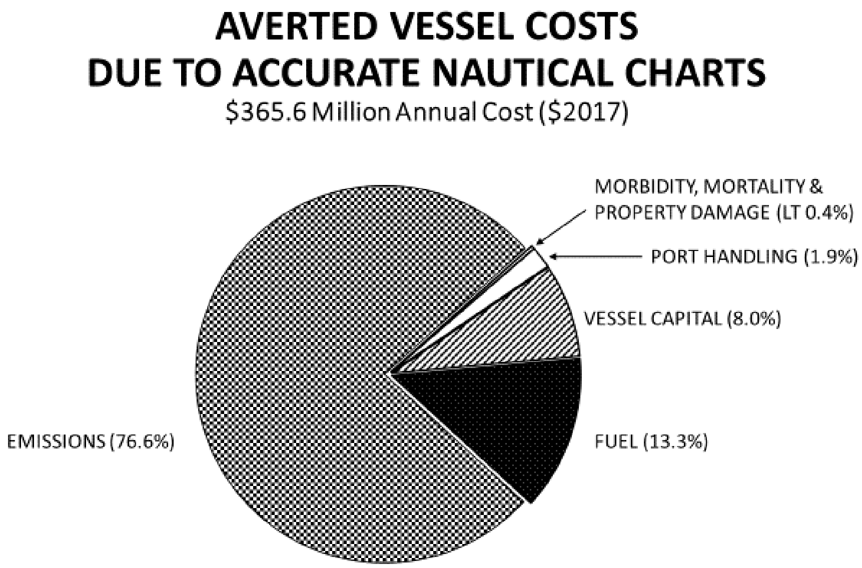
**Table 18**

## AVOIDED VESSEL COSTS DUE TO NAUTICAL CHART ACCURACY (30 PERCENT OF TOTAL AVOIDED COSTS IN THOUSANDS OF $2017)

| COST AREA | GREAT LAKES DRY BULK | COAST DRY BULK | COAST TANK | COAST CONTAINER | TOTAL AVOIDED COSTS (ALL AREAS) |
|---|---|---|---|---|---|
| VESSEL (CAPITAL AND OVERHEAD) | $845.7 | $5,707.7 | $8,120.8 | $14,606.8 | $29,281.0 |
| FUEL (MAIN PROPULSION AND AUXILIARY) | $1,092.4 | $6,600.4 | $6,766.5 | $33,987.2 | $48,446.5 |
| EMISSION (MAIN PROPULSION AND AUXILIARY) | $13,596.8 | $88,018.6 | $72,855.3 | $105,502.7 | $279,973.4 |
| PROPERTY | $0.5 | $1.7 | $1.6 | $0.9 | $4.7 |
| MORBIDITY & MORTALITY | $115.7 | $389.0 | $347.2 | $192.8 | $1,044.7 |
| PORT HANDLING[190] | $363.9 | $3,429.4 | $3,060.8 | $24.3 | $6,878.4 |
| TOTAL AVERTED COSTS | $16,015.0 | $104,146.8 | $91,152.1 | $154,314.7 | $365,628.5 |

[190] Does not include vessel loading and unloading costs as these were assumed to be the same regardless if the cargo was handled on one or more additional vessels.

**Figure 4**




Overall, societal costs of emissions accounted for almost $280 million which is 77 percent of all added vessel costs. Fuel and vessel capital costs represented approximately 13 and eight percent, respectively. (Figure 4)

**Table 19**

**POLLUTANTS AVERTED FROM MAIN PROPULSION AND AUXILIARY POWER DUE TO NAUTICAL CHARTS (30 PERCENT OF TOTAL AVOIDED IN METRIC TONNES)**

| EMISSION | GREAT LAKES DRY BULK | COAST DRY BULK | COAST TANK | COAST CONTAINER | TOTAL GREAT LAKES AND COAST |
|---|---|---|---|---|---|
| Particulate Matter (2.5) | 4.5 | 29.3 | 25.2 | 33.9 | 92.9 |
| Ammonia (NH3) | 0.0 | 0.2 | 0.2 | 0.3 | 0.7 |
| Methane (CH4) | 1.9 | 12.4 | 12.5 | 12.3 | 39.1 |
| Sulphur Oxide (SOx) | 0.3 | 1.7 | 1.4 | 1.9 | 5.3 |
| Nitrogen Oxide (NOx) | 159.0 | 1,029.4 | 848.8 | 1,237.9 | 3,275.1 |
| Carbon Dioxide ($CO_2$) | 7,561.2 | 48,947.0 | 41,995.8 | 57,048.9 | 155,552.9 |

| | | | | | |
|---|---|---|---|---|---|
| Carbon Monoxide (CO) | 16.2 | 105.1 | 88.9 | 123.8 | 334.0 |
| Reactive Organic Gases (ROG) | 8.0 | 51.9 | 43.6 | 61.4 | 164.9 |
| Particulate Matter (10.0) | 4.6 | 30.1 | 25.9 | 34.9 | 95.5 |
| Black Carbon (BC) | 0.0 | 0.2 | 0.0 | 0.1 | 0.3 |
| Total Emissions | 7,755.8 | 50,207.0 | 43,042.5 | 58,555.3 | 159,560.6 |

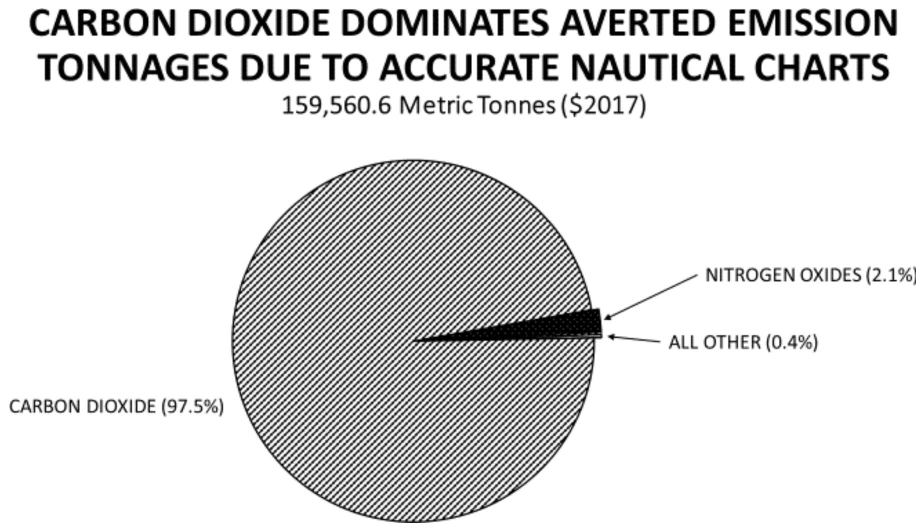
Atmospheric carbon dioxide measured at NOAA's Mauna Loa Atmospheric Baseline Observatory peaked for 2021 in May 2021 at monthly average of 419 parts per million (ppm), the highest level since accurate measurements began 63 years.[191] Over the next ten years, the nation's goal is to reduce carbon emissions by 78 million metric tons.[192]

Due to accurate nautical charts, between almost 160 thousand fewer metric tons of emissions would occur. Of these, almost 156 thousand metric tons (97.5 percent) are due to carbon dioxide and over three thousand metric tons (2.1 percent) are due to nitrogen oxide. (Table 19 and Figure 5)

[191] NOAA Research News, June 7, 2021.

[192] NOAA. 2022. "Building a Climate Ready Nation". NOAA FY22-26 Strategic Plan, page 56.

**Figure 5**




Overall, total averted emission costs approach $280 million per year. Nitrogen oxide emissions, while representing little over two percent of emission tonnage are over 800 times more costly to society than carbon dioxide.[193] Annual nitrogen oxide costs saved due to charts range are estimated to exceed $254 million to society. (Table 20 and Figure 6) With the mandates involving Sulphur emissions through scrubbers and low-Sulphur fuel, $SO_X$ emission costs are little more than five million dollars.

**Table 20**

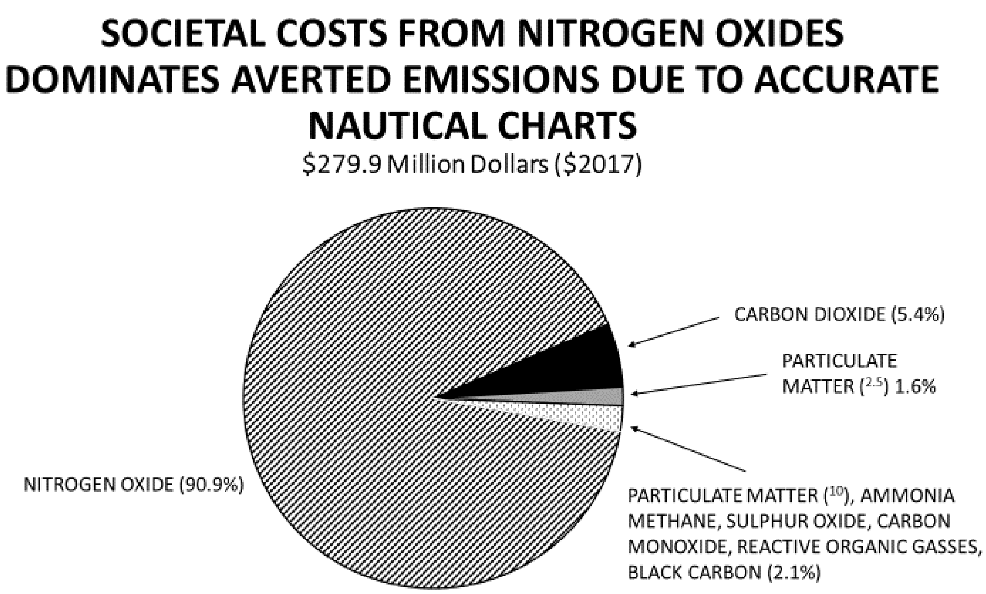
**SOCIETAL SAVING FROM FEWER EMISSIONS DUE TO NAUTICAL CHARTS (THOUSANDS OF $2017)**

| EMISSION | GREAT LAKES DRY BULK | COAST DRY BULK | COAST TANK | COAST CONTAINER | TOTAL GREAT LAKES AND COAST |
|---|---|---|---|---|---|
| Particulate Matter (2.5) | $213 | $1,377 | $1,188 | $1,598 | $4,376 |
| Ammonia (NH3) | $1 | $7 | $6 | $8 | $22 |

[193] $85,649 cost per ton of nitrogen oxide emissions versus $107 per ton of carbon dioxide. Refer to Table 12.

| | | | | | |
|---|---|---|---|---|---|
| Methane (CH4) | $10 | $66 | $67 | $65 | $208 |
| Sulphur Oxide (SOx) | $12 | $81 | $69 | $94 | $256 |
| Nitrogen Oxide (NOx) | $12,355 | $79,980 | $65,953 | $96,181 | $254,469 |
| Carbon Dioxide ($CO_2$) | $733 | $4,746 | $4,072 | $5,531 | $15,082 |
| Carbon Monoxide (CO) | $12 | $77 | $65 | $91 | $245 |
| Reactive Organic Gases (ROG) | $140 | $910 | $766 | $1,076 | $2,892 |
| Particulate Matter (10.0) | $110 | $714 | $616 | $829 | $2,269 |
| Black Carbon (BC) | $10 | $62 | $3 | $30 | $105 |
| TOTAL | $13,597 | $88,019 | $72,805 | $105,503 | $279,973 |

**Figure 6**




The conclusion that can be drawn from this study illustrates current reliance on nautical charts reduces the number of vessels employed to transport cargo. In turn, this reliance has reduced vessel fuel use and resultant emissions providing environmental and societal benefits.

It should also be noted that timely, accurate and complete nautical charts add to social equity as commercial ports and main waterway channels tend to be in economically distressed areas of the country. Any reductions in pollutants help improve the environment for those living in proximity to those areas.

**Table 21**

### SUMMARY OF ANNUAL BENEFITS DERIVED FROM ACCURATE NAUTICAL CHARTS DUE TO MORE HEAVILY LOADED VESSELS

| ANNUAL BENEFIT VALUE ($2017 MILLION) | AVOIDED EMISSIONS (ALL TYPES IN THOUSANDS OF METRIC TONS) | CONFIDENCE LEVEL[194] |
|---|---|---|
| $365.6 | 159.6 | HIGH TO VERY HIGH |

[194] In each benefit appraisal, a subjective assessment of the confidence of the estimate is made based on the quality of the underlying data, documented exactness of the relationship between nautical charts and resultant benefits and proximity to previous research findings.

# CHAPTER 3 - DANGER TO NAVIGATION AVOIDANCE TOOL – THE NAUTICAL CHART

## I. INTRODUCTION

The mariner standing on the bridge of the ship is unable to see what lies under the surface of the water and thus cannot see where it is safe to operate. Figure 1. They are completely reliant on the nautical chart. One of the most important values of the nautical chart is that of making safe navigation possible.

**Figure 1**

**PICTURE OF BOW OF A SHIP AT SEA**

Source: (https://www.saldo.ch/artikel/artikeldetail/fuer-wenig-geld-ueber-den-atlantik/, n.d.)

To promote safe and efficient marine transportation, fishing and recreational activities, nautical charts provide vessel operators with essential data involving shorelines, water depths, anchorages, rip-tides, channel locations and dimensions and placement of navigational aids (e.g., buoys). In addition, nautical charts promote safety through identification and location of dangers to navigation (DTON), rocks, reefs, wrecks and submerged or partially submerged obstructions which could result in an allision if not considered in vessel operations and trip planning.[195] (Table 1). Areas investigated included U.S. waters of Alaska, Atlantic, Great Lakes, Gulf of Mexico, Hawaii, Puerto Rico, U.S. Virgin Island, and West Coast.

**Table 1**

+ **CHARTED DTONs[196]**

| DTON DESCRIPTION | NUMBER OF REPORTED OCCURRENCES | PERCENT OF GRAND TOTAL OF ALL DTONs |
|---|---|---|
| Breakers | 1,107 | 0.4% |
| Dolphin | 12,027 | 4.7% |
| Eddies | 76 | 0.0% |
| Obstruction: Crib | 1,271 | 0.5% |
| Obstruction: Diffuser | 11 | 0.0% |
| Obstruction: Fish haven | 113 | 0.0% |
| Obstruction: Foul area | 1,249 | 0.5% |
| Obstruction: Foul ground | 3 | 0.0% |
| Obstruction: Ground tackle | 13 | 0.0% |
| Obstruction: Snag/stump | 24,724 | 9.7% |
| Obstruction: Unknown | 12,294 | 4.8% |
| Obstruction: Wellhead | 981 | 0.4% |
| Other Water Turbulence | 6 | 0.0% |
| Rock: Awash | 12,333 | 4.8% |
| Rock: Covers and Uncovers | 143,298 | 56.2% |
| Rock: Other | 55 | 0.0% |
| Rock: Submerged | 33,202 | 13.0% |
| Ruins (Not always dry) | 40 | 0.0% |
| Tide rips | 634 | 0.2% |
| Wreck: Awash | 15 | 0.0% |
| Wreck: Covers and Uncovers | 273 | 0.1% |
| Wreck: Other | 7,115 | 2.8% |
| Wreck: Submerged | 1,887 | 0.7% |
| Wreck: Visible | 2,432 | 1.0% |
| TOTAL: | 255,159 | 100.0% |

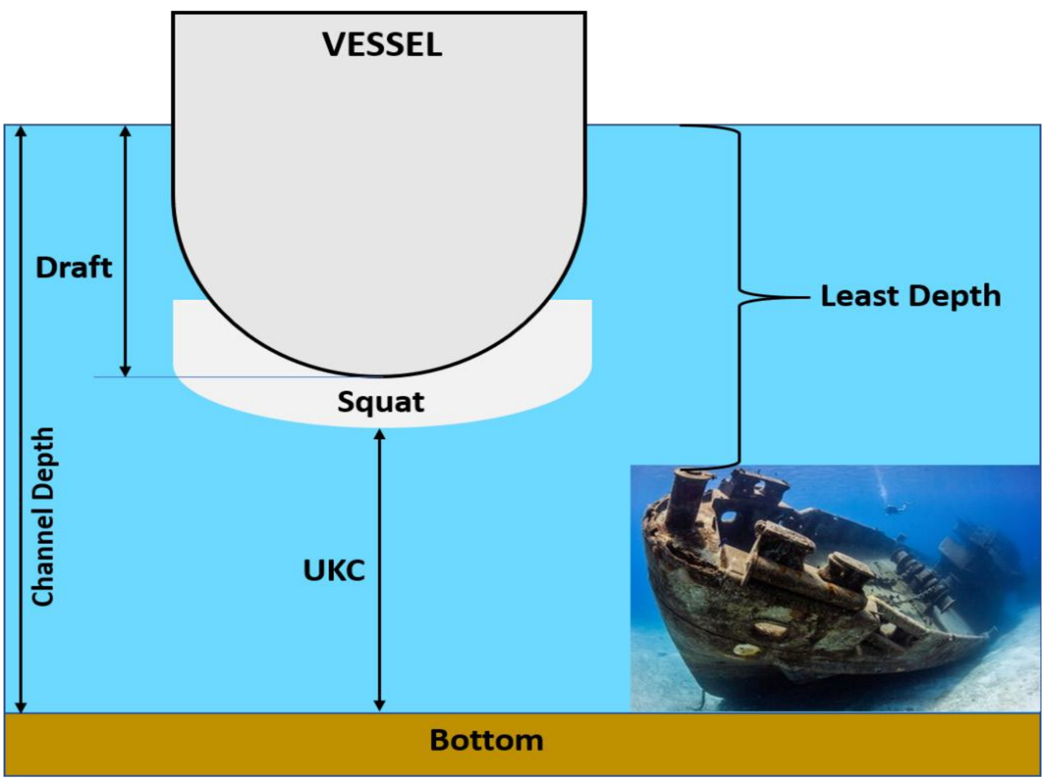
[195] Some obstructions might be visible only during certain portions of the day remaining submerged during times of high tide.

[196] All features of 11 fathoms (66 feet) or less in navigable waters are evaluated and may be charted as dangers to navigation.

DTONs in this study were extracted from NOAA's Electronic Nautical Charts (ENCs) by ENC bands to ensure no duplication of objects identifying more than 255,000. In addition to the position and type of obstruction, submerged DTON data included the depth of water over the highest point of the danger to navigation known as the least depth. Coupled with knowledge of vessel drafts, it is possible to judge if the vessel can safely pass over the obstruction (e.g., if the difference between the least depth of the obstruction and the draft of the vessel is a positive value). (Figure 2). A negative value indicates that it would be possible for the vessel to have an allision with the DTON.

**Figure 2**

**RELATIONSHIPS AMONG DEPTH MEASURES**



Also, as part of the assessment of potential allisions, Aids to Navigation (ATONs) in the vicinity of each of the dangers to navigation involved in potential allisions were examined to better understand their role in preventing allisions. These aids may be lighthouses, beacons, fog signals, snag/stump, covers and uncovers rocks, sound signals, buoys, and others to assist navigation. A U.S. Coast Guard's ATON geodatabase file consisting of 50,696 records was used to intersect with the 40m buffer for the 255,159 DTONs to understand the ATONs proximity with DTONs. The intersection found only 2,063 ATONs in the 40m circles. Only a few of the ATONS marked the precise position of the DTON accurately enough to enable mariners to navigate closely (less than 40m) to a DTON without the aid of a nautical chart.

To determine how important nautical charts are to the avoidance of vessel allisions with charted dangers to navigation, the DTON's believed not to be an important threat of grounding or allision of deeper draft commercial shipping were eliminated from consideration. Based on the attributes information of the DTONs database, only 27.8% of all DTONs (70,842) had depth data indicating they were whether awash or submerged at chart tidal datum (mean low water) and were considered possibly dangerous to deep draft vessels if not navigating with a nautical chart and GPS. These were retained for analysis. See Table 2 and Figure 3.

Table 2

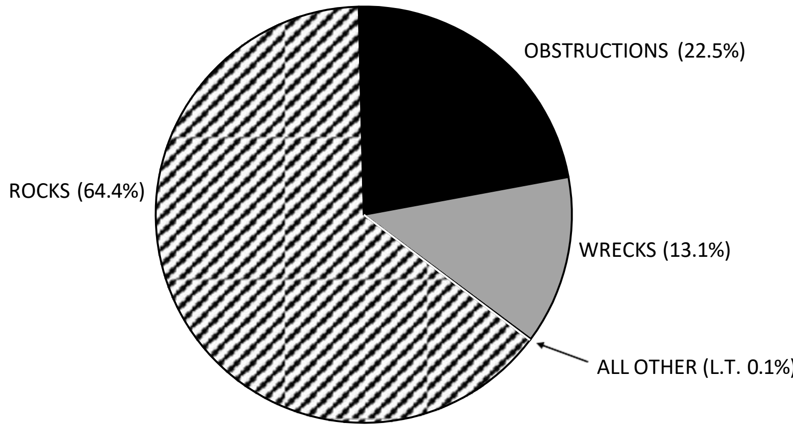
## DTONs RETAINED FOR ANALYSIS

| DTON DESCRIPTION | NUMBER OF REPORTED OCCURRENCES | PERCENT OF GRAND TOTAL OF ALL DTONs | PERCENT OF TOTAL RETAINED DTONs |
|---|---|---|---|
| Obstruction: Crib | 1,271 | 0.5% | 1.8% |
| Obstruction: Diffuser | 11 | 0.0% | 0.0% |
| Obstruction: Fish haven | 113 | 0.0% | 0.2% |
| Obstruction: Foul area | 1,249 | 0.5% | 1.8% |
| Obstruction: Foul ground | 3 | 0.0% | 0.0% |
| Obstruction: Unknown | 12,294 | 4.8% | 17.4% |
| Obstruction: Wellhead | 981 | 0.4% | 1.4% |
| Rock: Awash | 12,333 | 4.8% | 17.4% |
| Rock: Other | 55 | 0.0% | 0.1% |
| Rock: Submerged | 33,202 | 13.0% | 46.9% |
| Ruins (Not always dry) | 40 | 0.0% | 0.1% |
| Wreck: Awash | 15 | 0.0% | 0.0% |
| Wreck: Covers and Uncovers | 273 | 0.1% | 0.4% |
| Wreck: Other | 7,115 | 2.8% | 10.0% |
| Wreck: Submerged | 1,887 | 0.7% | 2.7% |
| TOTAL RETAINED | 70,842 | 27.8% | 100.0% |

Identification of DTONs originate form reports from NOAA hydrographic survey operations, U.S. Coast Guard (USCG), vessel operators, U.S. Army Corps of Engineers (USACE) and other waterway users. Once reported and verified, these obstructions are added to navigational charts. Only when identified as having been removed or no longer in existence, do nautical chart personnel in the NOAA's Office of Coast Survey (OCS) approve removal of obstructions from the chart.

**Figure 3**

## DTONs IMPACTING DEEP DRAFT COMMERCIAL SHIPPING




Just as mariners are unable to avoid dangers that they are unable to see without a nautical chart a danger to navigation cannot be avoided without a means of accurate positioning the vessel in relation to the charted dangers to navigation. The global positioning system (GPS) positioning is a very accurate positioning system employed on all commercial vessels and most recreational vessels [1]. The chart provides the location of dangers while the GPS provides the position of the vessel.

### A. Identification of Vessel Tracks

Automatic Identification System (AIS)[2] data was used to identify the track of vessels. AIS is an automatic tracking system that uses transceivers on ships and is used by vessel traffic services for ship-to-ship collision avoidance. (Refer to Appendix E for a detailed description of AIS). It facilitates communication of vessel position, speed and other data via a Very High Frequency (VHF) virtual data link.

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[1] Small recreational boaters are able to use their cell phone GPS with a nautical chart navigation app.

[2] https://www.navcen.uscg.gov/ais-requirements#:~:text=AIS%20Requirements%201%20%281%29%20Vessels%20that%20operate%20solely,likely%20to%20encounter%20other%20AIS-equipped%20vessels%3B%20More%20items
U.S. Coast Guard requires AIS reporting for all vessels including self-propelled vessels 65' or more in length, towing vessels 26' or more in length, self-propelled vessels of 300 gross tons or more certified to carry more than 150 passengers, and vessels of 150 gross tons or more when carrying 12 or more passengers. The AIS usually reports vessel position at least every 30 seconds but as often as every 5 seconds for most large commercial vessels.

Each year hundreds of millions of vessel transit segments are reported during the calendar year. To expedite calculations, data for one month was employed in this analysis. June was selected as representative for the year as reported cargo value and tonnage was closest to annual monthly averages.[197] In this study, 2017 point and track AIS data was obtained from the Vessel Traffic data page at the MarineCadastre.gov website.[198]

The data available in the MarineCadastre.gov originates from the Nationwide Automatic Identification System (NAIS) by the U.S. Coast Guard and contain records for U.S. coastal waters. The data represent 16 of the most important fields from the original AIS record and are filtered to a one-minute rate and formatted in zipped, monthly files by Universal Transverse Mercator (UTM) zone. The data show all vessels that the land-based antennas received, with the exception of certain law enforcement and military vessels that are excluded. The NAIS is composed of approximately 200 land-based receiving stations located near important navigation routes in the conterminous U.S., Alaska, Hawaii, Guam, and parts of the Caribbean. NAIS data is generally not available for the Arctic, waters beyond 40 to 50 miles of the coast, or foreign waters. Figure 4 illustrates the relationship between reported DTONs (green dots) and cargo vessel track lines (pink vessel transit lines).

In this analysis AIS track data for six vessel types (i.e., cargo, tanker, passenger, fishing, tug and tow, and pleasure craft/sailing vessels) were investigated. Table 3 provides the number of Vessels and Tracks by geo-region.

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[197] Total import and export traffic during June represented 99 percent of monthly average cargo value and 100 percent of monthly average cargo weight during 2017. International traffic during the December to February period is often lower than the annual average. Source: USA Trade On Line.

[198] The most recent available at the beginning of this analysis. As 2017 data for Hawaii was not available data from 2018 was instead used. Alaska 2017 AIS data not available at the marine cadastre.gov site were obtained from the MARINE Exchange of Alaska

**Figure 4**

**DTONS AND CARGO SHIP TRACK LINES
(JUNE 2017)**

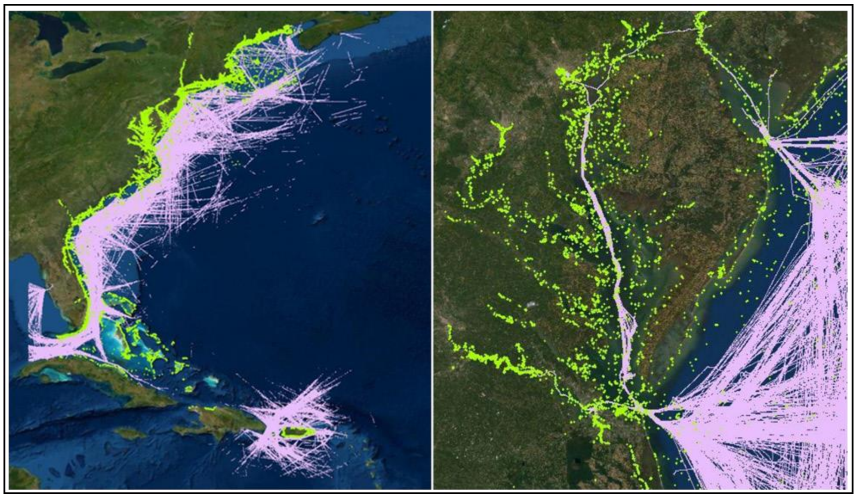


**Table 3**

**NUMBER OF VESSELS AND TRACKS BY REGION
(JUNE 2017)**

| REGION | CARGO | | TANKER | | PASSENGER | | FISHING | | TUG TOW | | PLEASURE | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | VESSELS | TRACKS | VESSELS | TRACKS | VESSELS | TRACKS | VESSELS | TRACKS | VESSELS | TRACKS | VESSELS | TRACKS |
| Alaska | 740 | 1,049,498 | 48 | 158,380 | 111 | 2,114,760 | 708 | 9,154,179 | 41 | 452,075 | 298 | 1,442,898 |
| Atlantic | 1,515 | 44,525 | 730 | 22,638 | 755 | 29,681 | 821 | 31,236 | 968 | 11,070 | 5,832 | 104,090 |
| Great Lakes | 212 | 2,380 | 56 | 587 | 147 | 5,512 | 4 | 46 | 269 | 3,308 | 583 | 9,701 |
| Gulf of Mexico | 735 | 20,141 | 771 | 27,833 | 378 | 26,937 | 650 | 29,214 | 2,225 | 33,438 | 563 | 11,334 |
| Hawaii | 91 | 1,465 | 54 | 791 | 22 | 1,034 | 105 | 1,428 | 43 | 1,266 | 42 | 264 |
| Puerto Rico | 452 | 8,073 | 258 | 4,668 | 64 | 4,231 | 5 | 105 | 58 | 619 | 147 | 1,815 |
| U.S. Virgin Island | 36 | 328 | 37 | 178 | 44 | 2,181 | 2 | 63 | 15 | 345 | 99 | 760 |
| West Coast | 1,152 | 33,899 | 246 | 9,588 | 461 | 12,651 | 524 | 10,029 | 471 | 6,528 | 3,063 | 34,569 |
| Total | 4,933 | 1,160,309 | 2,200 | 224,663 | 1,982 | 2,196,987 | 2,819 | 9,226,300 | 4,090 | 508,649 | 10,627 | 1,605,431 |

## II. INTERSECTIONS

The concept of a danger circle was introduced to represent that area around a DTON where it is imprudent for a mariner to navigate due to the risk of an allision. For the purposes of this study a radius of 40 meters from the center of the DTON was identified as an area dangerously close to the obstruction, even when navigating with a nautical chart and GPS. The 200 largest cargo carrier vessels have beams (width) between 59.1m and 48.2m. With a GPS receiver mounted on the vessel's centerline a vessel with a beam of 59.1m intersecting a danger circle would have no more than 10.5m from the vessel side to the charted danger. Vessels frequently experience departures from planned tracks from a few meters to significantly more. A number of factors can contribute to these unanticipated changes in direction including environmental factors such as changes in wind or current speed or direction and mechanical and human factors such as decision time and time to execute a rudder or engine order command. These can have an adverse effect on the intended vessel course. A prudent mariner allows for these unanticipated factors by building in a safety factor in their navigational plan. .

Since the mariner cannot see below the surface of the water to locate dangers to navigation that they are unable to take corrective action to avoid the danger unless they have a nautical chart. If the mariner has a nautical chart they know where the danger lays and are able to navigate in such a manner as to avoid striking the danger. Without a chart the mariner would not be aware that a danger exists extremely close to their vessel track.

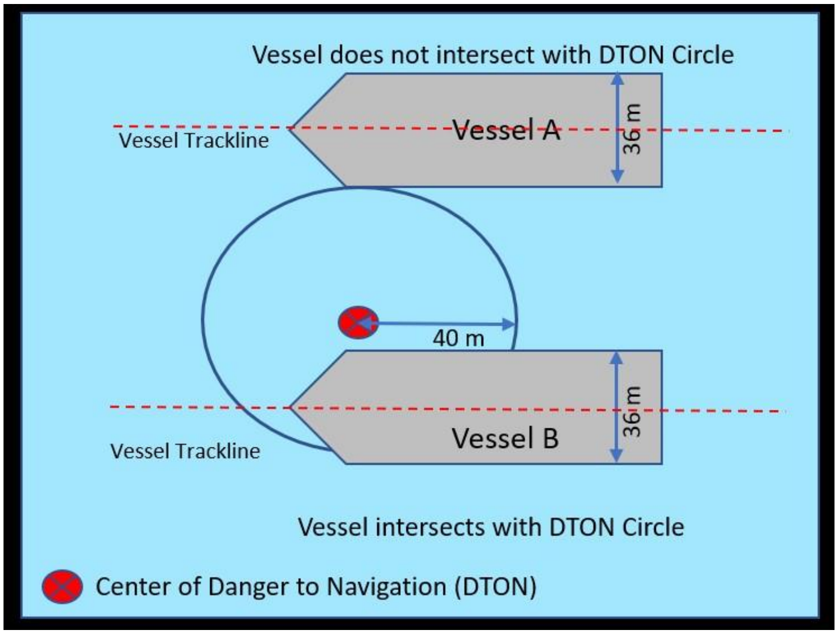
Estimation of the frequency of vessel traffic operating dangerously close to DTONS was undertaken by creating 40 meters buffer circle around each of the DTON locations (Figure 4) and determining the number of times in one-month vessel track lines touched or intersected these DTON danger circles. To illustrate this, Figure 5 shows the track lines of vessel "A" not intersecting the 40m danger circle surrounding the danger to navigation (DTON) red circle and thus not sailing dangerously close to the DTON. The track line of Vessel B does intersect the danger circle around the DTON and is thus sailing dangerously close to the DTON.[199] While of height above the channel or sea floor is known, the precise width and shape of the DTON is not

[199] It needs to be understood that there are large number of potential track lines within the 40-meter danger circle. Literally, a vessel's track could vary by millimeters from the center of the DTON.

known. For example, DTONs could be round, triangular, elliptical or take an irregular shape.

**Figure 5**

**VESSEL TRAFFIC OVER AND NEAR 40 METERS DTON CIRCLE BUFFER**




Additionally, the Office of Coast Survey, as the producer of the official U.S. nautical chart, has adopted the Zone of Confidence (ZOC) standards of the International Hydrographic Office (IHO) shown on Table 4.[200]

In addition to the depth accuracy standards that will be discussed in Section III of this chapter there is a positional accuracy that indicates the possible positional error in the location of the soundings or dangers to navigation. Considering the possibility of human error, mechanical issues, environmental factors and the uncertainty in the position of the danger, the prudent

[200] International Hydrographic Organization. 2020. *"S-67 Mariners' Guide to Accuracy of Depth Information in Electronic Navigational Charts (ENC)"*, p. 5, Edition 1.0.0 – October.

mariner is well advised where possible to steer at least 40 meters from a known danger to navigation.

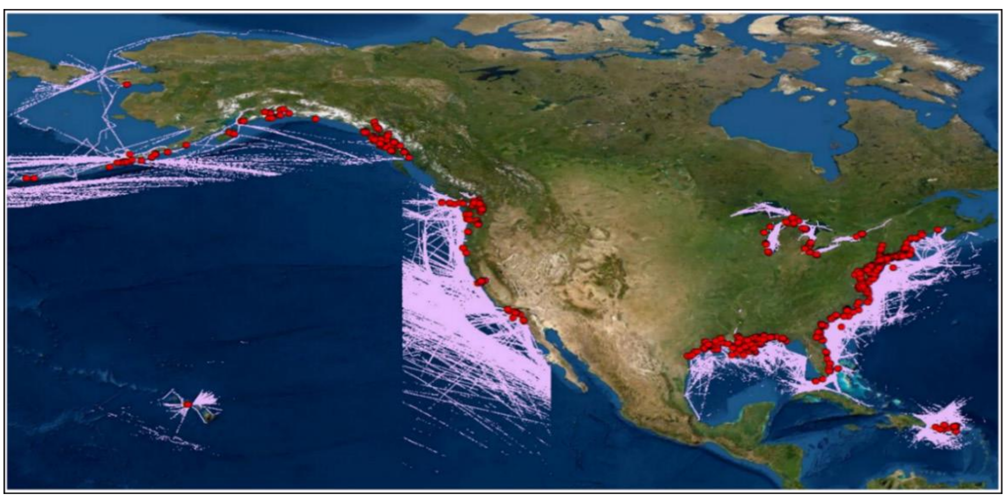
**Table 4**

**ZONES OF CONFIDENCE (CATZOC)
(X - Y POSITION ACCURACY)**

| ZOC RATING | POSITION ACCURACY[201] | NUMBER OF PORTS WITH CHANNELS (MAINTAINED AND NATURAL) WITH ZOC RATING[202] |
|---|---|---|
| A1 | ±5m + 5% Depth | 14 |
| A2 | ± 20m | 7 |
| B | ± 50m | 115 |
| C | ± 500m | 2 |
| D | Worse than ZOC C | 4 |
| U | Unassigned | 1 |

**Figure 6**

**DTON LOCATIONS AND CARGO TRACKS
(JUNE 2017)**



[201] Accuracy of the position east-west or north-south of the precise point reported (in meters).

[202] This Report, Chapter 2, Tables 5 and 6.

Only vessels with a draft greater than the least depth of the DTON were at risk of grounding or allision. The vessel reported draft was subtracted from the least depth of the danger (highest point off the sea bottom). Any negative values, where the vessel draft was reported deeper than the shallowest point of the DTON, were considered potential allisions.[203] Additional corrections were made to account for water level and the squat of the vessel. The potential error in the vertical measurement of the DTON least depth was accounted for by using the minimum and maximum correctors in the IHO CATZOC tables (Table 6). These were used to ensure the analysis was done on the best possible (deepest) water conditions and the worst possible (shoalest) water conditions.

The intersections were obtained by region and vessel type. After merging all AIS vessel track lines region files (almost 15 million records) and keeping only the DTON types listed in Table 2, there were 194,763 records (events) involving 10,581 unique DTONs remaining. Records that had missing values for both DTON least depth and AIS vessel draft were also eliminated reducing the number of events to 36,105 and the number of unique DTON locations to 2,751.

[203] Shoalest or lowest point.

**Table 5**

## INTERSECTION (DTON 40 METER RADIUS WITH AIS TRACKS)

| | NUMBER OF RECORDS BY VESSEL TYPE | | | | | | |
|---|---|---|---|---|---|---|---|
| | CARGO | TANKER | CRUISE | TUG &TOW | FISHING | PLEASURE | TOTAL |
| All Events | 14,337 | 6,849 | 1,785 | 101,976 | 17,312 | 52,504 | 194,763 |
| With Available DTON Depths and Vessel Drafts | 7,939 | 2,604 | 1,577 | 18,017 | 4,718 | 1,250 | 36,105 |
| With Available DTON Depths but Missing Vessel Drafts | 274 | 609 | 34 | 27,412 | 6,902 | 39,249 | 74,480 |

Separately, intersection cases having values of DTON least depth but vessel drafts missing were kept (74,480 events). Table 5. Potential allisions for these cases were also estimated. Figure 7 shows these DTON locations (red circles) over Cargo ship tracks. During one month there can be multiple vessel tracks going over DTONs. Figure 8 provides examples of multiple vessel transits over the same DTONs.

**Figure 7**

## CARGO TRACKS AND DTONS
## (JUNE 2017)

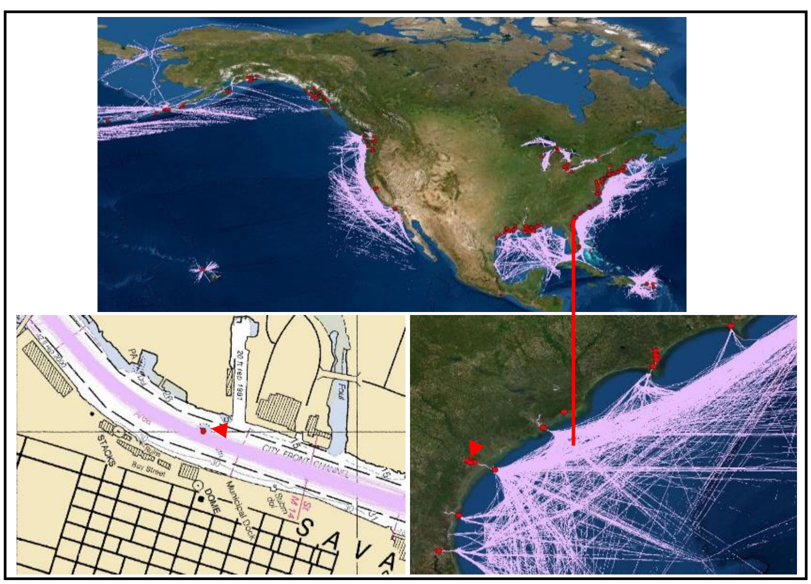
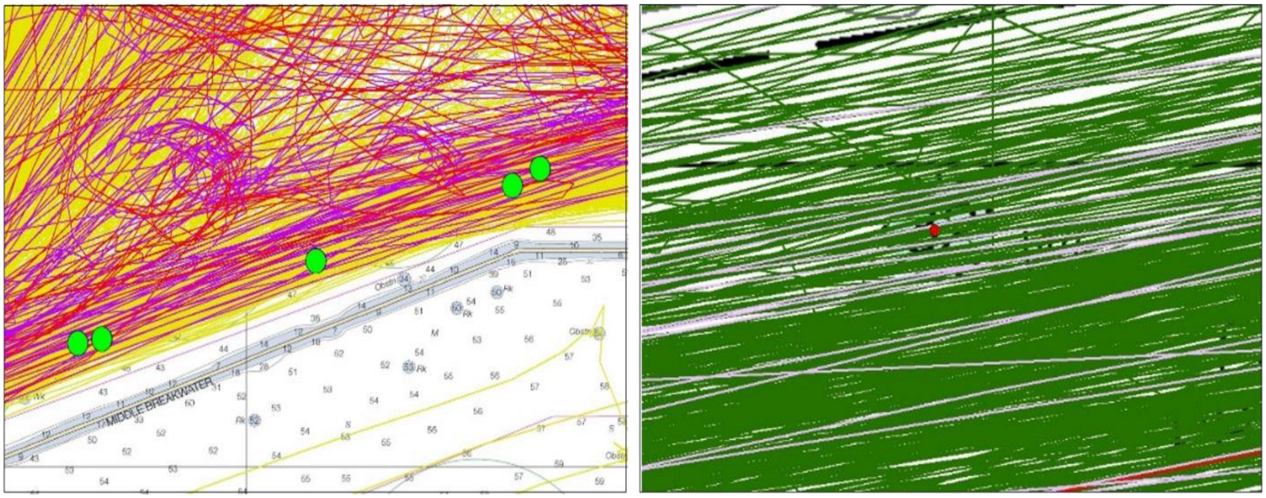


**Figure 8**

**EXAMPLES OF MULTIPLE VESSELS OVER ONE DTON**




(cargo, tanker, and tug and tow) tracking over five DTONs.

(cargo and tug and tow) vessels tracking over a DTON.

Cases of potential allisions are those where the DTON depth minus the Vessel draft equals less than zero. These instances of potential allisions in all 36,105 events resulted in 2,916 cases (negative values) some of which occurred in channels maintained by the United States Army Corps of Engineers. Annualizing this number then there would be 34,992 (2,916 x 12) indications of potential allisions between vessels and DTONs annually.

These results were compared with the 2017 U.S. Coast Guard Marine Information for Safety and Law Enforcement (MISLE) database of commercial shipping accidents. Through analysis of the 2,916 potential allisions in June, 2017 only one was found to match a reported allision/grounding included in the Coast Guard MISLE database[204] (June 2017) suggesting that all the remaining allisions were successfully avoided by the ship's navigation team with the use

[204] The vessel BIG AL (a sea-going tug with tow) struck a dangerous submerged wreck off the coast of Alabama in July 2017 with no injuries or damages to vessel or cargo reported (USCG MISLE case # 1088704).

of the nautical chart being aware of the danger. This means that, all other calculated allision instances are cases where the vessel would have been expected to have had an allision. The total calculated cost of allisions that didn't actually occur, was considered the benefit from allision avoidance.[205]

## III. APPLYING CORRECTIONS TO THE VESSEL DRAFT AND DTON LEAST DEPTH

Vessels involved in potential allisions would suffer damage. An equation was developed to obtain those negative values of "DTON minus AIS Draft" using other variables such as Category Zones of Confidence (CATZOC), Mean Sea Level, and SQUAT.[206] These were used to ensure the analysis was done on the best possible (deepest) water conditions and the worst possible (shoalest) water conditions.

### A. IHO CATZOC Hydrographic Depth Accuracy

All charts, whether paper or electronic, contain data which varies in quality due to the age, accuracy and completeness of individual surveys. A chart is made up with many hydrographic surveys pieced together to form a single image. Most charts contain a mixture of individual surveys of differing qualities.[207] IHO publication S-67 "Mariners Guide to Accuracy

[205] The MISLE 2017 reports 343 Allisions and 413 Groundings. There were only 52 intersections of those 756 accidents with 255,159 DTON 40 m Danger Circles and only one was visually verified to be in fact an allision/grounding case. (Refer to the vessel BIG AL delineated in the previous footnote). Because of the requirement for reporting vessel accidents to the U.S. Coast Guard, the other apparent allisions never occurred or occurred with DTONs not considered in this study (i.e. Obstruction: Snag/stump).

[206] "The squat effect is the hydrodynamic phenomenon by which a vessel moving quickly through shallow water creates an area of lowered pressure that causes the ship to be closer to the seabed than would otherwise be expected. This phenomenon is caused when water that should normally flow under the hull encounters resistance due to the close proximity of the hull to the seabed. Leonardo's law causes the water to move faster in water level (where section is smaller); according to Bernoulli's principle, the increasing velocity causes low pressure, such that the ship is pulled down. Squat effect from a combination of vertical sinkage and a change of trim may cause the vessel to dip towards the stern or towards the bow." Refer to Transportation Safety Board of Canada, Marine Investigation Report M00L0039, April 27, 2000 and https://en.wikipedia.org/wiki/Squat_effect

[207] International Hydrographic Organization, S-67 Mariners' Guide to Accuracy of Depth Information in Electronic Navigational Charts (ENC), p. 5, Edition 1.0.0 – October 2020.

of Depth Information in an Electronic Navigational Chart (ENC)" (Table 6) is a guide to navigators, and those planning 'navigational operations', on the degree of confidence they should have in the adequacy and accuracy of charted depths and their positions in an ENC.

**Table 6**

**ZONES OF CONFIDENCE (CATZOC)
(DEPTH ACCURACY)**

| ZOC CATEGORY | POSITION ACCURACY[208] | DEPTH ACCURACY |
|---|---|---|
| | | **DEPTH OF CATZOC + ACCURACY** |
| | | ± **A** (FIXED - Confidence Interval) +<br>**B** (DEPTH DEPENDENT - Confidence Interval) |
| A1 | ± 5 meter + 5% depth | ± (0.50 + 1% depth) |
| A2 | ± 20 meters | ± (1.00 + 2% depth) |
| B | ± 50 meters | ± (1.00 + 2% depth) |
| C | ± 500 meters | ± (2.00 + 5% depth) |
| D | Worse than ZOC C | ± Worse than ZOC C[209] |
| U | Unassessed - The quality of the bathymetric data has yet to be assessed[210] | |

The concept of Minimum Least Depth and Maximum Least Depth becomes important in the calculations to incorporate CATZOC depth accuracy variance.

*Minimum Least Depth* is defined as the minimum depth of water over the DTON. This is the least depth after the application of the negative portion of the correction from the

[208] Just as there was a maximum and minimum component to the CATZOC for the Depth (vertical component), there could be a minimum and maximum value for the horizontal component of the measurement (CATZOC tables). It was decided not to utilize this because most of the observed intersections occurred in the charted channel and the placement of the DTON in the channel is constrained in the cartographic process. That is, if the report indicates it is in the channel but the latitude and longitude of the reported DTON plots outside the channel, the cartographer will adjust the position slightly to make it fit in the channel. Anything that can be done with the CATZOC horizontal component of the positional error budget could abrogate this DTON-in-the-channel relationship.

[209] While not officially established, in this analysis, locations with ZOC D ratings were defined as 3.0 meters +/- 8 percent of depth.

[210] In this analysis, ports with a "U" rating were assigned a depth accuracy of 4.0 meters +/- 10 percent of depth.

Depth Accuracy column in Table 6. The CATZOC variance is the measurement of the depth of the DTON which is subtracted from the original measurement. This results in a shallower depth over the DTON and when the draft of the vessel is subtracted from the lower DTON depth the number of potential allisions increases.

*Maximum Least Depth* is defined as the maximum depth of water over the DTON. This is the least depth after the application of the <u>positive</u> portion of the correction from the Depth Accuracy column in Table 6. The CATZOC variance in the measurement of the depth of the DTON is added to the original measurement. This results in a deeper depth over the DTON and when the draft of the vessel is subtracted from the deeper DTON depth the number of potential allisions decreases.

There are two components for the CATZOC correction to the depth measurement. Part A is a fixed value dependent on the ZOC accuracy designation (e.g. ± 0.5 for A1). Part B is a variable value dependent on depth (e.g. 1 percent of depth value for A1).

### B. Minimum Correction Potential Allision (MinCPA) and Maximum Correction Potential Allision (MaxCPA)

Two equations by vessel type were used to calculate the Minimum and the Maximum Correction Potential Allisions as defined below:

<u>Equation 1: MinCPA</u>

MinCPA = Minimum Least Depth – (Draft + SQUAT)

where:

Minimum Least Depth = [(Depth of DTON + Mean Sea Level) – CATZOC Corrector A] – [(Depth of DTON + Mean Sea Level) x CATZOC Corrector B]

<u>Equation 2: MaxCPA</u>

MaxCPA = Maximum Least Depth – (Draft + SQUAT) where:

Maximum Least Depth = [(Depth of DTON + Mean Sea Level) + CATZOC Corrector A] + [(Depth of DTON + Mean Sea Level) x CATZOC Corrector B]

1. Category Zone of Confidence (CATZOC)
   The CATZOC accuracy designation for the DTON least depth information was determined by inspection of the NOAA ENC. Accuracy of CATZOC were obtained from Table 6.

2. Mean Sea Level (MSL)
   It is an average level of the surface of Earth's bodies of water from which heights such as elevation may be measured. MSL is affected by the tides, wind, atmospheric pressure, local gravitation differences, temperature, salinity, and so forth. The MSL was obtained from the NOAA Tides and Currents data site.[211]

3. Squat Correction
   Squat is the reduction of vessels Keel-Clearance, caused by the relative movement of the ship's hull through the surrounding body of water. Compared with the neutral position the hull sinks deeper into the water and at the same time will trim slightly.

$$\text{Open Water SQUAT (m)} = (\text{Block Coefficient} * \text{Speed}^2)/100$$

The block coefficient of a vessel is obtained by dividing the underwater volume of displacement of a ship by the volume of a block of the same length and breadth, and of height equal to the draught of the ship.[212]

Speed of a ship depends on various factors like displacement of the vessel, draft, wind force and direction, sea weather condition, condition of the hull and the propeller and so on. Typical vessel speeds by type of ship is listed in Table 7.

[211] https://TidesandCurrents.noaa.gov

[212] The block coefficient of a ship is the ratio of the underwater volume of ship to the volume of a rectangular block having the same overall length, breadth and depth.

**Table 7**

## VESSEL BLOCK COEFFICIENTS AND SPEEDS

| BLOCK COEFFICIENTS | | VESSEL SPEEDS | |
|---|---|---|---|
| Cargo: (0.60 to 0.75) | Used 0.675 | Speed (13 - 22) | Used 13 knots |
| Tanker: (0.82 to 0.86) | Used 0.840 | Speed (12 - 16) | Used 12 knots |
| Cruise: (0.55 to 0.60) | Used 0.575 | Speed (15 - 26) | Used 15 knots |
| Tug Tow: (0.54 to 0.58) | Used 0.560 | Speed (5 - 10) | Used 10 knots |
| Fishing: (0.47) | Used 0.470 | Speed (12 -26) | Used 12 knots |
| Pleasure Craft: (0.15 – 0.20) | Used 0.175 | Speed (12 -26) | Used 12 knots |

Source: Ship's Waterplane, Block, Midship & Prismatic Coefficient, Cultofsea.com., https://cultofsea.com/ship-stability/coefficients-of-form-ships-waterplane-block-midship-and-prismatic-coefficient/

The distribution of cases where the vessel draft for Cargo, Tanker, Cruise, Tug and Tow, Fishing, and Pleasure appeared to result in an allision is depicted in Table 8 (by negative ranges). Table 9 reflects the only 6 types of DTONs involved in the MinCPA and MaxCPA.

The events without vessel draft information were calculated by assuming same ratio of MinCPA and MaxCPA to the number of events where DTON depth and draft data existed. For example:

Number of cases with DTON Depth data and Vessel Draft missing x (Events of MinCPA with available DTON Depth and Vessel Draft / Number of cases with available DTON Depth and Vessel Draft) = Events of MinCPA with DTON Depth data and Vessel Draft missing.

The numbers in the equation for Cargo are:

274 x (2,780 /7,939) = 96

Table 10 lists potential allisions by vessel type.

**Table 8**

## DISTRIBUTION OF POTENTIAL ALLISIONS

## BY DISTANCE BETWEEN VESSEL DRAFT AND DTON LEAST DEPTH

| NEGATIVE RANGES (METERS) BETWEEN VESSEL DRAFT AND DTON LEAST DEPTH | MinCPA | | MaxCPA | |
|---|---|---|---|---|
| | FREQUENCY | PERCENT | FREQUENCY | PERCENT |
| <0.0 to -0.5 | 916 | 16.7% | 410 | 18.9% |
| -0.5 to -1.0 | 855 | 15.6% | 400 | 18.4% |
| -1.0 to -2.0 | 1,757 | 32.1% | 713 | 32.9% |
| -2.0 to -5.0 | 1,416 | 25.9% | 441 | 20.3% |
| -5.0 to -7.5 | 351 | 6.4% | 127 | 5.9% |
| -7.5 to -10.0 | 124 | 2.3% | 45 | 2.1% |
| Lower than -10.0 | 58 | 1.1 | 33 | 1.5 |
| TOTAL | 5,477 | 100.0 | 2,169 | 100.0% |

**Table 9**

## DISTRIBUTION OF POTENTIAL ALLISIONS BY TYPE OF DTON

| DTON TYPE DESCRIPTION | MinCPA | | MaxCPA | |
|---|---|---|---|---|
| | DTONs | EVENTS | DTONS | EVENTS |
| Obstruction Crib | 7 | 319 | 5 | 144 |
| Obstruction Unknown | 440 | 3,422 | 253 | 1,515 |
| Rock Awash | 44 | 277 | 31 | 127 |
| Rock Submerge | 124 | 397 | 51 | 87 |
| Wreck Other | 108 | 1,060 | 45 | 296 |
| Wreck: Submerged | 1 | 2 | 0 | 0 |
| TOTAL | 724 | 5,477 | 385 | 2,169 |

**Table 10**

## DISTRIBUTION OF POTENTIAL ALLISIONS BY VESSEL TYPE

| VESSEL TYPE DESCRIPTION | MinCPA (WITH DTON DEPTH) | | MaxCPA (WITH DTON DEPTH) | |
|---|---|---|---|---|
| | EVENTS WITH VESSEL DRAFT | EVENTS WITHOUT VESSEL DRAFT | EVENTS WITH VESSEL DRAFT | EVENTS WITHOUT VESSEL DRAFT |
| Cargo | 2,780 | 96 | 1,036 | 36 |
| Cruise | 89 | 2 | 31 | 1 |
| Tanker | 1,152 | 269 | 620 | 145 |
| Tug and Tow | 933 | 1,420 | 338 | 514 |
| Fishing | 474 | 693 | 139 | 203 |
| Pleasure | 49 | 1,539 | 5 | 157 |
| TOTAL | 5,477 | 4,019 | 2,169 | 1,056 |

As part of the assessment of potential allisions, Aids to Navigation (ATONs) were examined to better understand their role in preventing allisions. ATONs are guidance equipment or markers to aid mariners in determining position or a safe course. These aids also assist mariners in making a safe landfall, mark isolated dangers, enable pilots to follow channels, and provide a continuous chain of chartered marks for precise piloting in coastal waters. These aids may be lighthouses, beacons, fog signals, sound signals, buoys, and others to assist navigation.

A U.S. Coast Guard's ATON geodatabase file consisting of 50,696 records was used to intersect with the 40 m buffer for the 255,159 DTONs to understand the ATONs proximity with DTONs. The intersection found only 2,063 ATONs in the 40m circles. While applying an intersection of ATONs with the MinCPA 724 DTONs of 40m buffer, the intersection found only 20 ATONs in the 40m circles. From all of these identified ATONs only two marked DTONs, while all of the others were mostly buoys marking channels. A second exercise of intersecting ATONs with the MinCPA 724 DTONs of just 10m buffer, resulted in only one ATON (lighted bell buoy) in the circle.

The interpretation of this analysis confirms that ATONs are primarily used to aid in the process of safe navigation and to mark a possible danger, but not to indicate an exact location of a DTON. For ships to avoid allisions with DTONs while navigating perilously close to DTONs, mariners must use Nautical Charts in conjunction with available ATONs. ATONs should be used with Nautical Charts for safe navigation.

### C. Allision Cost Estimates

The average cost of an allision for Cargo, Tanker, Cruise, and Tug and Tow vessels in $2017 was determined to be $215,694 dollars and for Fishing and Pleasure vessels[213] was determined to be approximately $63,420 dollars from accidents reported in the U.S. Coast Guard MISLE database from 2005 to 2017. (Table 11).

**Table 11**

**ESTIMATED ALLISION COST**
**(2005 – 2017)[214]**

| LOSS DESCRIPTION | LOSS FROM ALLISIONS FOR CARGO, TANKER, CRUISE, AND TUG & TOW VESSELS ($2017 DOLLARS) | LOSS FROM ALLISIONS FOR FISHING, AND PLEASURE VESSELS ($2017 DOLLARS) |
|---|---|---|
| Death | $68.6 M | 0 |
| Injuries | $339.4 M | $34,420 |
| Vessel Losses | $170.0 M | $18,404 |
| Cargo Losses | $9.7 M | 0 |
| Facility Losses | $352.1 M | $5,594 |
| Other Losses | $364.1 M | $5,002 |
| Total Allision Loss | $1,303.9 M | $63,420 |
| Number Allisions 2005-2017 | 6,045 | 73 |
| AVERAGE LOSS PER ALLISION | $215,694 | $63,420 |

[213] Fishing and Pleasure vessels were comparable in length (8-68 meters and 11-53 meters, relatively)

[214] Wolfe, Eric and Percy Pacheco, 2020, "Gross Benefit Estimated from Reductions in Allisions, Collisions and Groundings Due to Electronic Navigational Charts", Journal of Ocean and Coastal Economics, Volume 7, Issue 1, Table 7.

# IV. AVERTED ALLISIONS AFTER ADJUSTMENT FOR CATZOC, MEAN SEA LEVEL AND SQUAT

## A. Estimated Intersections with DTONs

The effort so far has been two-dimensional through the identification of the number of vessels with drafts (adjusted for squat) that are greater than the least depth of a DTON (adjusted for tide and the potential CATZOC variance in depth measurement of the DTON) that are navigating dangerously close (within 40 m) to a DTON.[215] However, it is possible for a vessel to sail through a portion of the danger circle without striking the danger at its center. To determine the potential of a vessel striking the DTON the vessel's width identified through AIS data was analyzed.[216] As there is no information on the dimensions or orientation of the DTON it was considered as a single point feature with a position and least depth. An intersection of any part of the vessel with that point is considered an allision event. Tables 12 and 13 delineate vessel width and draft characteristics employed in the MinCPA and MaxCPA calculations.

**Table 12**

**MinCPA - VESSEL WIDTH AND DRAFT INFORMATION**

| VESSEL TYPE | NUMBER OF EVENTS | MEAN WIDTH (METERS) | MEAN DRAFT (METERS) | MIN - MAX WIDTH (METERS) | MIN - MAX DRAFT (METERS) |
|---|---|---|---|---|---|
| Cargo | 2,780 | 28 | 10.9 | 8 - 61 | 2.5 – 18.2 |
| Cruise | 89 | 40 | 13.2 | 27 - 61 | 7.1 – 22.6 |
| Tanker | 1,152 | 35 | 13.3 | 17 - 60 | 6.7 – 22.6 |
| Tug and Tow | 933 | 10 | 4.6 | 4 - 25 | 1.7 – 10.0 |
| Fishing | 474 | 10 | 2.6 | 4 - 19 | 2.0 – 13.0 |
| Pleasure | 49 | 7 | 2.7 | 3 - 10 | 1.7 – 7.0 |

[215] This is the "Z" dimension related to "height" over the DTONs.

[216] This is equivalent to an estimation of the "X" and "Y" coordinate relationship between the vessel and DTON. While the width of the vessel was employed in this analysis, no data is available regarding the width or shape of the DTON. Consequently, the center point of the DTON was used as the basis for measurement of vessels from the .

**Table 13**

## MaxCPA - VESSEL WIDTH AND DRAFT INFORMATION

| VESSEL TYPE | NUMBER OF EVENTS | MEAN WIDTH (METERS) | MEAN DRAFT (METERS) | MIN - MAX WIDTH (METERS) | MIN - MAX DRAFT (METERS) |
|---|---|---|---|---|---|
| Cargo | 1,036 | 30 | 12.0 | 10 - 49 | 3.5 – 18.2 |
| Cruise | 31 | 38 | 14.5 | 30 - 60 | 7.1 - 22.6 |
| Tanker | 620 | 39 | 14.3 | 17 - 60 | 6.7 – 22.6 |
| Tug and Tow | 338 | 10 | 5.4 | 6 - 25 | 2.1 - 10.0 |
| Fishing | 139 | 10 | 3.8 | 6 - 15 | 1.9 – 13.0 |
| Pleasure | 5 | 9 | 3.4 | 7 - 10 | 1.7 – 7.0 |

Vessels track lines operating dangerously close, within 40 meters of a DTON, do not necessarily strike the danger as in some cases the vessel might miss the DTON by fractions of a meter to much larger distances.

In the example shown in Figure 9 all vessels track lines intersect the 40 m radius danger circle around the DTON indicating they are all sailing dangerously close to the DTON. In this figure only vessels A, B, and C will strike the DTON (center of 40 m circle with black X) causing an allision. Vessel D will travel within the danger zone but not result in an allision. Therefore, a simple equation to determine the probability of intersecting the DTON and to better estimate the potential allision was developed as:

*Probability of Intersecting the DTON (PID)= (Vessel Width / Danger Circle Diameter)*

**Figure 9**

## POSSIBLE DANGER TO NAVIGATION INTERSECTIONS

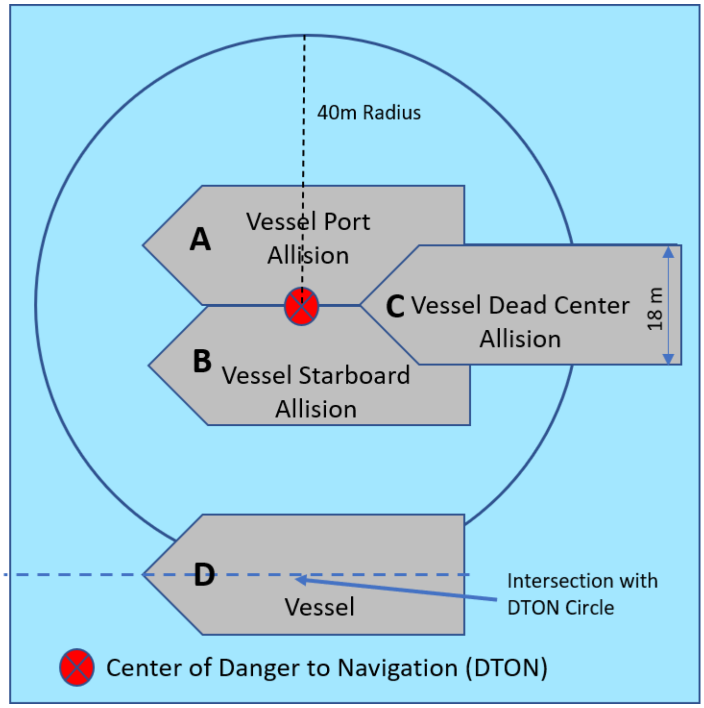



**Table 14**

## MinCPA EVENTS AFTER APLYING PID EQUATION

| | DTON DEPTH AND AIS DRAFT EXIST | | | DTON DEPTH EXIST BUT AIS DRAFT MISSING | | |
|---|---|---|---|---|---|---|
| VESSEL TYPE | EVENTS BEFORE PID | EVENTS AFTER PID | PERCENT OF TOTAL | EVENTS BEFORE PID | EVENTS AFTER PID | PERCENT OF TOTAL |
| Cargo | 2,780 | 931 | 33.49 | 96 | 32 | 33.49 |
| Cruise | 89 | 46 | 51.69 | 2 | 1 | 51.69 |
| Tanker | 1,152 | 464 | 40.28 | 269 | 109 | 40.28 |
| Tug and Tow | 933 | 97 | 10.4 | 1,420 | 148 | 10.40 |
| Fishing | 474 | 47 | 9.92 | 693 | 69 | 9.92 |
| Pleasure | 49 | 4 | 8.16 | 1,539 | 126 | 8.16 |
| Total | 5,477 | 1,589 | 29.01 | 4,019 | 485 | 12.07 |

**Table 15**

**MaxCPA EVENTS AFTER APLYING PID EQUATION**

| | DTON DEPTH AND AIS DRAFT EXIST | | | DTON DEPTH EXIST BUT AIS DRAFT MISSING | | |
|---|---|---|---|---|---|---|
| VESSEL TYPE | EVENTS BEFORE PID | EVENTS AFTER PID | PERCENT OF TOTAL | EVENTS BEFORE PID | EVENTS AFTER PID | PERCENT OF TOTAL |
| Cargo | 1,036 | 362 | 34.94 | 36 | 12 | 34.94 |
| Cruise | 31 | 13 | 41.94 | 1 | 0 | 41.94 |
| Tanker | 620 | 275 | 44.35 | 145 | 64 | 44.35 |
| Tug and Tow | 338 | 35 | 10.36 | 514 | 53 | 10.36 |
| Fishing | 139 | 15 | 10.79 | 203 | 22 | 10.79 |
| Pleasure | 5 | 1 | 8.16 | 157 | 31 | 20.0 |
| Total | 2,169 | 701 | 32.32 | 1,056 | 182 | 17.23 |

The results of this equation adjust the number of events of MinCPA and MaxCPA as shown in Tables 14 and 15. These numbers are less indicating that not all vessels sailing dangerously close to a DTON will actually strike the DTON resulting in an allision. Therefore, these MinCPA and MaxCPA are considered allisions.

In this analysis the width and shape of the DTON were unknown, the DTON was assumed to be a single point with no dimensions. In reality, these DTONs probably measure at least a portion to more than one meter in width. Consequently, the number of allisions would increase if the actual DTON width was known.

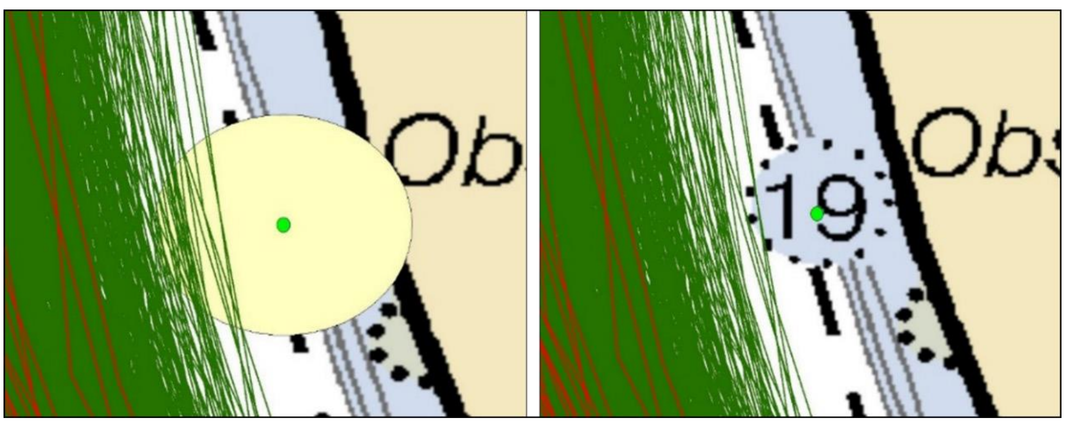
### B. Visual Review of Intersections

To ensure that all the calculated allisions were legitimate, a visual review of all 724 different DTONs involved in expected allisions was conducted to see if there were cases where the danger was barely outside a maintained channel or in water shallow enough that deep draft vessels could not navigate close enough to reach the DTON. A visual review of DTONS were not needed for Fishing and Pleasure vessels because of their operations outside the channel and in close to land.

Figure 10 depicts the example of vessels navigating within 40 meters of the DTON but the DTON is barely outside the maintained channel and thus is not actually a danger to deep draft vessels. The yellow circle around the DTON (green dot) on left image represents the 40 meters DTON radius circle. It was intersected multiple times by vessel tracks as illustrated in the right-hand image of Figure 10.[217] The DTON is just outside the channel and thus does not represent a danger that would have resulted in an allision. Consequently, the vessel tracks for this DTON do not represent a danger to shipping constrained to the channel, so they were not counted as allisions. This analysis was repeated for all 724 DTONs.

**Figure 10**

**DANGER TO NAVIGATION JUST OUTSIDE THE CHANNEL**




In performing the visual review of the DTONS involved in both the MinCPA and MaxCPA events resulted in:

1. **MinCPA (least depth over DTON).** Following visual inspection 86.5 percent of the affected DTONs were valid dangers to shipping.

[217] The 19 mentioned is the least depth of a dangerous submerged obstruction.

2. **MaxCPA (greatest depth over DTON).** Following visual inspection 83.5 percent of the affected DTONs were valid dangers to shipping.

## C. Annual Value of Chart

Applying the PID correction and the visual inspection correction and applying the average cost (2017 dollars) of an allision ($215,694) for Cargo, Tanker, Cruise, and Tug and Tow and applying the average cost (2017 dollars) of an allision ($63,420) for Fishing and Pleasure, the cost of allisions where the mariner was not able to navigate around the unseen danger for lack of a nautical chart can be calculated as:

Annual Value of Chart ($) = monthly number of vessels in danger circle x percent intersect DTON x percent DTONs that are dangerous to shipping x average cost of allision x 12 months

a. Cost of allisions where DTON depth and vessel draft data existed:

i. For cargo vessels:

Annual Value of Chart for MinCPA (minimum depth) =
2,780 x 0.3349 x 0.865 x $215,694 x 12 = $2,084.5 million

Annual Value of Chart for MaxCPA (maximum depth) =
1,036 x 0.3494 x 0.835 x $215,694 x 12 = $782.3 million

ii, For tanker vessels:

Annual Value of Chart for MinCPA (minimum depth) =
1,152 * 0.4028 x 0.865 x $215,694 x 12 = $1,038.9 million

Annual Value of Chart for MaxCPA (maximum depth) =
620 x 0.4435 x 0.835 x $215,694 x 12 = $594.3 million

iii. For cruise vessels:

Annual Value of Chart for MinCPA (minimum depth) =
89 x 0.5169 x 0.865 x $215,694 x 12 = $103.0 million

Annual Value of Chart for MaxCPA (maximum depth) =
31 x 0.4194 x 0.835 x $215,694 x 12 = $28.1 million

iv. For tug and tow vessels:

Annual Value of Chart for MinCPA (minimum depth) =
` 933 x 0.1040 x 0.865 x $215,694 x 12 = $217.2 million

Annual Value of Chart for MaxCPA (maximum depth) =
338 x 0.1036 x 0.835 x $215,694 x 12 = $75.7 million

v. For fishing vessels:

Annual Value of Chart for MinCPA (minimum depth) =
474 x 0.099 x $63,420 x 12 = $35.7 million

Annual Value of Chart for MaxCPA (maximum depth) =
139 x 0.108 x $63,420 x 12 = $11.4 million

vi. For pleasure vessels:

Annual Value of Chart for MinCPA (minimum depth) =
49 x 0.082 x $63,420 x 12 = $3.1 million

Annual Value of Chart for MaxCPA (maximum depth) =
5 x 0.108[218] x $63,420 x 12 = $0.4 million

b. Estimated cost of allisions where draft data was missing but DTON depth existed. It was calculated by assuming same ratio of MinCPA and MaxCPA to the number of events where DTON depth and draft data existed. Therefore:

i. For cargo vessels:

Annual Value of Chart for MinCPA (minimum depth) =
96 x 0.3349 x 0.865 x $215,694 x 12 = $72.0 million

Annual Value of Chart for MaxCPA (maximum depth) =
36 x 0.3494 x 0.835 x $215,694 x 12 = $27.2 million

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[218] The sample size was too small for the MaxCPA PID for Pleasure vessels; therefore, the MaxCPA PID value of Fishing was use.

ii. For Tanker:

Annual Value of Chart for MinCPA (minimum depth) =
269 x 0.4028 x 0.865 x $215,694 x 12 = $242.6 million

Annual Value of Chart for MaxCPA (maximum depth) =
145 x 0.4435 x 0.835 x $215,694 x 12 = $139.0 million

iii. For cruise vessels:

Annual Value of Chart for MinCPA (minimum depth) =
2 x 0.5169 x 0.865 x $215,694 x 12 = $2.3 million

Annual Value of Chart for MaxCPA (maximum depth) =
1 x 0.4194 x 0.835 x $215,694 x 12 = $0.9 million

iv. For tug and tow vessels:

Annual Value of Chart for MinCPA (minimum depth) =
1,420 x 0.1040 x 0.865 x $215,694 x 12 = $330.6 million

Annual Value of Chart for MaxCPA (maximum depth) =
514 x 0.1036 x 0.835 x $215,694 x 12 = $115.1 million

v. For fishing vessels:

Annual Value of Chart for MinCPA (minimum depth) =
693 x 0.099 x $63,420 x 12 = $52.2 million

Annual Value of Chart for MaxCPA (maximum depth) =
203 x 0.108 x $63,420 x 12 = $16.7 million

vi. For pleasure vessels:

Annual Value of Chart for MinCPA (minimum depth) =
1,539 x 0.082 x $63,420 x 12 = $96.0 million

Annual Value of Chart for MaxCPA (maximum depth) =
157 x 0.20 x $63,420 x 12 = $23.9 million

## V. VALUE OF CHARTS AND MARINE PILOTS IN DTON AVOIDANCE

### A. Nautical Charts

The nautical chart contains the necessary information for a mariner to safely navigate a vessel avoiding charted dangers to navigation. The mariner standing on the bridge of the ship is unable to see what lies under the surface of the water and thus cannot see where it is safe to operate. They are completely reliant on the nautical chart. One of the most important values of the nautical chart is that of making safe navigation possible.

To promote safe and efficient marine transportation, fishing and recreational activities, nautical charts provide vessel operators with essential data involving shorelines, water depths, anchorages, rip-tides, channel locations and dimensions and placement of navigational aids (e.g. lights, buoys, day shapes, channel markers, etc.). In addition, nautical charts promote safety through identification of DTONs. DTONs identify locations of rocks, reefs, wrecks and submerged or partially submerged obstructions which could result in an allision if not considered in vessel operations and trip planning.

The nautical chart is required by regulation. The U.S. Coast Guard (USCG) is responsible for establishing regulations that govern nautical chart and publication carriage requirements in U.S. waters. These regulations are found in Title 33 and Title 46 of the U.S. Code of Federal Regulations (CFR). Other recent Federal Register Notices issued by the USCG and NOAA also address current policies.

- Title 46 CFR - Shipping
- Title 33 CFR, Part 164 - Navigation and Navigable Waters, Navigation Safety Regulations
- Title 15 CFR, Part 995 - Certification Requirements for Distributors of NOAA Hydrographic Products
- Federal Register Notices
- July 14, 2004: Vol. 69, No. 134 - Carriage of Navigation Equipment for Ships on International Voyages
- August 15, 2002: Vol. 67, No. 158 - Carriage of Navigation Equipment for Ships on International Voyages
- June 10, 2002: Vol. 67, Number 111 - Identification of Items that are "Nautical Charts" under 1974 International Convention for the Safety of Life at Sea
- USCG Circulars

- Navigational and Vessel Inspection Circular No. 01-16 (NVIC 01-16) - Use of Electronic Charts and Publications in Lieu of Paper Charts, Maps, and Publications [219]

## B. Pilots

A maritime pilot, marine pilot, harbor pilot, port pilot, ship pilot, or simply pilot, is a mariner who maneuvers ships through dangerous or congested waters, such as harbors or river mouths. Maritime pilots are largely regarded as skilled professionals in navigation as they are required to know immense details of waterways such as depth, currents, and hazards, as well as displaying expertise in handling ships of all types and size. In order to obtain the title, maritime pilot, requires being an expert ship handler licensed or authorized by a recognized pilotage authority. Pilots are required by law in most major sea ports of the world for large ships.[220] Pilots use pilotage techniques that rely on nearby visual reference points and local knowledge of tides, swells, currents, depths and shoals that might not be readily identifiable on nautical charts without first-hand experience in certain waters.[221]

Navigation of a ship in United States pilotage waters is a shared responsibility between the pilot and the master/bridge crew. The compulsory state pilot directs the navigation of the ship, subject to the master's overall command of the ship and the ultimate responsibility for its safety. Pilots handle well over 90 percent of all large ocean-going vessels moving in international trade in U.S. waterways. The role and official responsibility of these pilots is to protect the safety of navigation and the marine environment on the waters for which they are

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[219] https://nauticalcharts.noaa.gov/charts/chart-carriage-requirements.html

[220] https://en.wikipedia.org/wiki/Maritime_pilot and https://www.americanpilots.org/pilotage_in_the_u.s_/index.php. Applies only to vessels in U.S. waters.

[221] https://en.wikipedia.org/wiki/Maritime_pilot#cite_ref-12

licensed.

While the pilot doesn't typically navigate with a nautical chart in the manner a ships mariner would, pilots commit large portions of the charts to memory. Pilot licensing requirements includes the memorization of the nautical charts covering the area of their expertise. They are expected to draw the chart or charts covering their area of license from memory. They maintain that knowledge by studying Notice to Mariners updates to the nautical charts as well as the changes made as new chart editions are published.

Pilots provide an essential service for the safe navigation of commercial vessels (Cargo, Tanker, and Cruise but not for Tug and Tow, Fishing or Pleasure vessels) in pilotage waters and are thus required by state and federal laws. Since both nautical charts and marine pilots are recognized as essential for safe navigation as evidenced by numerous regulations and laws requiring their use, the benefit from safe navigation is split evenly between the nautical chart and the marine pilot.

### C. Global Positioning System (GPS)

The Global Positioning System (GPS) is a satellite-based navigation system made up of a network of 24 satellites placed in orbit by the U.S. Department of Defense. GPS satellites circle Earth twice a day in a very precise orbit and transmit signal information to Earth. GPS receivers take this information and use triangulation to calculate the user's exact location. It is a very accurate positioning system employed on all commercial vessels and most recreational vessels for measuring accurately vessel's position, course and speed information for a more efficient traffic routing. This enables increased levels of safety and efficiency for mariners worldwide. While at sea, accurate position, speed, and heading are needed to ensure the vessel reaches its destination in the safest, most economical and timely fashion that conditions will permit. The need for accurate position information becomes even more critical as the vessel departs from or arrives in port. Vessel traffic and other waterway hazards make maneuvering more difficult, and the risk of accidents becomes greater.

## VI. Conclusions

Based on the aforementioned, benefits on Cargo, Tanker, and Cruise vessels range from $1,571.8million for MaxCPA to $3,543.3 million for MinCPA events. (Table 16).

**Table 16**

**ANNUAL NUMBER AND VALUE OF ALLISIONS**

| | MinCPA | | MaxCPA | |
|---|---|---|---|---|
| **VESSEL TYPE** | **ALLISIONS** | **VALUE OF ALLISIONS ($2017 Millions)** | **ALLISIONS** | **VALUE OF ALLISIONS ($2017 Millions)** |
| Cargo | 9,998 | $2,156.5 | 3,753 | $809.5 |
| Tanker | 5,941 | $1,281.5 | 3,400 | $733.3 |
| Cruise | 488 | $105.3 | 134 | $29.0 |
| Sub-Total | 16,427 | $3,543.3 **(Charts: $1,181.1)** | 7,287 | $1,571.8 **(Charts: $523.9)** |
| Tug and Tow | 2,540 | $547.9 | 884 | $190.8 |
| Fishing | 1,386 | $87.9 | 443 | $28.1 |
| Pleasure | 1,563 | $99.1 | 383 | $24.3.4 |
| Sub-Total | 5,489 | $734.9 **(Charts: $367.5)** | 1,710 | $243.2 **(Charts: $121.6)** |
| TOTAL | 21,916 | $4,278.2 | | $1,815.0 |
| TOTAL CHARTS | | $1,548.6 | | $645.5 |

Benefits on Cargo, Tanker, and Cruise were split equally between pilot services, GPS, and nautical charts. Therefore, the value of the nautical chart in DTON avoidance for Cargo, Tanker, and Cruise vessels ranges from $523.9 million to $1,181.1 million ($2017) per year. The individual estimated value for each, nautical charts and GPS for Tug and Tow, Fishing, and Pleasure vessels ranges between $121.6 to $367.5 million ($2017) per year. Collectively, based on average costs of an allision, savings from avoided allisions due to nautical charts in the U.S., was estimated to range between $645.5 million to $1,548.6 million ($2017) per year. Table 17 summarizes the value of the nautical chart as a DTON avoidance tool from all six types of vessels analyzed in this study and lists the confidence in the results as Very High[222].

**Table 17**

## ANNUAL VALUE OF NAUTICAL CHART FOR DTON AVOIDANCE

| ANNUAL BENEFIT VALUE ($2017 MILLION) | CONFIDENCE LEVEL[222] |
|---|---|
| $645.5 - $1,548.6 | VERY HIGH |

[222] In each benefit appraisal, a subjective assessment of the confidence of the estimate is made based on the quality of the underlying data, documented exactness of the relationship between nautical charts and resultant benefits and proximity to previous research findings.

# CHAPTER 4 – COMMERCIAL FISHING

## I. INTRODUCTION

In 2018 the U.S. Marine Economy (including goods and services) provided about $373 billion to the GDP and grew faster than the nation's economy as a whole. Between 2014 and 2018, marine related GDP increased by 5.8 percent as compared with a 5.4 percent increase in overall GDP. In 2018, businesses reported that the marine economy supported 2.3 million jobs.[223] It was estimated that almost 169 thousand commercial harvesters were employed in 2017 which represented over seven percent of total marine economy employment.[224]

Overall, the marine economy in the United States accounted for 1.9 percent ($397 billion) of current dollar GDP in 2019 and have average 1.9 percent from 2014 to 2019.[225] Between 2018 and 2019, the marine economy again outpaced the overall economy as measure by GDP (4.2 versus 2.2 percent) while businesses reported support of 2.4 million jobs in 2019.

Since 1950, commercial fish catch has almost doubled from 2.2 to 4.3 million metric tonnes in 2019. (Figure 1) During this time, the nominal value of fish catch was $5.6 billion in 2019, up from 326 million in 1950.[226] (Figure 2)

In 2017 the United Nations reported total employment in the U.S. commercial fishing

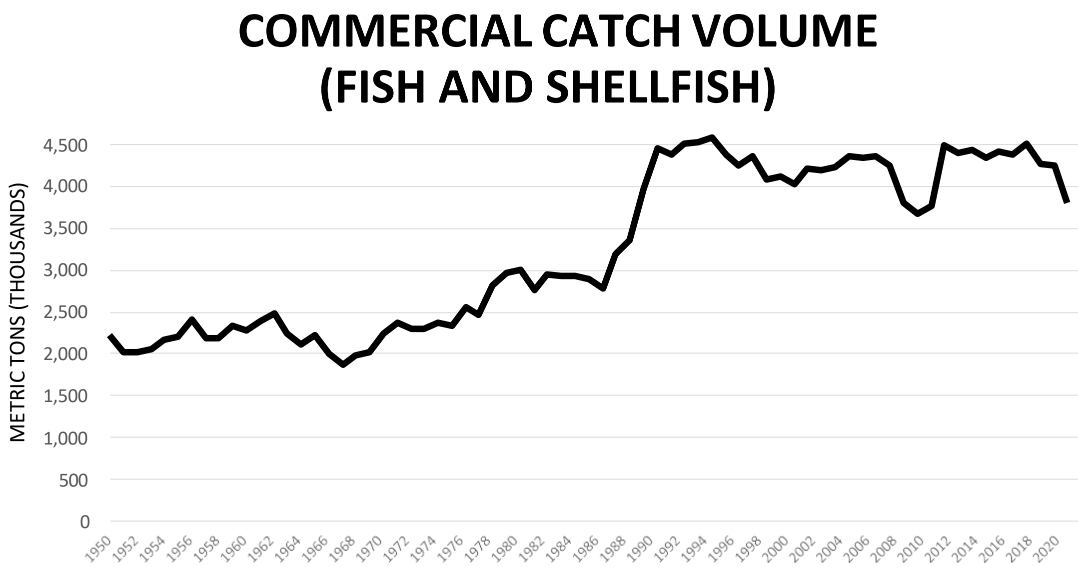
[223] NOAA. 2020. "Marine Economy in 2018 Grew Faster Than U.S. Overall". June 2.

[224] NOAA. Economic Impacts of the United States Seafood Industry, https://www.fisheries.noaa.gov/data-tools/fisheries-economics-united-states-interactive-tool. Downloaded June 10, 2021.

[225] Bureau of Economic Analysis, Table 3. Marine Economy Value Added by Activity as a Percentage of Gross Domestic Product.

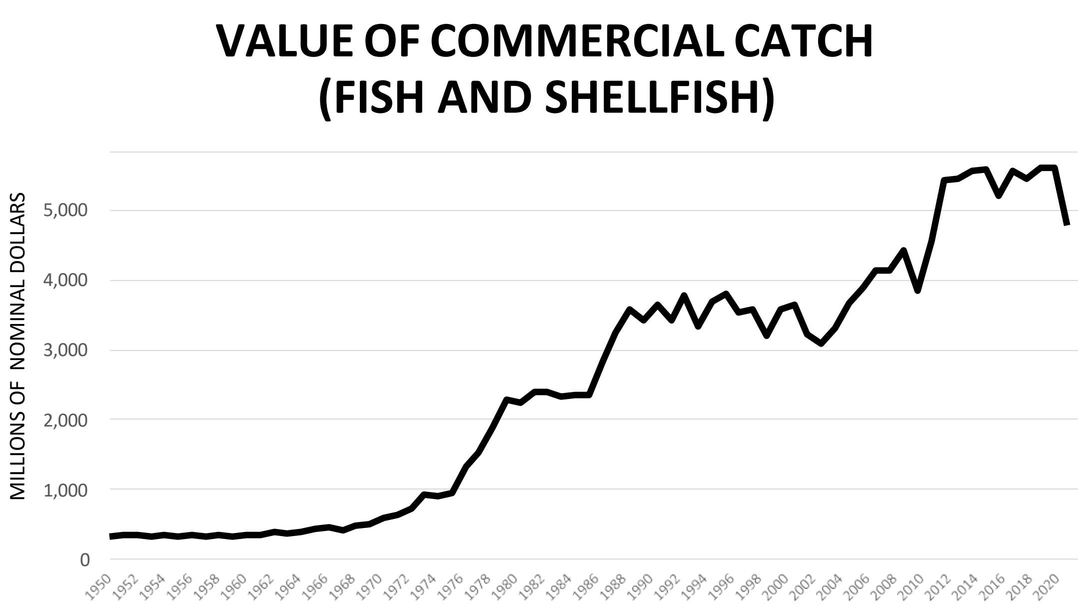
[226] During recessionary 2020, catch value declined almost 15 percent from 2019 levels reflecting a decline in catch weight by over ten percent.

**Figure 1**




Source: NOAA Fisheries

**Figure 2**




Source: NOAA Fisheries

industry approach 170 thousand among between the 25 to 27 thousand vessels that operated in the EEZ during 2017. In a report by The National Institute for Occupational Safety and Health

(NIOSH)[227] in 2020 suggested that there were approximately 39,000 commercial vessels in the United States from a Bureau of Labor Statistics study.[228] More recently, the National Transportation Safety Board (NTSB) later stated in September 2021:

> "*The commercial fishing industry remains largely uninspected and is a marine sector of concern," according to the NTSB announcement. "Approximately 58,000 U.S. commercial fishing vessels are in service today in the U.S.*[229]

## II. BACKGROUND

The chief importance of the nautical chart to the commercial fisherman is twofold: (1) safe navigation; and, (2) planning fishing operations. Just as all other vessel operators the marine fisherman is completely dependent on the nautical chart. While many might think of the large format printed paper chart as the nautical chart, commercial fishermen have for the most part switched to using some form of electronic chart product. It may be one of the chart plotters available with software packages that enable the vessel operator to plot a course to and from the fishing grounds to the home port avoiding all dangers to navigation. Without a nautical chart the vessel operators would be unaware of the location of submerged dangers the collision with could result in severe damage to the vessel or even its complete destruction. The depth of the water, the topography of the bottom, the type of bottom (e.g. rocky, mud, or sand), and the location of obstructions that might foul their fishing gear are all important to fishermen.

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[227] Centers for Disease Control and Prevention, The Institute for Occupational Safety and Health.2020. "Maritime Health and Safety", March 11. https://www.cdc.gov/niosh/maritime/industries/commercial_fishing.html

[228] BLS. 2019. Table 11b. Household data annual averages; Employed persons by detailed occupation and age. In: Current Population Survey. Washington, DC: U.S. Department of Labor, Bureau of Labor Statistics, https://www.bls.gov/cps/cpsaat11b.htmExternalexternal iconexternal icon

[229] https://www.nationalfisherman.com/national-international/ntsb-to-hold-fishing-vessel-safety-roundtable#:~:text=%E2%80%9CThe%20commercial%20fishing%20industry%20remains,service%20today%20in%20the%20U.S. Downloaded February 18, 2022.

Knowing the water depth is critical for properly setting the fishing gear nets, lines, or other dredging gear. Fish are known to inhabit waters of certain depths. Knowledge of the bottom topography, the location of rises, reefs, and ledges are some of the features fish have been known to congregate around. Knowledge of the type of bottom may be of importance. For example shellfish and bottom fish may prefer a sandy bottom to one that is rocky or muddy while other crabs and fish may prefer more rocky bottoms. These are just a few examples of what a fisherman might know about the type of fish they are focusing on for their fishing operations.

The location of obstructions on the bottom are important for the fisherman to be aware of in planning their operations so that their gear doesn't become entangled or damaged by the obstruction.

While the nautical chart is useful for operational planning the primary purpose and thus the design of the nautical chart is safe navigation. The data portrayed on the chart while very useful for fishermen is often not completely adequate. Fishermen have supplemented this information by keeping their own records including positions in a log book. More recently there are products like CMOR Mapping that are high-resolution seafloor maps for electronic chart plotters that show the vessel's exact location relative to ocean floor features. CMOR advertises that it has resolution as high as one meter showing "every ledge, coral head, and sunken culvert in unprecedented detail."[230]

## III. ENVIRONMENTAL CONSIDERATIONS

Observers such as Love (1997) have detailed several environmental conditions that are

[230] Refer to: https://www.cmormapping.com/

conducive to enhanced fish catch. (Table 1) Nautical charts in conjunction with timely accurate and complete knowledge of water depth, shorelines and seafloors as well as navigational hazards, information on tides and currents and local details of the Earth's magnetic fields, provide specific answers to each of these measurements.

**Table 1**

**BENEFICIAL USE OF CHARTS FOR FISHERMEN**

| FACTOR | CHART USE | EXPLANATION |
|---|---|---|
| Fish Habitat Depth | Location and Navigation | Species of fish frequently have preferred habitat depths |
| Habitat Location | Location and Navigation | Some species of fish prefer habitats centered on obstructions, man-made structures, reefs, rock shoals, etc. |
| Bottom Type | Location and Navigation | Some species prefer a specific bottom type (rocky, sandy, or mud bottoms) |
| Water Temperature | Navigation | Some species prefer feeding at the edge between warm and cold water (e.g., Gulf Stream). Fishermen plot the location of the edges of the Gulf Stream and then navigation there with a chart |
| Salinity Requirements | Navigation | For species with low tolerance for salinity changes fishermen can locate areas where freshwater plumes do not affect fish. Other species prefer lower salinity and will congregate near entrances to rivers. |

### A. Examples of Situations Where Charts Benefit Commercial Fishermen

Charts benefit both commercial and recreational fishermen by enabling them to identify prime fishing grounds and navigate to and from the sites safely. Many fishermen, particularly those chasing pelagic fishes such as tunas and swordfish, now use satellite images of the California coast which show sea surface temperatures. They look for regions where warm and cold oceanic fronts meet and they fish there. Mako shark and swordfish fishermen know that these species tend to stay on the warmer side of the temperature break, while blue sharks often remain on the cooler edge. This knowledge helps them target makos or swordfish but avoid blues, which are largely unmarketed. Fishermen often track the edge of the Gulf Stream where warm Gulf waters meet the cold Atlantic Ocean waters. Large predator fish frequently feed in this area.

Reef fishes often station themselves at the up-current side of the reef, in order to be the first predators to get a crack at whatever food is carried onto the reef by the current. Thus, often there will be a school of fishes on one end of the reef, but few on the other. In turn, the species which prey on these fishes may concentrate on the up-current end.

## IV. COMMERCIAL FISHING BENEFITS

Unlike recreational fishing, NOAA's Fisheries records the market value of commercial fishing catch. Commercial catch from 0 to 3 miles from shore from 2004 to 2019 has ranged between 1.1 and 1.7 million metric tonnes with an average of almost 1.4 million metric tonnes. Catch from 3 to 200 miles from 2004 to 2019 spanned between and 2.0 and 3.5 million metric tonnes and averaged over 2.8 million per year. (Table 2)

**Table 2**

**AVERAGE COMMERCIAL CATCH SUMMARY
(AVERAGE 2004 to 2019)**

| MEASURE | 0 to 3 MILES FROM SHORE | 3 to 200 MILES FROM SHORE | 0 to 200 MILES FROM SHORE |
|---|---|---|---|
| CATCH WEIGHT (Metric Tonnes) | 1,398,898 | 2,824,587 | 4,223,479 |
| CATCH VALUE (MILLIONS $2017) | $2,369 | $3,121 | $5,490 |
| AVERAGE VALUE / POUND ($2017) | $0.77 | $0.50 | $0.59 |

Overtime, the majority of commercial catch occurred with the U.S. Exclusive Economic Zone (EEZ). (Figures 3 and 4) Over the study period, catch within the EEZ represented 95.8

percent of catch weight and 92.0 percent of inflation-adjusted catch value. (Table 3)

While commercial fishermen utilize nautical charts data either directly or indirectly from another source, no empirical data exists as to the precise extent of that usage or the specific value of that information. Nevertheless, nautical chart information supports commercial fish catch whether it is where to navigate vessels, set lines or nets, or the location and depth of where to fish among other considerations.

**Figure 3**

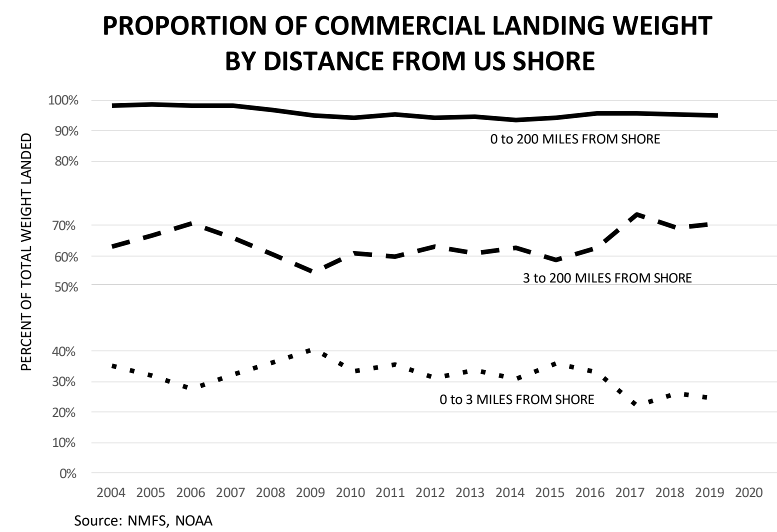



**Figure 4**

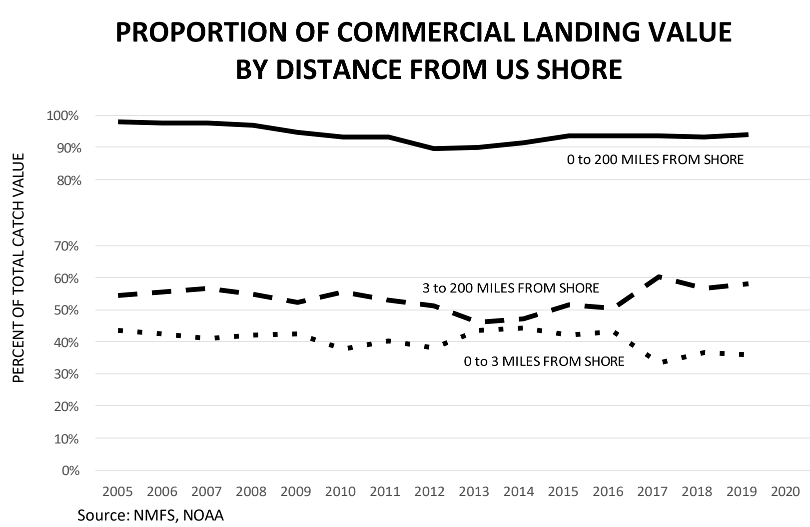


**Table 3**

## SUMMARY OF COMMERCIAL FISHING CATCH[231]

| YEAR | METRIC TONS LANDED (0 to 3 MILES FROM SHORE) | NOMINAL VALUE (000's DOLLARS) (0 to 3 MILES FROM SHORE) | METRIC TONS LANDED (3 to 200 MILES FROM SHORE) | NOMINAL VALUE (000's DOLLARS) (3 to 200 MILES FROM SHORE) | TOTAL METRIC TONS LANDED (ALL DISTANCES)[232] | TOTAL NOMINAL VALUE (000's 2017 DOLLARS) ALL DISTANCES[233] |
|---|---|---|---|---|---|---|
| 2004 | 1,565,689 | $2,176,874 | 2,821,305 | $2,763,463 | 4,467,173 | $5,066,349 |
| 2005 | 1,423,012 | $2,218,689 | 2,973,995 | $2,782,363 | 4,463,184 | $5,110,739 |
| 2006 | 1,210,526 | $2,132,534 | 3,088,441 | $2,795,441 | 4,373,958 | $5,041,671 |
| 2007 | 1,378,253 | $2,069,816 | 2,802,338 | $2,871,639 | 4,259,396 | $5,067,204 |
| 2008 | 1,407,652 | $2,307,839 | 2,361,060 | $2,991,890 | 3,890,450 | $5,467,997 |
| 2009 | 1,515,565 | $2,163,933 | 2,045,888 | $2,653,430 | 3,745,575 | $5,083,346 |
| 2010 | 1,324,587 | $2,204,442 | 2,400,506 | $3,254,240 | 3,952,394 | $5,861,443 |
| 2011 | 1,666,475 | $2,715,565 | 2,798,216 | $3,593,125 | 4,676,261 | $6,760,150 |
| 2012 | 1,445,441 | $2,530,399 | 2,916,731 | $3,404,622 | 4,625,068 | $6,632,548 |
| 2013 | 1,595,098 | $3,052,439 | 2,877,187 | $3,220,737 | 4,733,397 | $6,982,787 |
| 2014 | 1,418,853 | $2,939,454 | 2,872,763 | $3,127,581 | 4,594,751 | $6,637,485 |

[231] Fish and shell fish catch.

[232] Includes high seas and off foreign shores.

[233] Ibid.

## ESTIMATED GROSS BENEFITS PROVIDED BY NAVIGATIONAL CHARTS IN THE UNITED STATES

| | | | | | | |
|---|---|---|---|---|---|---|
| 2015 | 1,666,323 | $2,524,664 | 2,730,355 | $3,097,615 | 4,656,507 | $6,013,275 |
| 2016 | 1,490,965 | $2,595,243 | 2,838,646 | $3,036,044 | 4,532,556 | $6,025,801 |
| 2017 | 1,039,016 | $2,007,879 | 3,445,876 | $3,611,179 | 4,688,385 | $5,997,642 |
| 2018 | 1,157,292 | $2,204,940 | 3,087,791 | $3,409,152 | 4,457,253 | $6,016,799 |
| 2019 | 1,077,626 | $2,058,810 | 3,132,286 | $3,316,668 | 4,438,728 | $5,722,802 |

Source: "*Fisheries of the United States, Current Fisher Statistics*", National Marine Fisheries Service, NOAA for involved years.

Recognizing the underlying logical contribution of navigational charts to commercial fishing, a Nordhaus approach was employed where a very conservative figure of one percent of average annual catch value (about $58 million within the U.S. EEZ) was attributable to nautical charts.[234]

Kite-Powell (2007) determined a willingness to pay for commercial vessel charts at $2,600 per vessel per year.[235] This figure ranged between $3,200 for self-propelled ships and $1,850 for tug/tows. Adjusted to 2017, these average annual willingness to pay figures would exceed $3,000 per vessel, $3,700 for self-propelled ships and $2,100 for tug/tows. He concluded that total commercial vessel benefits from charts were between $35.8 to 39.8 million for existing and "ideal" charts, respectively. Employing $2017 values for self-propelled ships, current commercial fishing vessel benefits would range between $41.4 to $46 million.[236]

The Kite-Powell study was done in 2007 when mariners were using a combination of chart types. The Electronic Navigational Chart (ENC) was the ultimate in nautical charting. Being vector information, it was information rich, easily updated and able to be rescaled to give the mariner greater information as well as being able to be used with the most advanced navigation systems (Electronic Chart Display and Information Systems (ECDIS). These charts would be the equivalent of the Kite-Powell "ideal" chart. There was also a raster nautical chart that was a digital picture of the paper chart with the same one-scale data. It was able to be used

[234] Applying a variation of the rule of thumb developed by Nordhaus originally employed in estimating the relationship between the value of weather and climate forecasts and economic activities that are sensitive to weather /climate trends. Absent more detailed information, relationships between total benefits and those associated with a specific activity tends to be on the order of (at least) one percent.

[235] Page 23.

[236] Based on estimates of 2,223 self-propelled and 1,965 towboats user U.S. flag and an additional 7,600 foreign flag vessels in U.S. waters for a total of less than 12,000 vessels.

with navigation software that was less capable than the ECDIS. Lastly, there was the older paper chart format which would be the "existing" chart mentioned in the Kite-Powell study. In 2017, the base year of this study the ENC was the standard nautical chart with the raster being used by smaller boat operators. Now, in 2022, the paper and raster chart products are being eliminated as part of the Coast Survey's "Sunsetting" program. The concept of "ideal chart" also included the chart being waterproof. With the migration of the nautical chart from a physical paper chart to a digital data set displayed on an ECDIS or as a raster file displayed on a chart plotter or even a cell phone with one of the many aps the requirement for waterproof is no longer an issue.

Levinson (2012) calculated the commercial fishing fleet size at almost 60 thousand vessels from a 2010 National Transportation Safety Board report and estimated an annual benefit between 78.8 to $87.6 million ($2011) [237] These translate to between $90.6 to $100.7 million in $2017 dollars.

## V. CONCLUSIONS

Collectively, commercial fishing benefit estimations are significantly impacted by the number of fishing vessels operating in U.S. EEZ waters. (Table 4) Given the current low barriers to obtain and use nautical charts (e.g., chart plotter or cell phone applications), a large number of smaller fishing vessels that may not technically be required to carry charts most likely actually do so.

[237] National Transportation Safety Board, "Commercial Fishing Vessel Count by State/Jurisdiction and Federally-Documented by the U.S. Coast Guard," http://www.ntsb.gov/news/events/2010.fishing_vessel/background/USCG%202008%20CFVs%20Cont%20vt%

**Table 4**

## SUMMARY OF COMMERCIAL FISHING BENEFITS FROM NAUTICAL CHARTS ($2017)

| APPROACH | MILLIONS ($2017) |
|---|---|
| Kite-Powell (2007) Employing about 12,000 vessel fleet size estimate and $2017 value ($3,700) for self-propelled vessels. | $ 44.4[238] |
| Current Study (one percent of the value of commercial catch) from 2017 reported value[239] | $58.4 |
| Current Study (Updated Kite-Powell with $2017 dollar value ($3,700) for self-propelled vessels and NTSB (2021) reported self-propelled fishing vessel count of 58,000 vessels). | $214.6 |

Based on the number of commercial fishing vessels operating in U.S. waters, the annual benefit from nautical charts is thought to approximate $215 million. Table 5.

**Table 5**

## ANNUAL BENEFITS FROM NAUTICAL CHARTS DERIVED FROM COMMERCIAL FISHING IN U.S. WATERS

| ANNUAL BENEFIT VALUE ($2019 MILLION) | CONFIDENCE LEVEL[240] |
|---|---|
| $214.6 | MEDIUM |

[238] For ”ideal” charts

[239] Average $2017 from 2004 to 2019, National Marine Fisheries Service, NOAA, p. 9, September, 2018.

[240] In each benefit appraisal, a subjective assessment of the confidence of the estimate is made based on the quality of the underlying data, documented exactness of the relationship between nautical charts and resultant benefits and proximity to previous research findings.

# CHAPTER 5 – RECREATIONAL BOATING

## I. INTRODUCTION

The concept of leisure is as old as mankind itself; its definitional nature being culturally specific (Neulinger, 1971, 1974). Therefore, it is beneficial for the researcher not to seek one definition of leisure to apply to all mankind, but instead conceptualize the development of the leisure concept as man himself has changed. In this manner the behavioral foundations of beliefs, attitudes, behavioral intentions, and actual elicited actions can be incorporated.

Classically conceptualized, leisure was the state of existence, noted by "meaningful and nonutilitarian" activity (DeGrazia, 1962). The ancient Greeks placed leisure above all else in that both work and routine daily activities were placed in subordinate positions to leisure. Aristotle, revealing the intrinsic goodness of leisure, defined it as any activity *"for its own sake and its own end"* (Brown, 1969).[241] Stebbins (2006) also believed that contemplation was a leisure activity.[242] Ouellette et al. (2004, 2005) also makes a critical observation in that it is important to find time for reflection that leads to personal revitalization which is achieved through getting to know oneself better.[243]

The need for global analysis has been identified by several researchers. Kretsch (1963) states:

> *"While much worthwhile and much nonsense has been written about the values of outdoor recreation, it remains that there is an important economic demand for it which is clearly demonstrable. However, we have been quite ill-prepared to include the values of*

[241] See DeGrazia page 13.

[242] In Stebbins' analysis, contemplation is seen as both a leisure and non-leisure activity.

[243] In essence, by knowing oneself better, activities which are restorative in nature (e.g., recreation) can be sought out when one feels the need for "recharging".

> *outdoor recreation in the social calculus in ways that lead to a better allocation of our land and water resources."*[244]

Neulinger (1974) observed that, gradually in philosophic thought, the ideal of contemplation gave way to a search for understanding using nature's laws, at first through alchemy, astrology, magic but later by way of medicine.[245]

More than anyone else, Thorstein Velben (1953) brought the concept of leisure into the American arena of thought. Velben in this, the *Theory of the Leisure Class,* satirically documented the group of very rich Americans for whom work in its traditional sense was unnecessary. He viewed work as man's only honorable profession. Seppo (1980) in evaluating the need for recreation stated that the economic person should be replaced by the psychological person.[246]

The role of recreation has increased in modern times owing to enhanced work productivity, affluence, population trends and increased commercialization of recreational opportunities. The *"need to do something for recreation"* is cited by Daniels (1995) as an essential element of human biology and psychology".

Earlier Burt et al. (1971) wrote:

> *"The need for objective, quantitative criteria to evaluate investments in outdoor recreation is acute and recognized by most public agencies delegated responsibility for allocation of public funds among such investments"*[247]

[244] Refer to Knetsch, page 387.

[245] Refer to page 5.

[246] Refer to Seppo, page 394.

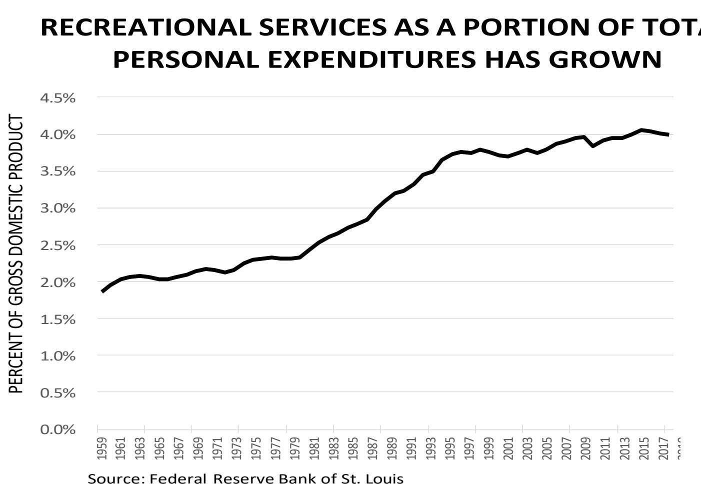
[247] Refer to Burt, page 813.

West (1977) details those previous attempts at forecasting future recreational demand has been inconsistent. He states that for recreational forecasts to be accurate:

> *"A more adequate projection methodology must rest on a sound sociological understanding of how underlying social forces can determine stability and change in group-specific participation rates. An introduction to the kind of understanding needed requires a discussion of status group theory and its relation to leisure lifestyles."* [248]

More recently, Dardis et al. (1981) suggested that income plays a major role in concert with demographic characteristics in determining household expenditures on recreation. Dardis concluded that recreation expenditures were positively related to income and education, and negatively related to age of household head. Households headed by minorities and households with young children spent less on recreation than other households. Location also proved to be a significant variable with urban households spending proportionately more on recreation expenditures than rural households.

**Figure 1**

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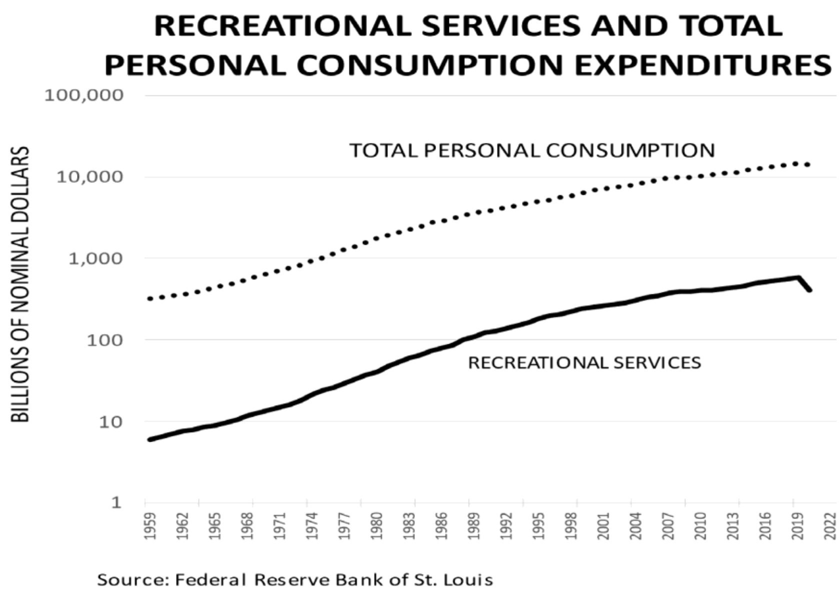
[248] Page 198.

Over sixty years (1959-2019), the level of total personal and recreational expenditures increased significantly. (Figure 1) During this time the portion of total expenditures represented by recreational expenditures more than doubled from two to four percent. The need for recreation thorough history has been well documented from social, anthropological and personal perspectives. Given the long-term relational growth between total personal consumption and acquisition of recreational services future leisure purchases are not foreseen to diminish. (Figure 2)

**Figure 2**




## II. RECREATIONAL BOATING EXPOSURE AND EXPENDITURES

In a 2003 study for the United States Coast Guard (USCG), Strategic Research Group observed that over 70 million Americans enjoyed recreational boating with over 13 million registered recreational vessels. The National Marine Manufacturers Association (NMMA) stated that recreational boating and fishing involved 16.7 million boats in 2010.[249] National retail spending on inland and coastal recreational boating was $30.4 billion.[250]

**Table 1**

**SIZE AND ACTIVITY OF THE RECREATIONAL BOATING INDUSTRY**

| BOAT TYPE | NUMBER OF BOATS | AVERAGE NUMBER OF DAYS USED PER YEAR[251] | AVERAGE NUMBER OF HOURS ON WATER PER USE DAY | AVERAGE NUMBER OF PEOPLE ABOARD PER USE DAY | BOATING PERSON HOURS (MILLIONS) |
|---|---|---|---|---|---|
| Power Boats | 10,147,000 | 12.0 | 6.0 | 2.7 | 2,035 |
| Sailboats | 735,000 | 11.1 | 7.8 | 2.4 | 154 |
| Pontoon Boat | 854,000 | 14.9 | 4.1 | 3.8 | 220 |
| Personal Water Craft | 1,704,000 | 11.0 | 4.7 | 2.3 | 212 |
| Canoe | 2,508,000 | 8.6 | 6.3 | 2.3 | 362 |
| Kayak | 3,916,000 | 11.2 | 4.6 | 1.3 | 280 |
| Row/Inflatable/Other Boat | 1,747,000 | 10.0 | 6.8 | 2.4 | 322 |
| Total | 21,611,000 | 11.3 | 5.7 | 2.4 | 3,584 |

Source: USCG, 2012 National Recreational Boating Survey, Table 40, Page 63.

By 2012, an updated USCG's survey suggested that more than 32.3 million of 118.1 million households (27.3 percent) in the U.S. had at least one member who boated during in 2012. They also reported that over 21.6 million boats of all kinds were used in the U.S. during 2012.[252] (Table 1) In 2019, the U.S. outdoor recreation economy accounted for 2.1 percent ($459.8) of current dollar gross domestic product. Boating and fishing was the dominant area of value added among outdoor recreational activities at $19.9 billion.[253] (Figure 3)

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[249] NMMA, Table 1.3

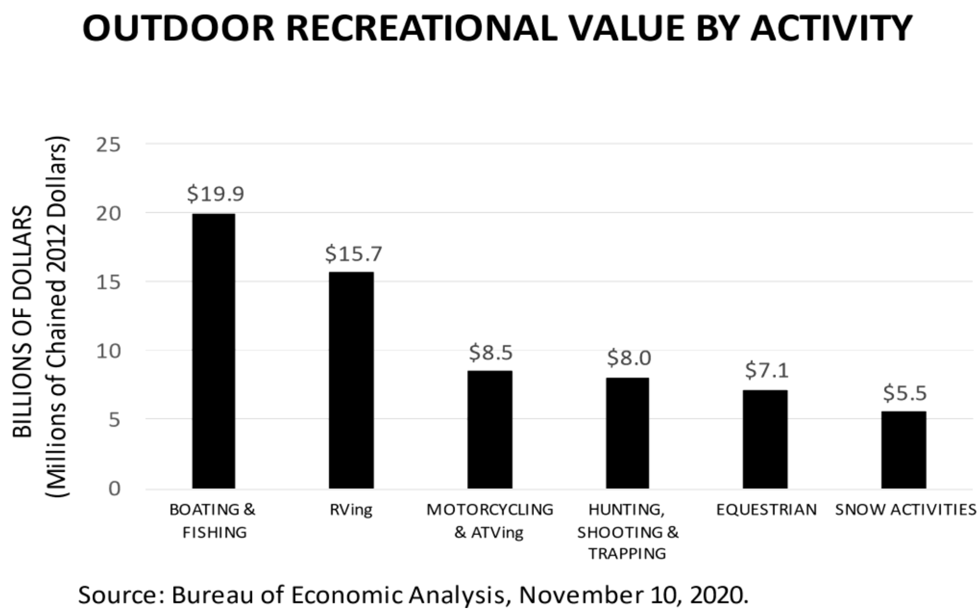
[250] NMMA, Table 5.1

[251] Number of trips

[252] Source: USCG, "National Recreation Boating Survey", 2012. Table 40, Page 63.

[253] Value added is the selling price of the good or service minus costs of the materials and components to produce that good or service.

**Figure 3**




A 2018 study by the National Marine Manufacturers Association (NMMA) reported the majority of economic impact is concentrated in 31 coastal states and estimated that 141.6 million Americans experience recreational boating.[254] (Table 2) About 8.9 million (52.6 percent) of all boats can be characterized as power boats (45.5 percent), sail boats (3.3 percent) and pontoon boats (3.8 percent.) which are more likely to use charts than the remaining types of watercraft. (Figure 4)

[254] States with coastlines on the Atlantic, Pacific, Gulf coasts and Great Lakes

**Table 2**

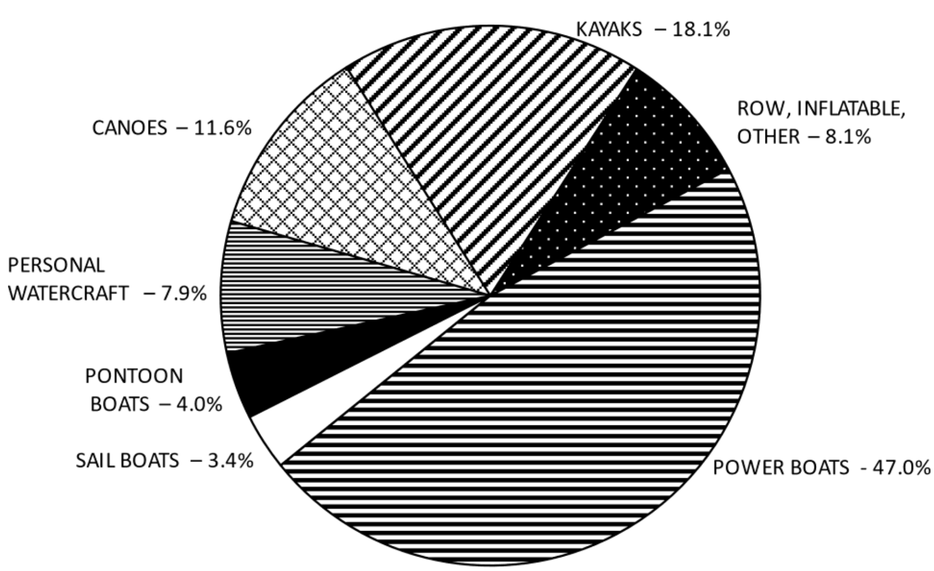
## IMPACT OF THE RECREATIONAL BOATING INDUSTRY

| | TOTAL UNITED STATES | 31 COASTAL STATES | 31 COASTAL STATES AS A PERCENT OF TOTAL |
|---|---|---|---|
| ANNUAL ECONOMIC IMPACT ($ Billions) (Manufacturers, suppliers, sales and service, boating activities, and business tax revenues) | $170.3 | $142.7 | 83.8% |
| JOBS | 691,149 | 586,376 | 84.8% |
| NUMBER OF BUSINESSES | 35,277 | 31,019 | 87.9% |
| REGISTERED BOATS | 11,900,000[255] | 9,632,244 | 80.9% |
| ANNUAL SALE OF BOATS AND MARINE PRODUCTS AND SERVICES ($Billions) including Maintenance, storage, fuel, insurance, taxes and services | $42.0 | $18.2 | 43.3% |

Source: National Marine Manufacturers Association 2018 Recreational Boating Statistical Abstract, 2018 Boating Economic Impact Study and 2016 Recreational Boating Participation Study.

**Figure 4**

## TYPES OF RECREATIONAL BOATS




Source: USCG, National Recreational Boating Survey, 2012, page 74.

[255] Many smaller craft (e.g., kayaks, personal watercraft, rowboats) many may not require registration . Collectively, these craft accounted for almost 9.9 million craft in the 2012 USCG study the approximate difference between NMMA and USCG estimates.

## III. IMPORTANCE OF NAUTICAL CHARTS

Recreational boaters suffer from the same major disadvantage that all mariners do. They are unable to see what lies below the surface of the water for any appreciable distance. To navigate safely the boater must have knowledge of the water depths, shoals, and channels, the location of aids to navigation and landmarks, the location of ports, harbors, marinas, dock facilities and boat ramps. The boater cannot avoid a submerged danger they cannot see unless they use a nautical chart that shows the location of all known dangers in the area.

There are more than 255 thousand dangers to navigation located on NOAA nautical charts almost 160 thousand of which are located between the shore and two miles off shore. This is the area frequented by recreational boaters.

### A. Boaters Cannot Avoid the Dangers They Cannot See

While large ships are required by law to carry up-to-date nautical charts it is left to the discretion of the recreational boater.

An easier to use format for recreational boaters is a paper book chart (BookletCharts™) which are reduced scale copies of NOAA paper nautical charts divided into a set of a dozen 8.5" x 11" pages that show different portions of a chart that can be downloaded and printed at home. BookletCharts™ are available free on the Web, cover the 95,000 miles of U.S. coastline and the Great Lakes, and are favored by recreational boaters. These are usually spiral bound and printed

[256] Chapman Piloting and Seamanship 68th Edition, 2017, Hearst communications, Inc. p.50.

on water proof material.[257]

Available to boaters are also U.S. Coast Pilot nautical books that cover a variety of important supplementary information such as channel descriptions, anchorages, bridge and cable clearances, currents, tide and water levels, prominent features, pilotage, towage, weather, ice conditions, wharf descriptions, dangers, routes, traffic separation schemes, small-craft facilities, and Federal regulations applicable to navigation. Additionally, on April 1, 2021, NOAA's Office of Coast Survey released NOAA Custom Chart version 1.0, a dynamic map tool which enables users to create their own paper and PDF nautical charts derived from the official NOAA electronic navigational chart (NOAA ENC®), NOAA's premier nautical chart product.[258]

Boaters are rapidly moving away from the old style of analog paper chart products to the more useful electronic chart products. Fraser (2021) on the reality of modern boating in stating *"the general boating public now relies almost exclusively on electronics."*

**B. Chart Plotters and GPS Receivers**

A wide variety of handheld and installed chart plotters integrated with GPS receivers are now available from many manufacturers.

**1. Chart plotters**

A variety of chart plotters are available for use on recreational boats with a protected space to keep the electronics dry. These systems are usually paired with a GPS receiver to enable the mariner to locate their position on the chart plotter chart image.

[257] West Marine web site. https://www.westmarine.com/WestAdvisor/Selecting-Paper-Charts

[258] Refer to: https://nauticalcharts.noaa.gov/updates/category/recreational-boating/.


Example of SITEX Chart Plotter. The unit needs a separate GPS receiver to integrate the vessels position on the chart background.

Chart Plotters are hardwired in the recreational boat and are suitable for larger boats where they can be protected from the elements. *Raymarine* and *Simrad* are examples of such products.[259] These typically cost about two thousand dollars.

**2. Cell phone chart navigation apps**

Mariners not wanting to purchase expensive chart plotter systems may opt for the numerous apps available for the ubiquitous cellphone. The chart image is linked to the cell phones GPS receiver so that the users position on the chart can be determined and monitored during boating operations. These apps are very inexpensive. The disadvantage of these systems is the small screen format. There are a great many nautical chart navigation applications for small formats (e.g., Apple iPhones or Android cell phones. INav X: Marine Navigation is one example.[260] *Marine-US East* is another application which covers the East region of the U.S. It has plenty of points of interests and has very useful charts too. It lets the boater check tides and

[259] Raymarine Axiom 12 - 12" Multi-Function Display Chart plotter E70368-00, https://www.wmjmarine.com/e70368-00-101.html, Furuno GP170 IMO GPS Navigator, https://www.wmjmarine.com/marine-electronics-gps-furuno-gps-furuno-gps.html and Simrad Cruise 9 Fishfinder/Chart plotter, https://simrad.factoryoutletstore.com/Category/CategoryListNoCache.aspx?

[260] iNavX: Marine Navigation APP Advertised as the world's #1 handheld Chart plotter. Access marine charts, maps, weather, AIS and more! iNavX is the only app to give you complete worldwide chart coverage, from all your favorite charts providers, including Navionics!. Available for $4.99. https://apps.apple.com/us/app/inavx-marine-navigation/id286616280

do many other things on their iPhone. *Navionics* has plenty of other apps for lakes, and other areas of our world.[261]

Now with marine navigation / GPS positioning cell phone apps with their nautical chart backgrounds as commonly available as driving directions / GPS positioning with their road map backgrounds it is difficult to claim that mariners do not have access to a nautical chart anytime they are within cell phone coverage.

MX Mariner - cost $9.99

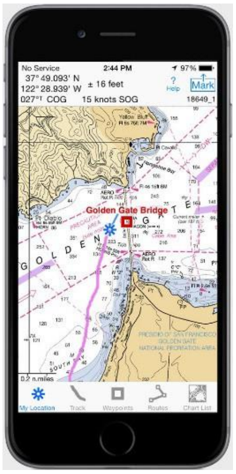
NOAA Raster Chart image

https://www.boatus.com/expert-advice/expert-advice-archive/2019/december/best%20marine-navigation-apps-for-2020

iSail GPS – costs $7.99

NOAA Raster Chart image

https://www.boatus.com/expert-advice/expert-advice-




In U.S. waters all nautical chart products whether paper or electronic are either direct copies of official NOAA Office of Coast Survey nautical charts or are derived directly from their data and may have other value-added information included.

An important consideration in the use of any chart plotter or cell phone nautical navigation display is the smaller formats of the electronic screens make it very difficult to picture the entire operational area. What may be readily apparent on a large format nautical chart can be obscured on small format electronic screens. This is especially true for voyage planning in unfamiliar waters. The large format of the paper chart enables the user to view the entire area of

261 https://apps.apple.com/us/app/marine-us/id376844755

the voyage. This is particularly helpful in selecting the most economical course or identifying areas that might be of interest, or perhaps most importantly, identifying the vessel track that will keep the vessel away from the invisible dangers beneath the water surface. Once the desired track is decided the mariner can utilize any of the popular electronic chart formats to navigate.

In a survey of recreational boaters in 2005-2006 Kite-Powell (2007) found that an overwhelming majority of recreational boaters carry some chart products such as NOAA paper, raster or vector charts or copies of NOAA products sold by private vendors. He stated:

> *"Nautical charts and chart data play an important role in enabling the activities of both commercial vessels and recreational boats. Charts are "necessary for the vessel to operate efficiently, safely and legally."*[262]

He also noted that only 15% of boaters responded that they do not carry charts most of those saying that they were familiar with the waters they boated in.

### C. U.S. Coast Guard & Carriage Requirements

While large ships are required by law to carry up-to-date nautical charts it is left to the discretion of the recreational boater. Chapmans Piloting and Seamanship tells the recreational boater:

> *"The conscientious skipper however, will always have at hand the proper charts for the waters he is traveling on. These together with the appropriate navigation tools, will do much to ensure the safety of his craft and those on board."*[263]

The U.S. Coast Guard (USCG) has not published regulations requiring recreational boaters to carry up-to-date nautical charts. However, they recognize the value of nautical charts

[262] Kite-Powell, Page 31.

[263] Chapman Piloting and Seamanship 68th Edition, 2017, Hearst communications, Inc. p.116.

and strongly encourage recreational boaters to carry charts for the waters they plan to navigate. The USCG's states, "One of the most important tools for safety navigating waterways is a nautical chart. Today, many recreational boaters use GPS receivers and perform electronic waypoint navigation. Although GPS can tell you where you are in terms of latitude and longitude, it cannot show what is around or beneath the boat, or what obstacles may be in the way. Changes brought about by people and nature require that nautical charts be constantly maintained and updated to aid safe navigation."[264] In the USCG's Boaters Pre-Departure Checklist it lists Charts of the Area and Navigation Tools in the list of recommended Equipment and supplies.[265]

## IV. RECREATIONAL BOATING TYPES OF OPERATIONS

Boaters operate either in waters they are familiar with or waters they have little or no knowledge.

### A. Boating Operations in Familiar Waters

Boaters operating in waters they know well may not need to constantly refer to a nautical chart during their recreational activity (e.g. fishing, water skiing, sightseeing, etc.). They have piloted in these waters many times and have developed a local knowledge of the waters that would include location of dangers, landmarks, general water depths, applicable aids to navigation, local tides and currents and perhaps the location of fishing spots. Boaters may have gotten much of their information from a nautical chart on the wall of the marina or yacht club, at the fuel station or even at the fishing tackle shop, or by talking with other boaters or marina

[264] USCG, A Boater's Guide to the Federal Requirements for Recreational Boaters. Page 45

[265] Ibid, Pages 70-71.

personnel who told them about dangers to watch out for. Continued discussions with locals can keep them abreast of changes in local conditions such as a new obstruction or changes in water depth from siltation or storm damage. The point being is that the important information from the chart is disseminated in ways other than the boater purchasing a nautical chart. In a study covering a 2005 and 2006 survey, Kite Powell (2007) found almost 40 percent of respondents to his study that did not use a chart reported "familiarity with local waters / "no need"" as the reason why they did not use chart products.[266]

Covering recreational boaters between September 2001 and September 2002, a study by the Strategic Research Group (2003) for the USCG reported that 31 percent carried navigational charts, 37 percent carried general maps and 44 percent carried a compass.[267] Later, Kite-Powell (2007) from a 2005 and 2006 study reported that 85 percent of all survey respondents reported carrying a chart product on board their vessels.[268] As he reported *"A total of 96 respondents (24% of total) indicated they do not use chart products either all or some of the time*"[269], this suggests about 69 percent of recreational boaters used charts at least some portion of time.[270]

Boaters may find that they don't need to refer to a nautical chart during boating operations in familiar waters . This was especially true when charts were only in unwieldly, large format paper sheets. Now with the advent of cell phone apps coupled with the cellphone GPS receiver mariners have a backup chart navigation system in the event of poor visibility (e.g.

[266] Table 9, pages 11-12. (38 out of 96 responses)

[267] Page 92.

[268] Page 9. 15 percent of all respondents reported that did not carry a chart product on board.

[269] Page 12.

[270] 76 percent use charts of 85 percent who carry them

rain, fog, darkness, etc.)

### B. Boating Operations in Unfamiliar Waters

Part of the enjoyment in recreational boating is visiting new areas and exploring unfamiliar waters. Boaters will go to other areas they are not familiar with and find they don't know where dangers to navigation exist, shoals, obstructions, marina and channel depths, aids to navigation, and landmarks. In these cases, they need to rely on a nautical chart at least in the voyage planning stage. Larger recreational boats will have a chart plotter and perhaps a set of paper charts of the area for voyage planning and general reference. A navigation app on their cell phone is a great backup for way point navigation.

In U.S. waters all nautical chart products whether paper or electronic are either direct copies of official NOAA Office of Coast Survey nautical charts or are derived directly from their data and may have other value-added information included.

## V. RECREATIONAL BOATING ACCIDENT REPORTING

The USCG has the legal responsibility to collect, analyze, and publish recreational boating accident data and statistical information for the fifty states, five U.S. territories, and the District of Columbia. Federal law requires the operator – or owner to file a boating accident report with the State reporting authority when, as a result of an occurrence that involves a boat or its equipment:

- A person dies;
- A person disappears from the vessel under circumstances that indicate death or injury;
- A person is injured and requires medical treatment beyond first aid;
- Damage to vessels and other property totals $2,000 (lower amounts in some states and territories) or more; or,

- The boat is destroyed.

Annually, the USCG compiles statistics on reported recreational boating accidents referred as the Boating Accident Report Database (BARD). These statistics are derived from accident reports that are filed by the owners / operators of recreational vessels involved in accidents. The fifty states, five U.S. territories and the District of Columbia submit accident report data to the USCG for inclusion in the annual Boating Statistics publication and the USCG boating recreational accident database. While the USCG has maintained the boating accident data for almost two decades it hasn't been until 2005 that the data can be considered reliable from all states and territories.

The database contains information on:

- Year – of the accident
- State – in which accident took place
- Water – name of the body of water the accident occurred in
- City – nearest city or town
- County – name of the county nearest the accident
- Additional Location Information – a more exact descriptor of the location
- Dead – number of deaths attributed to the accident
- Injuries – number of injuries attributed to the accident
- Damage – damage estimate
- Cause 1 – major result from accident (e.g. grounding, collision[271], flooding, etc.)
- Cause 2 – major reason directly leading to the accident

[271] In this database allisions were not separately identified but included with collisions.

- Cause 3-5 – issues leading up to the accident. Cause 3 issues are more significant to the accident than are those for Causes 4 and 5.

## VI. RECREATIONAL BOATING ACCIDENT OVERVIEW

In this analysis, recreational accidents were limited to those accidents involving vessel collisions, allisions and groundings defined as:

- Collisions – the striking of a (moving) vessel upon another (moving) vessel;[272]
- Allisions[273] – the striking of a moving vessel with a stationary object (another vessel, bridge, dock, etc.); and,
- Groundings – the impact of a vessel on the seabed or waterway side (within or outside of the channel).[274]

Nautical chart information can be of help to recreational boaters in avoiding groundings as well as allisions. Vessel groundings usually occur when the mariner becomes disoriented and navigates into an area with a shoal. Allisions with fixed objects whether visible or submerged could be mitigated with proper use of a navigational chart and accurate positional information.

During the 2011 to 2018 study period a total of 34,287 accidents were reported which represented all mishaps from all causes across all states, commonwealths and territories in the US. Nearly 26 percent of all recreational boating accidents causes in all states (8,889) were the result of grounding, collision or allisions. Accidents that occurred in non-coastal

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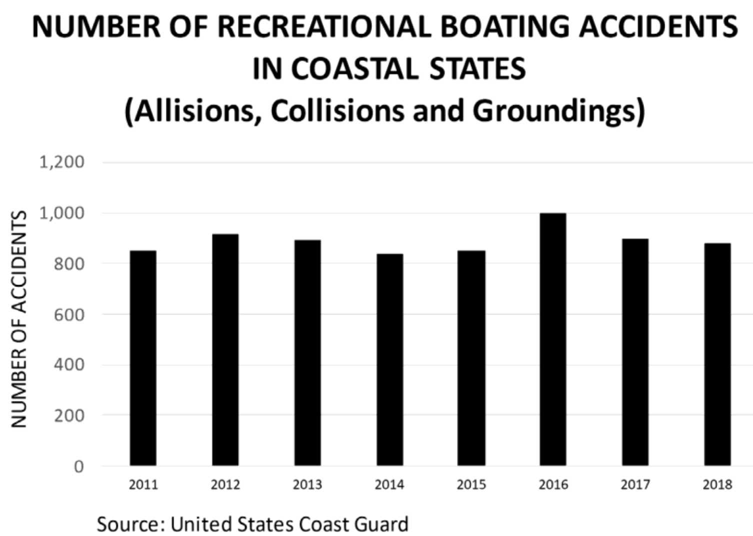
[272] Includes BARD reported collision with floating object and collision with a recreational vessel

[273] BARD does not report allisions under that nomenclature. Instead, BARD reports collisions with fixed objects as well as (fixed) submerged objects.

[274] This also includes incidents characterized as "aground".

states and U.S. territories were also eliminated leaving 7,108 events.[275] (Figure 5)

**Figure 5**




During 2011 to 2018**,** these 7,108 accidents occurred resulting in 437 deaths, 4,439 injuries and total property damages of almost $194 million nominal dollars ($2017). Total deaths and accidents as well as property damages from all causes remained fairly consistent over time. (Figures 6 and 7).

[275] This excluded accidents on rivers and lakes. NOAA does develop charts in those areas. The United States Army Corps of Engineers provides Inland Electronic Navigational (IENC) charts.

**Figure 6**

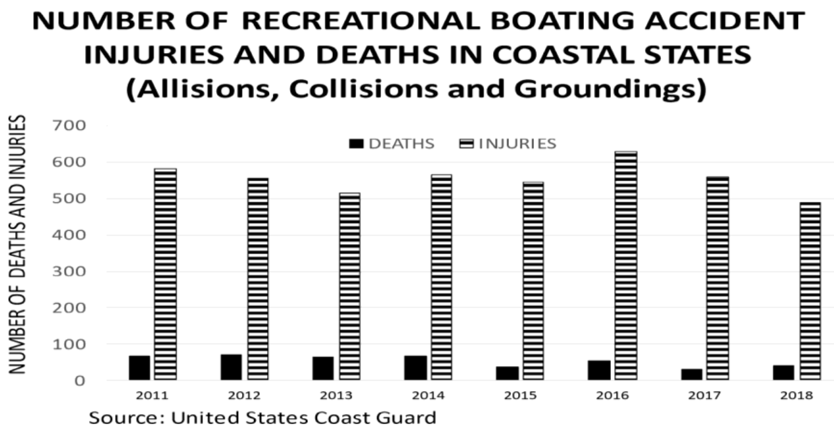
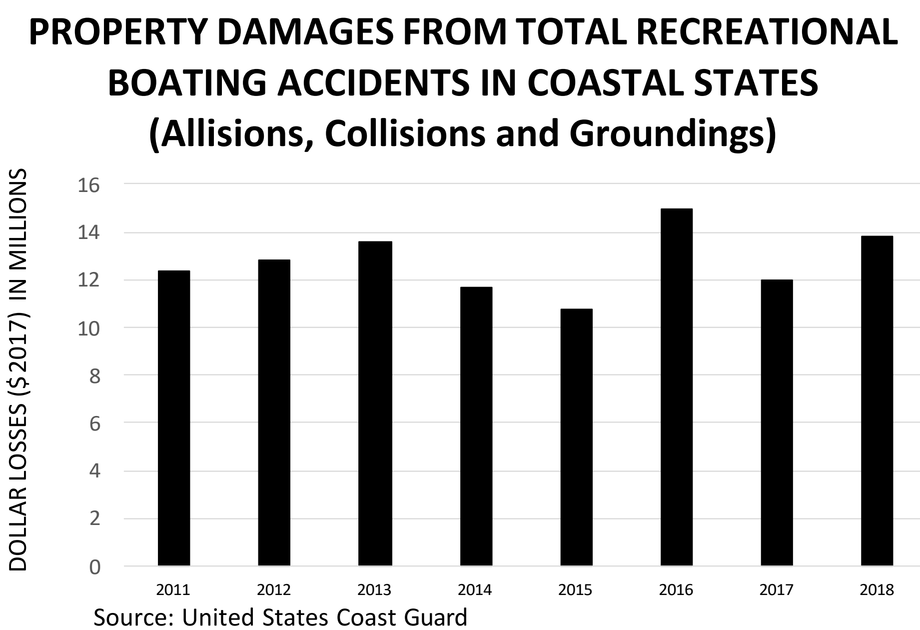



**Figure 7**




## VII. RECREATIONAL BOATING ACCIDENTS

Across the 7,108 accidents documented over 30 causes of accidents were identified in the

BARD. Many of these reasons would probably not have been remedied by the presence of nautical charts. For example, if the operator of the boat had suffered a medical emergency, experienced machinery failure, etc. the presence of charts would not have had an impact on the accident.[276] (Table 3)

**Table 3**

**RECREATIONAL BOATING ACCIDENT CAUSES ACROSS ALL EVENT TYPES (2011 – 2018)**

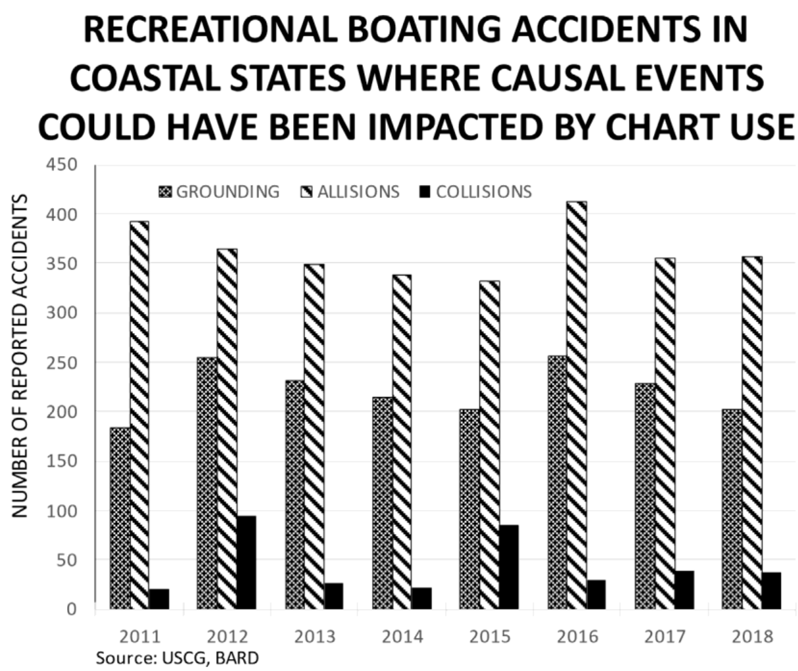
| ACCIDENT CAUSES INCLUDED IN STUDY | NUMBER OF ACCIDENTS | ACCIDENT CAUSES EXCLUDED IN STUDY | NUMBER OF ACCIDENTS |
|---|---|---|---|
| Operator inattention | 1,415 | Alcohol | 565 |
| Improper lookout | 958 | Machinery failure | 554 |
| Operator inexperience | 773 | Other | 506 |
| Excessive speed | 665 | Unknown | 134 |
| Navigation rules violation | 311 | Force of wake/wave | 78 |
| Hazardous waters | 268 | Equipment failure | 43 |
| Weather | 223 | Sudden medical condition | 22 |
| Missing or inadequate nav | 213 | Drug | 13 |
| Restricted vision | 189 | Hull failure | 12 |
| Improper anchoring | 54 | Overloading | 11 |
| Congested waters | 44 | People on gunwale, bow | 7 |
| Sharp turn | 31 | Failure to vent | 4 |
| Dam/lock | 8 | Ignition of spilled fuel | 2 |
| Inadequate onboard navigation | 1 | Starting in gear | 2 |
| | | Carbon monoxide exposure | 1 |
| | | Improper loading | 1 |
| TOTAL | 5,153 | | 1,955 |

Sixteen accident causes were identified to underlay 1,955 accidents. Nautical charts would probably have had little prophylactic impact on prevention or intensity of these accidents

[276] While some primary accident causes may have ultimately resulted in groundings or collisions as secondary or tertiary events, (e.g., a machinery failure led to a grounding), as they were not the primary cause of the accident, they were excluded from the analysis.

and were excluded from the analysis.[277] Recreational boating accidents analyzed in this study took place during a variety of environmental conditions. While external events from winds (none, light, moderate, strong), visibility (clear, good, fair, poor), water (calm, choppy, rough, very rough), weather (cloudy, fog, rain, snow, hazy) and time of day (day, night) may have impacted the ultimate effectiveness of charts, charts were nevertheless available to all boaters and if properly used could have had some impact on accident reduction.

**Figure 8**




[277] Of the 7,108 coastal recreational boating accidents, 1,955 (27.5 percent) were dropped leaving 5,153 in the database.

**Figure 9**

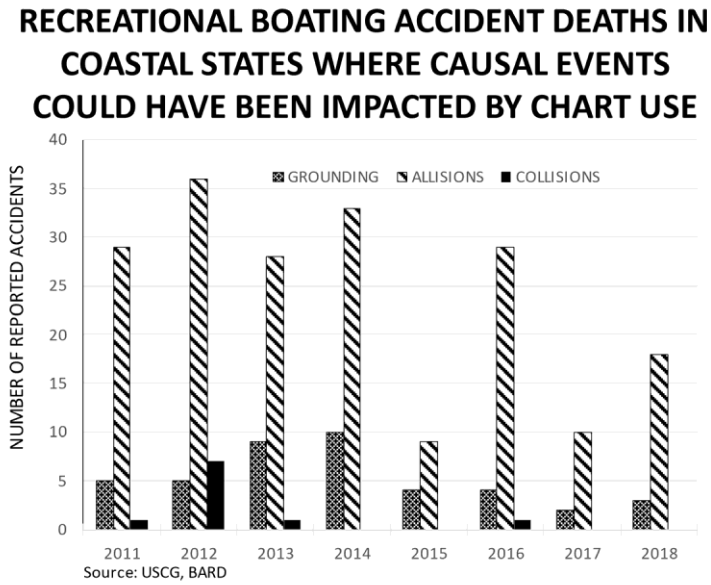



**Figure 10**

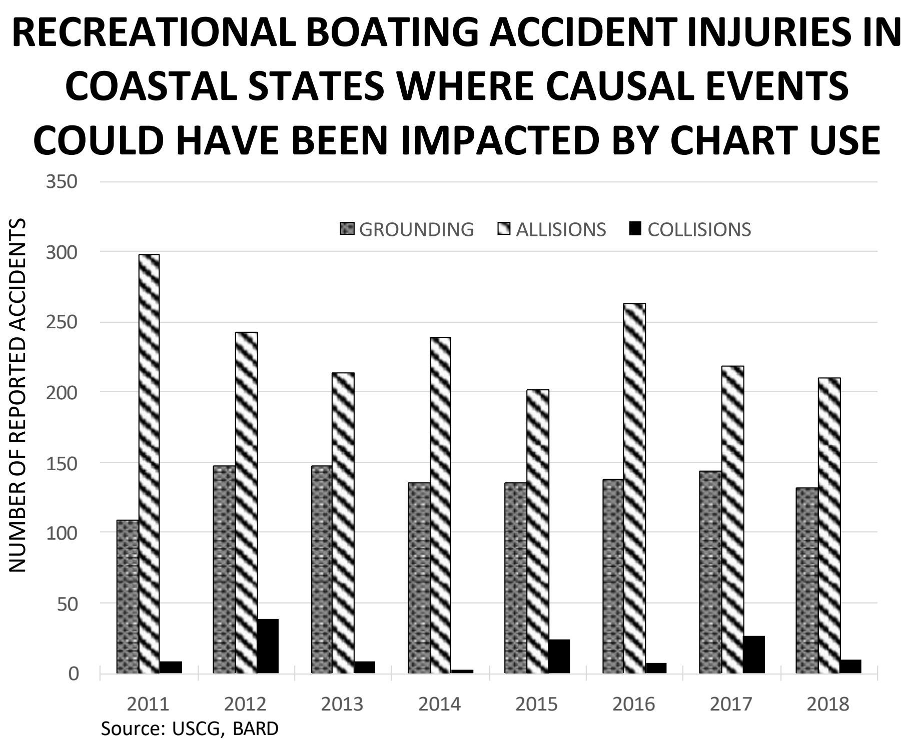
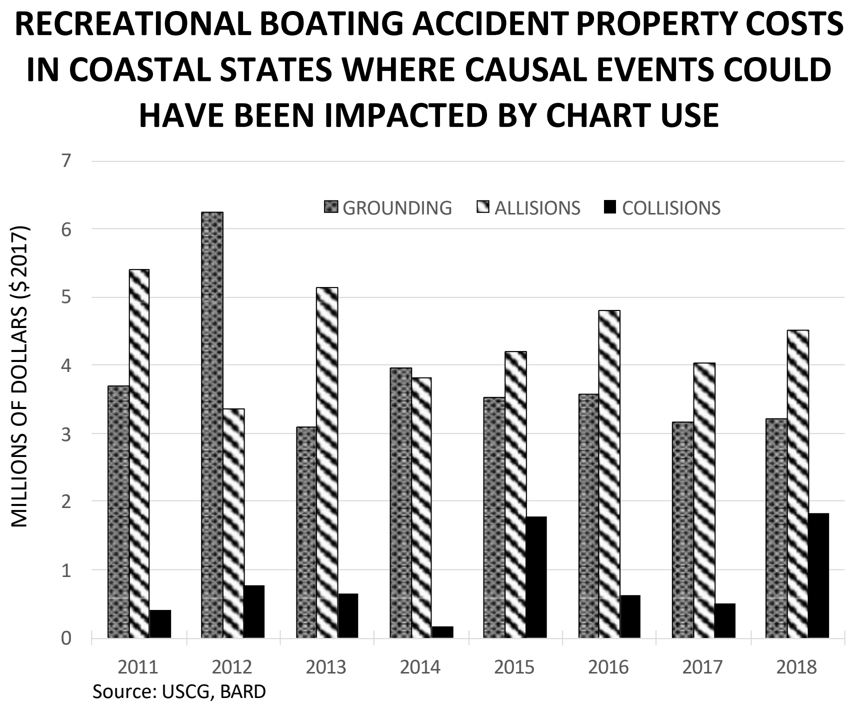


**Figure 11**




Across the accidents retained over the eight year study period, allisions and groundings dominated accident occurrences. (Figure 8) Allisions accounted for 59 percent of accident events and resulted the largest losses from morbidity (61 percent), mortality (79 percent) and property damages (49 percent of total losses). (Table 5) Groundings accounted for 36 percent of accident events, 35 percent of morbidity, 17 percent of mortality and 42 percent of property damages. (Figures 9, 10 and 11)

## VIII. RECREATIONAL BOATING ACCIDENT LOSSES

Allisions, collisions and groundings which occurred under circumstances which could have been aided by navigational charts resulted in 244 deaths, 3,100 injuries and property damages of $72.5 million ($2017). (Table 4)

**Table 4**

## LOSSES FROM RECREATIONAL BOATING ACCIDENTS IN COASTAL STATES WITH ACCIDENT CAUSES THAT COULD HAVE BEEN IMPACTED BY NAVIGATIONAL CHARTS (2011-2018)

| ACCIDENT CLASSIFICATION | NUMBER OF DEATHS (MORTALITY) | NUMBER OF INJURIES (MORBIDITY) | DAMAGES MILLIONS ($2017) |
|---|---|---|---|
| Groundings | 42 | 1,089 | $30.4 |
| Allisions (Collisions With Fixed or Submerged Objects) | 192 | 1,887 | $35.3 |
| Collisions (Commercial, recreational and floating objects) | 10 | 124 | $6.7 |
| Total | 244 | 3,100 | $72.5 |

**Table 5**

## ANNUAL LOSSES FROM RECREATIONAL BOATING ACCIDENTS IN COASTAL AREAS ($2017)

| ACCIDENT CLASSIFICATION | MORTALITY COSTS (MILLIONS) | MORBIDITY COSTS (MILLIONS) | DAMAGE COSTS (MILLIONS) | TOTAL COSTS (MILLIONS) | COST PER ACCIDENT (THOUSANDS) |
|---|---|---|---|---|---|
| Groundings | $51.9 | $108.3 | $3.6 | $168.3 | $92.5 |
| Allisions (Collisions With Fixed or Submerged Objects) | $237.2 | $187.8 | $4.2 | $429.2 | $148.1 |
| Collisions (Commercial, recreational and floating objects) | $12.4 | $12.4 | $0.8 | $25.5 | $72.2 |
| Total | $301.5 | $308.5 | $8.6 | $618.5 | $123.1 |

Based on updated costs for mortality and morbidity employed by Wolfe et al. (2020), annual losses from all three types of accident events reviewed approached $619 million ($2017). Appendix F provides a detailed explanation of how morbidity and mortality costs were estimated. This equates to about $123 thousand ($2017) per accident event per year. (Table 5)

## IX. ESTIMATION OF CHART BENEFITS

In estimating the value of nautical charts several approaches were investigated: (1) detailing previous research findings updated to $2017; (2) employing accident data from the current period of analysis (2011-2018) in prior benefit estimation formulas; and, (3) estimating reductions in costs from updated estimation procedures based on previous research and accident trends. Collectively, these approaches provide a lower and upper range for benefit potential for recreational boaters.

Kite-Powell (2007) studied the value of paper and electronic charts to recreational and commercial boaters by employing survey data from 2005 to 2006.[278] Kite-Powell collected responses from a mail and email survey of recreational boaters and commercial vessel operators. The survey determined $13 million was spent by recreational boaters for chart products excluding hardware and software or digital chart display.[279] Kite-Powell's study was based on estimating the level of consumer surplus which represents the value of nautical charts to users above what they actually pay for the charts. From the survey, it was reported that the majority of recreational boaters making use of vector and raster chart product did so more than 75 percent of the time.[280]

In their responses, recreational boaters described several attributes of an "ideal" chart which included: (1) a smaller format for paper charts and chart books; (2) waterproof charts and

[278] It was reported that among the roughly 500,000 U.S. recreational boaters with auxiliary sailboats, cabin motorboats, and larger (>20') open motorboats, an estimated 57% carry NOAA paper charts, 36% use paper chart books, and 33% use digital chart systems. Page 30.

[279] At this time, paper charts were still being produced by NOAA. The survey suggested that $1.8 million of the $13 million was spent on paper charts.

[280] Table 5 page 10

books; and, (3) that they are updated more frequently. Ideal digital charts should include additional layers such as tide current speed/direction. Chart plotter software has options to utilize tidal and tidal current predictions. With the significant improvements in chart accuracy from modern surveys, the continuous updated chart data the chart data is now equal to the Kite-Powell "ideal chart" figure. The analysis estimated a benefit of $15.3 million per year ($18.7 million $2017) for "ideal" chart products.[281] The study concluded that this figure was considered by the author to be the "lower bound" of such estimates.[282]

The VOLPE Center (2009) undertook an assessment of NOAA's National Ocean Service (NOS) navigational products which included navigational charts, tides and currents data, navigational response team services and the Physical Oceanographic Real-Time System (PORTS®). VOLPE assumed that 20 percent of recreational boaters used electronic nautical charts.[283] They also assumed the usage rate of charts was 25 percent for tankers, 35 percent for containerships and 20 percent for freight vessels. Later, they estimated by the 2010 to 2018 period the usage rate overtime for tankers would expand to 50 percent.[284]

In their survey of recreational boaters, involving convenience, (issues including route planning, route monitoring and use as a reference device), they indicated a willingness to pay of $32.20 per year (2006 dollars) for an "ideal chart".[285] They assumed a usage rate of 20 percent for all NOS products.[286]

In their analysis based on the reduction of boating accidents between 1996 and 2006, they assumed an efficacy rate of 36 percent for the combined effects of electronic nautical charts and

[281] He noted a strong preference for electronic charts over the then dominate paper charts.

[282] This was considered a lower bound as it did not include military users, commercial fishing vessels or marine resource managers among others, Page 5.

[283] Table 4, Page 56

[284] Page 80.

[285] About $50 in $2019.

[286] VOLPE Center, Final Report Task 4, Page 112.

tides and current data by recreational boaters and Search and Rescue officers given a twenty percent usage rate by boaters.[287] VOLPE's total benefit estimates from Averted Fatalities (AF) and Averted Injuries (AI) approached $61 million. Adjusted for general inflation, total losses would be about $72.8 ($2017) million. (Table 7)

Averted Fatalities (AF) were estimated as:

AF = (Δ Avoided Fatalities) * (Value of Statistical Life (VSL) for an Avoided Fatality) * (Effectiveness Rate) * (Usage Rate)
AF = (70 * $5,800,000 * 0.36 * 0.20)
AF = $29,232,000.

Averted Injuries (AI) were estimated by VOLPE as:

AI= ((Δ Avoided Injuries) * (WTP for Maximum Abbreviated Injury Scale (MAIS) for avoided injuries (663) =
200 MAIS1: minor + 200 MAIS 2: moderate + 100 MAIS3: serious + 100 MAIS 4: Severe; + 63 MAIS 5 = Critical)) * (Effectiveness Rate * Usage Rate)
AI = ((200 * $11,600 + 200 * $89,900 + 100 * $333,500 + 100 * $1,087,500 + 63 * $4,422,500)) * 0.36 * 0.20)
AI = $31,753,260.

In 2012 Leveson expanded on the work of Kite-Powell (2007) by estimating direct and indirect economic benefits where direct benefits accrue only to users while indirect benefits are those from benefits provided to supplier and user industries. Using an updated willingness to pay of $56.31[288] per user times an estimated 2.4 million coastal and Great Lakes recreational boat users suggested a benefit of $135.1 million. The benefit range was also created by reducing the $135.1 figure by ten percent ($121.6 million) to reflect that nautical charts may have a lower

[287] VOLPE, Final Report Task 4, Page 117

[288] Updated from $49.70

value than "ideal charts".[289] Updated for $2017 this estimate range would be between $136.2 and $151.3 million.

Reductions in annual morbidity, morality and property damages between the VOLPE study employing accidents from 2000 to 2006 and the current analysis which covered the period 2011 to 2018 were examined. In the current study it was found that on average an annual 10.2 fewer deaths, 129.2 fewer injuries, and $6.8 million lower property damages. There were average reductions in annual losses were almost $214 million less across all accident types which occurred from events that could be impacted by the use of navigational charts if they were employed 100 percent of the time and were 100 percent effective. (Table 6)

Reductions in deaths, injuries and property damaged are due to the collective and synergistic impacts of more easily obtained nautical chart information, user training, enhanced use as well as the timeliness and accuracy of the chart itself.[290] To reflect the impact of human factors, where past history and human nature suggests that even perfect charts would be less than 100 percent effective and used in only a portion of the time a recreational boater was underway, two assumptions were made.

First, in place of the historical 20 percent utilization figure used by VOLPE, Kite-Powell (2007) estimated that a chart utilization rate of 69 percent.[291] Since 2009, annual navigational chart sales from a Certified NOAA ENC® Distributor (CED) rose from 154 to 926 thousand – an

[289] Page 53.

[290] Boating Industry stated that the USCG in 2020 observed that about 34.4 percent of recreational boaters that operated a boat in 2018 had taken a boating safety course.

[291] Weighted average of vector and raster chart use in 2007. Kite-Powell, 2007 Table 5, Page 10

over 500 percent increase.[292] (Chart 12) From Kite-Powell and changes in 2009 to 2020 sales figures which include all types and sizes of both recreational and commercial boating, a 69 percent usage rate. (Figure 12)

Second, measures of effectiveness have been related to avoided causalities and property damages.[293] While a 36 percent nautical chart effectiveness rate was used by VOLPE, since the time of that study technological improvements (e.g., expanded use of cell phones and other electronic devices, elimination of paper charts), have no doubt enhanced this figure as reflected in the reduction in grounding accidents (down 19 percent) between time periods when the number of registered boats declined less than seven percent. During this time the annual reduction in the number of deaths and injuries between the VOLPE and current study (10 fewer deaths and 129 fewer injuries) suggests advanced effectiveness and use of charts.[294] A modest reduction in property damages was also noted.

Due to noted reductions in accident, advances in technology and lowered acquisition time and cost, it was assumed that the current effectiveness of charts had increased from 36 percent in 2009 to 50 percent in 2020. Employing the VOLPE approach with a 50 percent effectiveness and 69 percent usage rate along with 2011 to 2018 annual morbidity and mortality costs results in a benefit estimate of almost $92.7 million. (Table 6)

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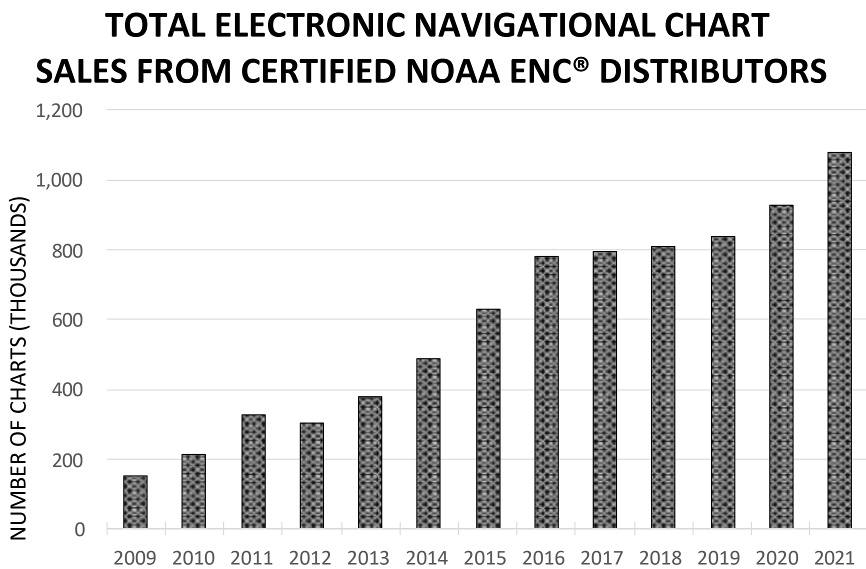
[292] CEDs are permitted to download NOAA ENC® files, perform exact copying, and redistribute those copies of NOAA ENC® data. A CEVAD is a "Certified NOAA ENC® Value Added Distributor" who is permitted to reformat official NOAA ENC® data into a System Electronic Navigational Chart (SENC) using type-approved software, and may distribute the SENC. Certification type requirements are listed in the Federal Register/Vol. 70, No.171.

[293] VOLPE final Task Report 4, Page 20.

[294] VOLPE Task 4, Table 32.

**Figure 12**




Sources: From 2009 to 2016 data was from Creative Map Corporation, Chartworld Navigation Services, Jeppensen Sanderson, Inc, (C-MAP Norway AS), PRIMAR, and United Kingdom Hydrographic Office; Since 2017 data from International Centre for Electronic Navigational Charts

**Table 6**

## ESTIMATES OF RECREATIONAL BOATING BENEFITS FROM CHARTS

| STUDY / APPROACH | ANNUAL BENEFIT (MILLIONS $2017) |
|---|---|
| KITE POWELL (2007) Willingness to Pay | $17.9 |
| VOLPE (2009 Groundings only) employing 2009 value of life and injury costs (assuming 36 percent effectiveness rate and 20 percent usage rate) | $66.0 |
| LEVENSON (2012) (recreational boating and fishing) | $142.3 - $158.1 |
| CURRENT STUDY – Reduction in average annual allisions, collisions and grounding occurrences from 2000 – 2006 and 2011-2018 using current life, injury and property costs with a 50 percent effectiveness rate and 69 percent usage rate.[295] | $211.6 |
| CURRENT STUDY SALTWATER BENEFITS – portion of the number of fish caught in coastal saltwater areas as compared with total catch in inland and coastal areas ($211.6*0.438) | $92.7 |

[295] ((30.5 deaths * $9.8 million) + (387.5 injuries * $789,233) + ($8.6 million property damages) * (0.50 effectiveness rate) * (69 percent usage rate)).

## ESTIMATED GROSS BENEFITS PROVIDED BY NAVIGATIONAL CHARTS IN THE UNITED STATES

The central conclusion that can be drawn from this study as well as the previous studies is that the use of nautical charts by recreational boaters is essential for boater safety. The use of nautical charts while engaging in recreational boating activities reduces the incidence of allisions and groundings, reduces boat damage and injuries from boating accidents. (Table 7)

**Table 7**

### SUMMARY OF ANNUAL RECREATIONAL BOATING BENEFITS DERIVED FROM NAUTICAL CHARTS IN U.S. WATERS

| ANNUAL BENEFIT VALUE ($2017 MILLION) | CONFIDENCE LEVEL[296] |
|---|---|
| $92.7 | MEDIUM |

[296] In each benefit appraisal, a subjective assessment of the confidence of the estimate is made based on the quality of the underlying data, documented exactness of the relationship between nautical charts and resultant benefits and proximity to previous research findings.

# CHAPTER 6 – RECREATIONAL FISHING

## I. INTRODUCTION

Saltwater and Great Lakes recreational fishing is an integral part of American coastal life and communities. Recreational fishing is both a cultural cornerstone and an important economic driver. Millions of Americans annually migrate to the water to temporarily separate themselves from the stress and boredom of their daily life and work routine seeking solitude on the water or the comradery of friends all the while hoping to catch fish in numbers or size to afford them "bragging rights". There is no doubt that the emotional, societal and aesthetic values of a quality environment, healthy fish and wildlife populations, and safe and sustainable recreation exceed our ability to quantify them in dollars, but nonetheless the dollar figures are impressive.

Recreational fishing, also known as sport fishing, is undertaken for a variety of reasons including personal pleasure, recreation and competition as opposed to commercial fishing which is defined as fishing for profit. During 2018, the International Game Fish Association reported that almost two-thirds of recreational fish catch were released alive.[297] Earlier, Cooke and Cowx (2004) estimated that discard/release rates for recreational catch were near 60 percent.

## II. OVERVIEW OF INDUSTRY

Pendleton et al. (2006) reported that fishing represents a large portion of marine recreation in the United States. Saltwater fishing alone draws nearly 21.3 million participants nationwide which accounts for 10.3 percent of the population age 16 or older. Saltwater fishing ranked third most popular activity in marine recreation in the United States. Saltwater fishing is expected to attract over 24 million participants by 2010.

[297] Sixty-four percent of recreational catch in terms of the number of fish caught were released alive in 2018. Refer to: https://igfa.org/2020/04/23/fisheries-of-the-united-states-2018-report/

Recreational fishing is an important part of the recreational economy for three of the largest recreational boating states California, Florida and Texas. California ranks second in the nation in terms of participation in saltwater fishing with more than 2.7 million participants, falling only behind Florida. Texas is ranked third with more than 1 million fewer saltwater fishing participants than in California. Based on the 2000 participation estimates and an estimated value range of $75 to $200 per participant per year, the annual expenditures associated with recreational fishing in California ranged from $205 million to $545 million in the year 2000. This would be equivalent to $283 and $753 million in 2017 dollars. Based on the 2000 participation estimates (20.3 million person-days) and an estimated value range of $15 to $90 per person day, the annual [non-market] value of recreational fishing in California likely ranged from $305 million ($421 million $2017) to $1.83 billion ($2.52 billion $2017) in the year 2000.

Detailed information on marine recreational fishing is required to support a variety of fishery management purposes and is mandated by the Sustainable Fisheries Act, 1996 (PL 104-297) and the Magnuson-Stevens Fishery and Conservation Act of 2006 (PL109-479).[298]

Data on the Atlantic and Gulf coasts is collected via a coastal household telephone survey as well as a field survey of completed angler fishing trips. This information is augmented with state and local records. In Oregon and Washington ocean boat surveys are used to develop catch estimates. Alaskan data is collected through an annual mail survey administrated by the Alaska

[298] Each year, a comprehensive survey is undertaken which covers all fishing modes (e.g., private/rental boat, party/charter boat and shore). Literally millions of recreational anglers are annually monitored in order to accurately assess the stocks of many fish species as recreational fishing significantly impacts the stocks of many finfish species as well as the fact that recreational landings of some finfish actually surpass commercial landings.

Department of Fish and Game. Data is summarized in an annual report by the National Marine Fisheries Service. [299]

A 2011 report by NOAA's National Marine Fisheries Service stated

> *"In 2011, there were approximately 11 million recreational saltwater anglers across the U.S. who took 70 million saltwater fishing trips around the country. These anglers spent $4.5 billion on fishing trips and $22 billion on durable fishing-related equipment. These expenditures contributed $70 billion in sales impacts to the U.S. economy, generated $32 billion in value added impacts, and supported over 455,000 job impacts".*[300]

During 1999 to 2016, between 7.8 and 14.0 million participated in recreational boating making between 56.9 and 89 million fishing trips.[301] (Table 1) This averaged seven trips per year.

**Table 1**

## RECREATIONAL ANGLERS

| YEAR | NUMBER OF ANGLERS (Millions) | NUMBER OF FISHING TRIPS (Millions) | AVERAGE NUMBER OF TRIPS PER YEAR PER ANGLER | PERCENT PARTICIPATION OF U.S. POPULATION |
|---:|---:|---:|---:|---:|
| 1999 | 7.8 | 56.9 | 7.3 | 2.8% |
| 2000 | 9.0 | 76.0 | 8.4 | 3.2% |
| 2001[302] | 12.0 | 84.0 | 7.0 | 4.2% |
| 2002 | 10.5 | 73.0 | 7.0 | 3.6% |
| 2003 | 13.0 | 82.0 | 6.3 | 4.5% |
| 2004 | 14.0 | 82.0 | 5.9 | 4.8% |
| 2005 | 12.0 | 83.0 | 6.9 | 4.1% |
| 2006 | 13.0 | 89.0 | 6.8 | 4.3% |
| 2007 | 12.0 | 87.0 | 7.3 | 4.0% |
| 2008 | 12.0 | 85.0 | 7.1 | 3.9% |

[299] Refer to: U.S. Department of Commerce, *"Fisheries of the United States 2010",* National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Current Fishery Statistics NO. 2010, August 2011,

[300] NOAA, NMFS, 2012. "Fisheries Economics of the United States 2011", Page 9.

[301] Due to changes in collection methods beginning in 2017, later data is not strictly comparable with earlier data.

[302] Recession from March 2001 to November 2001

ESTIMATED GROSS BENEFITS PROVIDED BY NAVIGATIONAL CHARTS IN THE UNITED STATES

| | | | | |
|---|---|---|---|---|
| 2009[303] | 10.0 | 75.0 | 7.5 | 3.3% |
| 2010 | 11.0 | 81.0 | 7.4 | 3.5% |
| 2011 | 11.0 | 70.0 | 6.4 | 3.5% |
| 2012 | 9.4 | 70.0 | 7.4 | 3.0% |
| 2013 | 11.0 | 71.0 | 6.5 | 3.5% |
| 2014 | 10.4 | 68.0 | 6.5 | 3.3% |
| 2015 | 8.9 | 61.0 | 6.9 | 2.8% |
| 2016 | 9.8 | 63.3 | 6.6 | 3.0% |
| AVERAGE (1999-2016) | 10.9 | 75.4 | 7.0 | 3.6% |

Source: "Fisheries Economics of the United States, *Fisheries of the United States, Current Fishery Statistics*", National Marine Fisheries Service, NOAA for involved years.

## III. BENEFIT OF NAUTICAL CHARTS FOR RECREATIONAL FISHING

The benefits of the nautical chart for those engaged in recreational fishing occur for the boating operations and the fishing operations. In summary, boating operations can be broken into voyage planning before the boating voyage takes place, the actual boating operations during the voyage, and during any emergency or unscheduled operations.

### A. Voyage Planning

Boater determines the destination (s) and plans a route from the starting marina to the destination (s) via a safe route that avoids shoals and submerged dangers to navigation, busy vessel traffic lanes while taking the shortest route or one incorporating waypoints of interest.

### B. Boating Operations

The chart is used to monitor the progress of the vessel utilizing a nautical chart base on which is plotted the GPS vessel position. Tracking the vessel position relative to the desired track ensures the vessel doesn't stray into dangerous water with shoal water or submerged dangers.

[303] Recession from December 2007 to June 2009

### C. Emergencies or Unscheduled Events

These events can occur to even the most experienced and well prepared boater. The experienced boater ensures in the voyage planning that anchorage sites are located in the boating area and facilities where emergency services (medical, fuel, mechanical repair etc.). One emergency that happens too often is when a boater is delayed and find themselves on the water after dark. When landmarks disappear with the onset of darkness the boater is left with a confusing myriad of lights on shore with some that are red or green and some flashing. These are meaningless to an uninformed boater but one using a nautical chart can identify the color and flashing characteristics of aids to navigation to identify those that will guide them to their marina destination. The navigation on a chart with the GPS position of the vessel shown on the chart becomes a much more manageable operation if the boater is using an electronic chart and GPS positioning. The mariner can safely navigate avoiding dangerous areas and obstructions.

Kite-Powell (2007) from a 2005 and 2006 study reported that 85 percent of all survey respondents reported carrying a chart product on board their vessels and at least using it part of the time. Since 2005 the improved chart plotters and navigation apps for cellphones when coupled with free NOAA raster chart images have enabled all mariners to have access to very accurate navigational tools. Even a mariner on the water without a chart can download the necessary app with a nautical chart and the GPS from the cell phone to navigate in an emergency.

Fishermen have several nautical chart formats available to them from large format paper charts or electronic chart plotters for the larger recreational boats to the smaller paper book charts, smaller electronic displays or even one of the many cell phone application utilizing electronic chart with the GPS navigation. Refer to Appendix J.

### D. Fishing Operations

Nautical charts also provide information relevant to determining the location of where to fish, how to fish as well as the ability to of their vessels to reach locations where fishing conditions are favorable.

Knowing the water depth and bottom topography is critical for properly choosing and setting the fishing gear. Fish species are known to inhabit waters of certain depths. The location of rises, reefs, and ledges are some of the features fish have been known to congregate around. Knowledge of the type of bottom may be of importance. Bottom fish may prefer a sandy bottom to one that is rocky or muddy while other crabs and fish may prefer more rocky bottoms. These are just a few examples of what a fisherman might know about the type of fish they are focusing on for their fishing operations. Much of this information is available from the nautical chart.

The location of obstructions on the bottom are important for the fisherman to be aware of in planning their operations so that their gear doesn't become entangled or damaged by the obstruction.

Observers such as Love (1997) have detailed several environmental conditions that are conducive to enhanced fish catch.[304] Nautical charts assist to provide specific answers to each of these measurements along with timely accurate and complete knowledge of water depth, shorelines and seafloors as well as navigational hazards, information on tides and currents and local details of the Earth's magnetic fields.

While the nautical chart is useful for operational planning the primary purpose and thus the design of the nautical chart is safe navigation. The chart is used by the vessel operator to plot a course to and from the fishing grounds avoiding all shoals and dangers to navigation. Without a nautical

[304] Refer to Table 1 in Commercial Fishing Chapter 3

**Table 2**

## U.S. RECREATIONAL FISH HARVEST BY DISTANCE FROM SHORE

| YEAR | METRIC TONS | NUMBER OF FISH LANDED (THOUSANDS) | AVERAGE WEIGHT PER FISH (POUNDS) | METRIC TONS | NUMBER OF FISH LANDED (THOUSANDS) | AVERAGE WEIGHT PER FISH (POUNDS) | METRIC TONS | NUMBER OF FISH CAUGHT (THOUSANDS) | AVERAGE WEIGHT PER FISH (POUNDS) |
|---|---|---|---|---|---|---|---|---|---|
| | **0 TO 3 Miles** | | | **3 TO 200 Miles** | | | **0 to 200 Miles** | | |
| 2011 | 25,358 | 41,275 | 1.35 | 11,544 | 21,387 | 1.19 | 36,902 | 62,662 | 1.30 |
| 2012 | 24,889 | 41,153 | 1.33 | 13,243 | 26,039 | 1.12 | 38,132 | 67,192 | 1.25 |
| 2013 | 28,188 | 55,531 | 1.12 | 17,379 | 31,461 | 1.22 | 45,567 | 86,992 | 1.15 |
| 2014 | 25,099 | 55,396 | 1.00 | 17,303 | 26,117 | 1.46 | 42,402 | 81,513 | 1.15 |
| 2015 | 24,425 | 53,910 | 1.00 | 15,583 | 29,861 | 1.15 | 40,008 | 83,771 | 1.05 |
| 2016 | 27,528 | 57,197 | 1.06 | 16,323 | 26,161 | 1.38 | 43,851 | 83,358 | 1.16 |
| 2017 | 68,272 | 152,262 | 0.99 | 38,519 | 61,399 | 1.38 | 106,791 | 213,661 | 1.10 |
| 2018 | 54,078 | 129,368 | 0.92 | 32,196 | 50,026 | 1.42 | 86,274 | 179,394 | 1.06 |
| 2019 | 49,505 | 135,491 | 0.81 | 47,536 | 36,752 | 2.85 | 97,041 | 172,243 | 1.24 |
| 2011-2019 Average | 36,371 | 80,176 | 1.00 | 23,292 | 34,356 | 1.49 | 59,663 | 114,532 | 1.15 |

Source: "*Fisheries of the United States, Current Fisher Statistics*", National Marine Fisheries Service, NOAA for involved years.

chart the vessel operators would be unaware of the location of submerged dangers and any collision with the obstruction or grounding in shallow water could result in severe damage to the vessel or even its complete destruction and injury or even death to passengers aboard the vessel. The depth of the water, the topography of the bottom, the type of bottom (e.g. rocky, mud, or sand), and the location of obstructions that might foul their fishing gear are all important to fishermen.

## IV. CALCULATION OF BENEFITS

Between 2011 and 2019, 56.2 percent of recreational catch, measured by weight, was in inland fresh waters. The remaining 43.8 percent of the fish landed were caught in salt water between zero and 200 miles from shore. (Table 2 and Figure 1)

In this study, recreational fishing benefits attributable to nautical charts were estimated to be derived from two sources. The first, is a measure of the recreational boaters' expenditures associated with the infrastructure needed (e.g., boats, tackle, etc.) to facilitate fishing activity. The second is related to the value of the catch retained ostensibly for consumption. (Figure 2)

**Figure 1**

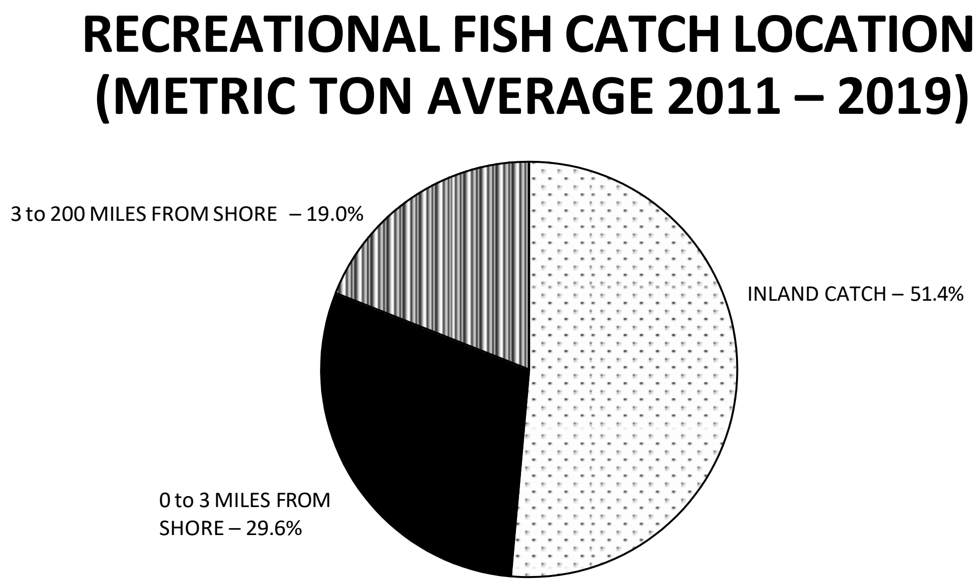
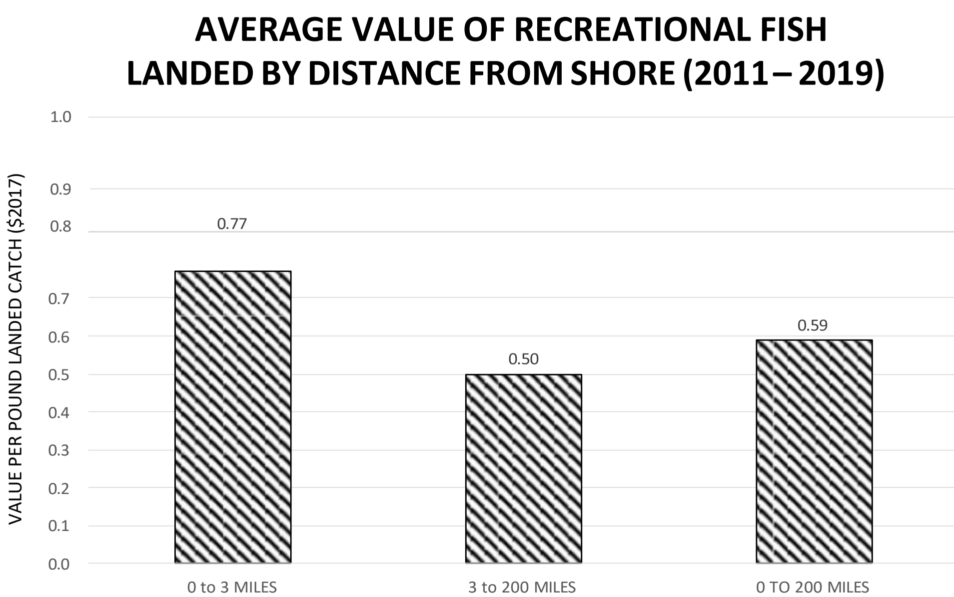



**Figure 2**




Source: NMFS, NOAA

### A. Recreational Expenditures

Participants of recreational fishing expend significant monies in pursuit of this activity. NOAA (2016) reported there were approximately 10 million recreational saltwater anglers. In the same report, related U.S. recreational fishing trip and durable expenditures approached $31 billion resulting from boat expense ($15.4 billion), trips ($4.3 billion), fishing tackle ($3.7 billion), vehicle expense ($3.5 billion), second home expense ($2.1 billion) and other equipment cost. ($1.9 billion).[305] In a broader measure of total impact involving all recreational boaters (freshwater and saltwater), the National Marine Manufacturers (2018) have estimated that total annual economic impact exceeded $170 billion from manufacturers, suppliers, sales and service, boating activities and business tax revenues.[306] Recreational boating is seen to be essential to the U.S. economy as 95 percent of boats sold in the U.S. are made in the U.S., 93 percent of U.S. boat manufacturers are small businesses and 61 percent of boat owners have an annual household income of $75,000 or less.

Based on the portion of total tonnage caught in areas 0 to 200 miles from coasts, a portion of total recreational trip and durable expenses were allocated to activities in those areas. As boating equipment used in ocean versus inland locations tend to be larger, stronger and as a result tend to be more expensive, the estimate of 48.6 percent (total number of landed recreational catch between 0 and 200 miles from shore as compared with inland landings) is considered to be conservative in nature.

[305] NOAA, 2018. "Fisheries Economics of the United States, 2016". Fact Sheet and Highlights from the Annual Report., NOAA Fisheries, Office of Science & Technology, December 12. Graph 5, Page 13.

[306] NMMA. 2019. "Economic Impact Study, 2018"; and reported in Aquafinance. 2019. "Recreational Boating Industry Growth A Boon to American Economy", March 25.

**Table 3**

**ESTIMATE OF ANNUAL SALTWATER RECREATIONAL BOATING BENEFITS**

| | **NOAA ESTIMATE ($2017)** |
|---|---|
| Recreational Fishing Trip and Durable Expenditures (Fresh and Salt Water) | $31.6 billion |
| Percent Assumed Proportionately Spent 0-200 miles (Salt Water only) from shore (43.8%)[307] | $13.8 billion |
| One Percent of Annual Expenditure Due to Charts | $138.4 million |

Source: NOAA, NMFS.

Taking the portion of recreational fishing activity between 0 and 200 miles offshore where nautical charts could have their greatest impact, a total of about $13.8 billion could result. If only one percent of these expenditures support activities 200 or fewer miles from shore (based on the proportion of total catch weight), an annual benefit to the U.S. economy of about $138.4 million ($2017) could result. (Table 3)

**B. Catch Value**

The total value of retained fish catch was estimated based on catch and retained catch data by recreational by the National Marine Fisheries Service (NMFS). With the value of commercial catch ($0.59 per pound) obtained from zero to 200 miles from shore were valued at almost $28 million, under a Nordhaus assumption if one percent were attributable to nautical charts, annual benefit would approach $0.3 million. (Table 4)

[307] Based on percent of total number of landed recreational catch between 0 and 200 miles from shore as compared with inland (lake and river) landings.

**Table 4**

### ESTIMATE OF RECREATIONAL CATCH ESTIMATION

| | |
|---|---|
| Average Annual Catch Weight 2011-2019 (0 to 200 Miles) in Short Tons | 65,767 |
| Percent Catch Retained[308] | 36% |
| Annual Catch Retained (Pounds) | 47.4 Million |
| Catch Value Per Pound (0 to 200 miles based on Commercial Catch) | $0.59 |
| Total Annual Value | $28.0 Million |
| One Percent of Annual Value Due to Charts | $0.3 Million |

## V. CONCLUSIONS

Collectively, recreational fishing benefits are estimated to be $138.7 million ($138.4 million plus $0.3 million in catch value) in $2017. (Tables 3 and 4) Based on known annual expenditures for recreational fishing and a highly conservative apportionment of total benefits to nautical charts, it is assumed that an annual benefit of almost $138.7 million occurs. (Table 5)

**Table 5**

### ANNUAL BENEFIT DERIVED FOR SALTWATER RECREATIONAL FISHING FROM NAUTICAL CHARTS IN U.S. WATERS

| ANNUAL BENEFIT VALUE ($2017 MILLION) | CONFIDENCE LEVEL[309] |
|---|---|
| $138.7 | MEDIUM |

[308] Source: NMFS. 2019. "Fisheries of the United States, 2019", Page 36.

[309] In each benefit appraisal, a subjective assessment of the confidence of the estimate is made based on the quality of the underlying data, documented exactness of the relationship between nautical charts and resultant benefits and proximity to previous research findings.

# CHAPTER 7 - CONCLUSIONS

International trade allows countries to expand their markets and access goods and services that otherwise may not have been available domestically. In the U.S. the cargo value of total imports exceeded $2.8 trillion while imports approached $1.8 trillion for a total of $4.6 trillion ($2021). Concurrently, total imported tonnage exceeded 1 billion tons while exports approached 1.2 billion tons for a total of over 2.2 billion tons in 2021. Over the last 12 years, waterborne transportation represented over 72 percent of international tonnage and about 42 percent of international cargo value.

Safe navigation is based on the concept that from the bridge of a ship the mariner is unable to see beneath the surface of the water. Without a nautical chart they cannot avoid dangers that they cannot see. Safe and efficient offshore commercial and recreational transportation, whether involving cargo transportation or fishing, is the result of quality information and prudent human interaction. Nautical charts provide value from a number of perspectives for both commercial and recreational users. The benefits to major user groups include:

- Commercial Mariner – voyage planning, navigating avoiding dangers to navigation and shoal water, aiding in calculation of optimal vessel loading.
- Commercial Fishing / Recreational Fishing – voyage planning to fishing grounds, navigating to avoid dangers to navigation and shoal waters, aid in fishing operations (setting and deploying fishing equipment).
- Recreational Boating – voyage planning, piloting and navigating to avoid dangers to navigation and shoal waters.

Without a nautical chart, ships and boats are in extraordinary danger of an allision or grounding with the resultant death and injury of passengers and crew, the damage or total loss of the vessel and its cargo and perhaps most costly, damage to the environment from the release of fuel, and oil and chemical cargoes. Following estimation of total averted costs from the combined influences of nautical charts, water level and PORTS® data and the decisions of port pilots and bridge managers, the portion attributable to nautical charts was calculated. In each benefit appraisal, a subjective assessment of the confidence level associated with the estimate based on the quality of the underlying data, documented exactness of the relationship between nautical charts and resultant benefits and proximity to previous research findings.

Due to fewer accidents navigational costs were either averted or diminished. Costs reductions included: (1) mortality; (2) cargo losses; (3) facility/other losses; (4) morbidity; and, (5) vessel losses.

Cost savings also result from efficient voyage planning as charts provide a graphical representation of relevant information to mariners for planning and executing safe navigation making it one of the most fundamental tools available to the mariner. In addition to avoided accidents and voyage planning the ability to more efficiently load and navigate vessels results in fewer vessel transits, lesser port congestion, lower total energy use and resultant fewer emissions which contributes to societal equity as commercial ports and main waterway channels tend to be in economically distressed less diverse areas of the country. Any reductions in pollutants help improve the environment for those living in proximity to those areas.

Finally, the economic impact of charts on commercial and recreational fishing was assessed in relation to levels of capital investment and the value of catch. Overall, total annual benefits due to nautical charts was estimated to range between almost $1.5 and $2.4 billion ($2017). Table 1

**ESTIMATED GROSS BENEFITS PROVIDED BY NAVIGATIONAL CHARTS IN THE UNITED STATES**

**Table 1**

**ANNUAL VALUE OF NAUTICAL CHARTS**

| VALUE | ESTIMATED BENEFITS ($ 2017 MILLION) | CONFIDENCE LEVEL |
|---|---|---|
| Commercial Shipping[310] | $365.6 | High – Very High |
| Allision Avoidance[311] | $645.5 - $1,548.6 | Very High |
| Commercial Fishing | $214.6 | Medium |
| Recreational Boating | $92.7 | Medium |
| Recreational Fishing | $138.7 | Medium |
| **TOTAL** | **$1,457.1 – 2,360.2** | |

Nautical charts benefit the environment and promotes societal equity. Aside from lesser port and channel congestion, the reduced number of vessel trips also has a societal benefit from fewer emissions from the burning of ships fuel. (Table 2) As many ports and vessel transit lanes are located in or adjacent to relatively economically disadvantaged areas, reductions in emissions proportionately assist individuals living in or in proximity to these areas.

[310] The value of the pilot & water levels was recognized and the total benefit was divided between chart, water level and pilot.

[311] The value of the pilot and accurate GPS positioning was recognized and the total benefit was divided between chart, GPS and the pilot.

**Table 2**

**SOCIETAL SAVING FROM FEWER EMISSIONS DUE TO ACCURATE NAUTICAL CHARTS (THOUSANDS OF $2017)**

| | Great Lakes Dry Bulk | | Coastal - Dry Bulk, Tanker, Container | | TOTAL | |
|---|---|---|---|---|---|---|
| **EMISSIONS** | **Metric Tonnes** | **Thousands $2017** | **Metric Tonnes** | **Thousands $2017** | **Metric Tonnes** | **Thousands $2017** |
| Particulate Matter ($PM_{2.5}$) | 4.5 | $213 | 88.4 | $4,163 | 92.9 | $4,376 |
| Ammonia ($NH_3$) | 0.0 | $1 | 0.7 | $21 | 0.7 | $22 |
| Methane ($CH_4$) | 1.9 | $10 | 37.2 | $198 | 39.1 | $208 |
| Sulphur Oxide ($SO_x$) | 0.3 | $12 | 5.0 | $244 | 5.3 | $256 |
| Nitrogen Oxide ($NO_x$) | 159.0 | $12,355 | 3,116.1 | $242,114 | 3,275.1 | $254,469 |
| Carbon Dioxide ($CO_2$) | 7,561.2 | $733 | 147,991.7 | $14,349 | 155,552.9 | $15,082 |
| Carbon Monoxide (CO) | 16.2 | $12 | 317.8 | $233 | 334.0 | $245 |
| Reactive Organic Gases (ROG) | 8.0 | $140 | 156.9 | $2,752 | 164.9 | $2,892 |
| Particulate Matter ($PM_{10.0}$) | 4.6 | $110 | 90.9 | $2,159 | 95.5 | $2,269 |
| Black Carbon (BC) | 0.0 | $10 | 0.3 | $95 | 0.3 | $105 |
| **TOTAL** | **7,755.8** | **$13,596** | **151,805.0** | **$266,327** | **159,560.7** | **$279,973** |

Finally, the importance of precision charting was also investigated through the calculation of the theoretical impact of increasing all port depth accuracy measurements from their current CATZOC accuracy levels to an accuracy level of “A1”. As traffic may not currently be present at all port locations to fully utilize these potential allowable increases in safe navigation, monetary benefit estimates other than the potential of the opportunity for added vessels (over 8,600 vessels hauling over 836 million tons) which could be safely handled without added USACE channel dredging were not calculated.

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# APPENDIX A

## HISTORY OF NAUTICAL CHARTS

**ESTIMATED GROSS BENEFITS PROVIDED BY NAVIGATIONAL CHARTS IN THE UNITED STATES**

The first marine charts were actually maps with continents and islands located usually inaccurately. There were no chart projections that would enable the accurate depiction of continents and islands. There weren't any indications of subsurface features indicating dangers to be avoided. There were no soundings or information on dangers to navigation. There wasn't even a projection that would enable the continents and islands to be located accurately. All of that would be developed later.

An example of one of the earliest nautical charts is the 1339 Dulcert Portolan chart hand drawn on a calf hide velum. Figure A-1

**Figure A-1**

**PORTOLAN CHART**

Portolan chart attributed to Angelino Dulcert mid-1300s. Drawn on velum.

Source: https://www.bl.uk/collection-items/portolan-chart-attributed-to-angelino-dulcert#

Even several hundred years later charts had little information other than coast line and sometimes included mythical sea creatures. Figure A-2

## LATER NAUTICAL CHART

**Figure A-2**

**Figure A-4**

## CARTA MARINA "MAP OF THE SEA" 1539[1] (Olaus Magnus)


[1]https://www.bing.com/images/search?view=detailV2&ccid=z6Up1U53&id=3FCABE9141FD9E77DAD4E73553533180178B48D2&thid=OIP.z6Up1U53VJYxhST2K3BnlwHaFf&mediaurl=https%3A%2F%2Fth.bing.com%2Fth%2Fid%2FRcfa529d54e775496318524f62b706797%3Frik%3D0kiLF4AxU1M15w%26riu%3Dhttp%253a%252f%252fwww.publicdomainpictures.net%252fpictures%252f160000%252fvelka%252fancient-map

**Figure A-4**

## MANUS CARTA MARINA SHOWING ICELAND AND NORWAY


Enlargement of the Manus Carta Marina showing Iceland, the west coast of Norway and a number of mythical "sea monsters" a mariner might encounter.  Figures A-3 and A-4

Between 1650 and 1700 while the English, Dutch, and French were competing as sea powers, the American colonies, principally the shipbuilders of Massachusetts had built and launched over one thousand ships by 1700[2].  In the years leading up to the Revolutionary War there was a rapidly growing American merchant marine and a growing dependence of marine

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[2] Peter Whitfield. 1996. "*The Charting of the Oceans*", Pomegranate Books, PO Box 6099, Rohnett Park, California 94927, p 89.

trade both for the export of raw materials and goods produced in the Colonies and for the import principally from Europe of manufactured goods not yet produced in America.

By the time the American colonies declared their independence from Great Britain in 1776 charts were completing an amazing period of technical development transforming marine maps from inaccurate artistic representations of the continents and oceans to highly modern nautical charts complete with accurately located shoreline, depth soundings, dangers to navigation and even some aids to navigation as well as an accurate projection. Mariners likewise had progressed form inaccurate piloting to being able to compute their position in both latitude and longitude plotting the results on a chart (both large and small scale) based on a refined projection.

**B. Technical Improvements**

Technical Developments transformed the chart from a marine map as a picture of the world's oceans and coasts to a navigational chart. These improvements included:

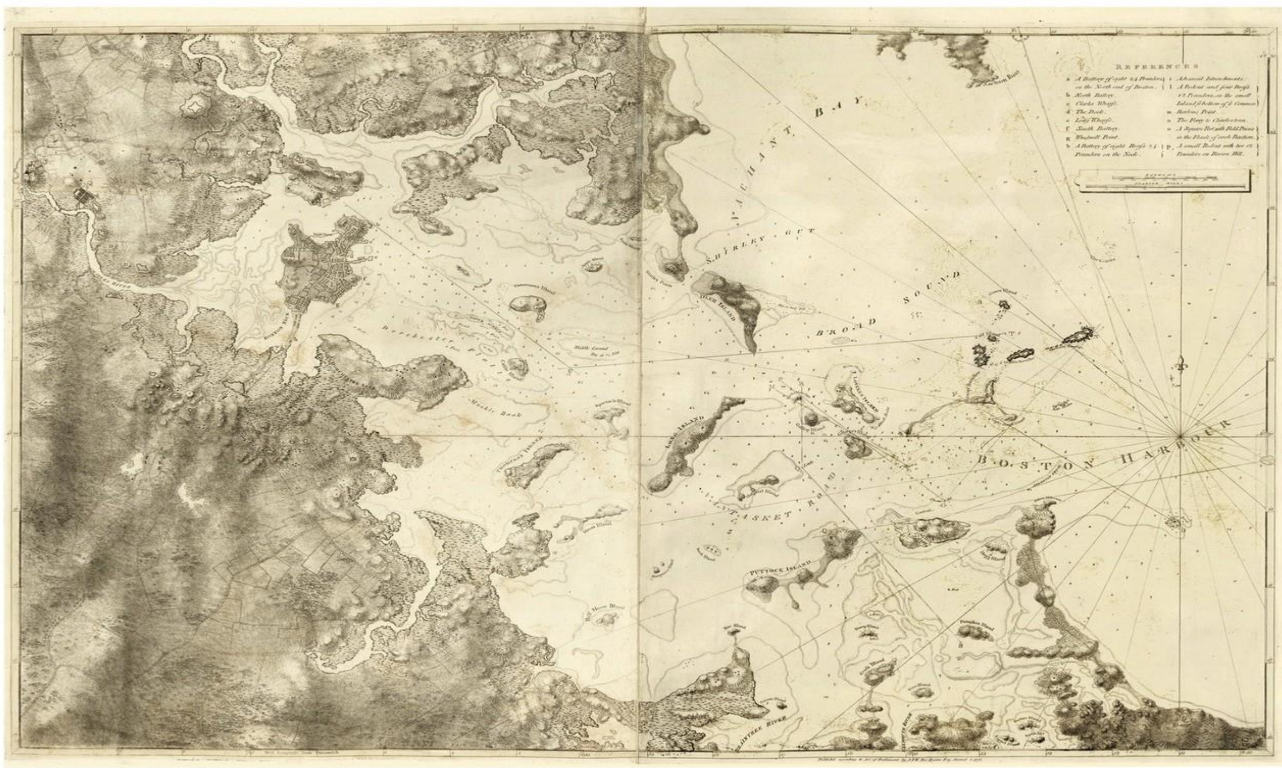
- 1584 - Dutch devised new marine map with soundings on large scale
- 1569 - Gerard Mercator developed a projection of the earth's surface on a chart. It took the marine community many more years before they began using this on their nautical charts.
- 1701 - First chart of the world-wide magnetic variation.
- 1757 - First sextant
- 1760 - First highly accurate chronometer for ship use enabling mariners to aid in the determination of longitude.
- 1765 - First set of Lunar Tables enable mariners to accurately determine their position at sea

In the late 18th century, the British Navy still had no original charts of the colonies in

North America and were dependent on small-scale French charts. The British were aware of the inadequacy of the charts of the American coast but didn't publish new updated charts with new sounding information until 1784.[3] Larger scale nautical charts just prior to the Revolutionary War had remarkably little sounding information. Figure A-5

**Figure A-5**

**BRITISH CHART OF BOSTON HARBOR 1775[4]**
**(NOTE THE LACK OF SOUNDINGS AND DETAIL)**




Following the Revolutionary War, it is interesting to see the priority the colonial governments placed on hydrographic surveying and compiling modern nautical charts to support

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[3] The Charting of the Oceans, Peter Whitfield, 1996, Pomegranate Books, PO Box 6099, Rohnett Park, California 94927, p 110 & 113.

[4] https://shop.old-maps.com/new-england-maps/

economic development through the transport of goods and passengers between colonies and foreign nations. Following the formation of the United States in 1789 Congress began to examine the prospect of a national approach to the charting of the United States waters.

In 1795 Congress was deciding on the funding for the survey and charting of the Georgia coast but recognized the need to have a larger more systematic approach to the charting of the Nation's waters and ports.

> *"The coast not only of Georgia, but also of South Carolina, North Carolina, and Virginia, has never been surveyed with the degree of accuracy which their importance to the commerce and navigation of the United States demands. As to Georgia, in particular, whose harbors are numerous and as yet little known, few observations have been made upon this coast, and those few have now become uncertain, from the shifting of bars, banks, and channels."*[5]

Most significant in this discussion was the recognition that charts covering large sections of the new nation needed to be authorized and paid for and that those areas needed to be periodically resurveyed and the charts updated.

In 1802 Congressman Dana of Connecticut arguing for surveys of the waters of the United States stated in a House of Representatives debate:

[5] Dawn Forsythe, 2017. "*Nautical Charts Contribute to Economic Growth and National Defense, 1807-1945"*, unpublished white paper, p.5. NOAA, National Ocean Service, Office of Coast Survey, April 20.

**ESTIMATED GROSS BENEFITS PROVIDED BY NAVIGATIONAL CHARTS IN THE UNITED STATES**

> *"With a correct chart of every part of the coast, our seamen would no longer be under the necessity of relying on the imperfect or erroneous accounts given of our coast by foreign navigators. I hope the lives of our seamen, the interest of our merchants, and the benefits to the revenue, will be regarded as affording ample compensation for making a complete survey of the coasts of the United States."*[6]

Congressman Dana proposed a survey of the entire nation under the authority of the national government.

> *"The surveys which have thus been authorized (Long Island Sound and the waters of North Carolina), were perhaps most urgent but other surveys of the coast are desirable. What has already been done may be regarded as introductory to a general survey of the coasts of the United States under authority of the Government. With a correct chart of every part of the coast, our seamen would no longer be under necessity of relying on the imperfect or erroneous accounts given of our coast by foreign navigators."*
>
> *"I hope the lives of our seamen, the interest of our merchants, and the benefits to the revenue (of the nation), will be regarded as affording ample compensation for making a complete survey of the Coasts of the United States, at the public expense."*[7]

Accurate nautical charts were seen as essential for safety, for vital commerce and as a source of revenue from tariffs on trade. The House of Representatives passed a resolution to, "inquire into the expediency of making provision for survey of the coasts of the United States, designating the several islands, with the shoal and roads or places of anchorage within twenty leagues (69 miles) of any part of the shores of the United States.[8]

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[6] Ibid.

[7] Ibid.

[8] Ibid.

**ESTIMATED GROSS BENEFITS PROVIDED BY NAVIGATIONAL CHARTS IN THE UNITED STATES**

In 1807, the House passed H.R. 21 *"authorizing and requesting President Jefferson to "cause a survey to be taken of the coasts of the United States."* President Jefferson signed the bill the next day authorizing that a survey be taken of the coasts of the United States.[9]

**C. Results Of Early Charting**

Lieutenant Commanding George Blake in a letter to Superintendent Hassler discussing the results of his surveys of Delaware Bay, January 11, 1844, *"Many dangerous shoals having but few feet water upon them, and upon which numerous wrecks have occurred…"* [10]

William Mitchell writing to Superintendent Bache in 1846 concerning the need for a survey of Nantucket Shoal over and around which nearly 13,000 vessels sailed annually, stated

> *"The history of this most dangerous and fatal shoal is startling. Situated in mid-ocean; having, in low ebbs, scarcely a foot of water; in a region proverbial for its heavy swell; rising, at times without a moment's warning; the dread of all mariner, and the grave of thousands…"*[11]

As settlers moved west in the 1850s ship traffic increase through the Strait of Florida and most significantly passed the Florida Reef along the Florida Keys. James Tilghman states

> *"By the mid-1800s the reef lay on the margin of one of the busiest shipping lanes in the world, and the number of shipwrecks reached a vessel a week." "Losses and salvage awards approached $2 million*

[9] https://celebrating200years.noaa.gov/foundations/nautical_charts/welcome.html)

[10] Dawn Forsythe, 2017. "*Nautical Charts Contribute to Economic Growth and National Defense, 1807-1945"*, unpublished white paper, p.5. NOAA, National Ocean Service, Office of Coast Survey, April 20.

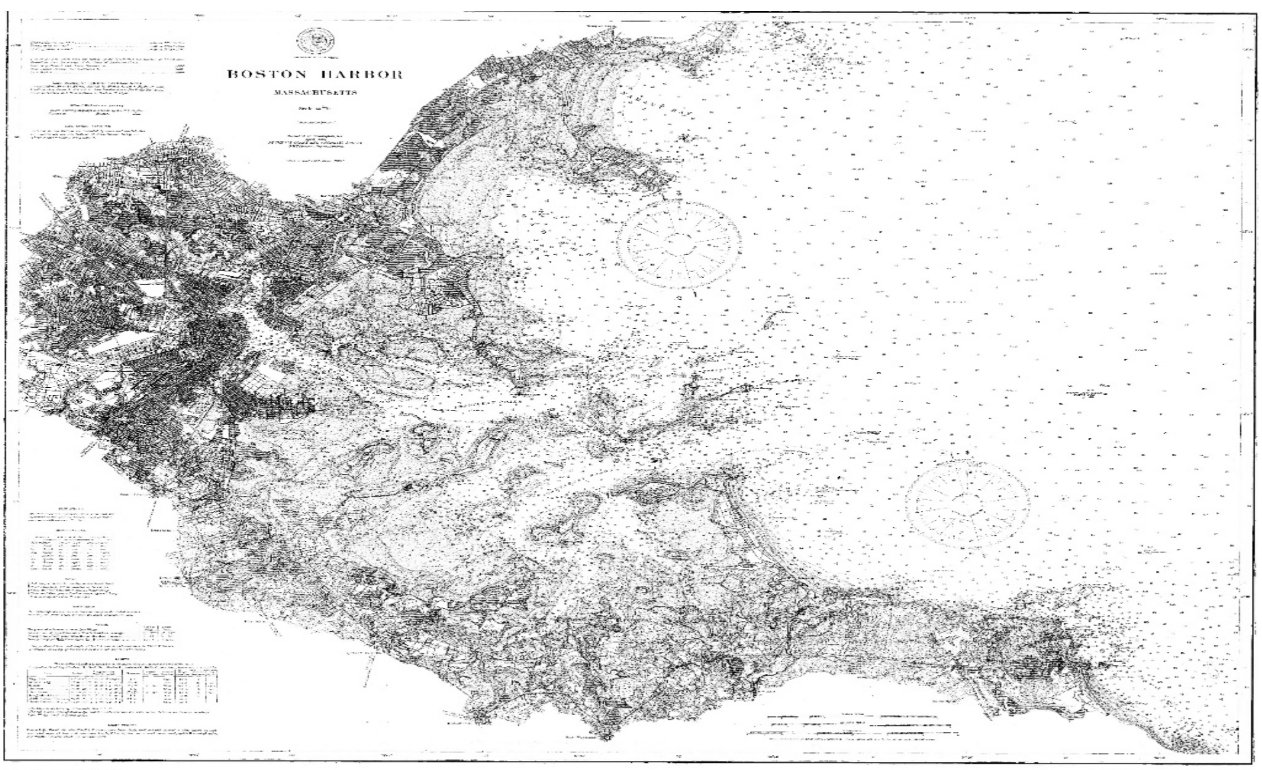
[11] Ibid.

> *annually; insurance rates skyrocketed; and Key West, the closest port with a court to adjudicate salvage claims, was on its way to becoming the richest city in Florida and one of the richest on a per capita basis in the United States."*[12]

Note the difference in detail from the 1775 British chart (Figure A-5) and number of soundings and detail in all areas of the harbor. Figure A-6

**Figure A-6**

**COAST SURVEY CHART OF BOSTON HARBOR (1867)**




President Wilson in his message to Congress on December 8, 1914 stated:

> *"We cannot use our great Alaskan domain, ships will not ply thither, if those coasts and their many hidden dangers are not thoroughly*

[12] James Tilghman, "Surveying the Florida Reef," Hydro International Magazine, July 26, 2012., p. 18

> *surveyed and charted. The work is incomplete at almost every point. Ships and lives have been lost in threading what were supposed to be well-known main channels."*[13]

The Coast and Geodetic Survey in their 1911 Annual Report stated:

> *"Surveys must be made at frequent intervals to keep pace with changes due to natural causes, to artificial improvements, changes in lights and buoys, and newly discovered rocks and shoals. Many waterways formerly but little frequented are now extensively used and the great development of motor boating, has caused an extensive demand for accurate charts of the inland waterways and shallower waters along the coast."* [14]

The Coast and Geodetic Survey in their 1918 Annual Report stated that in Alaska,

> "*The amount of these natural resources ripe for exploitation had been so great and the prize they offered so tempting that transportation could not wait for the Government to make the way to them secure (chart). It has gone ahead, finding its own path to each new field, suffering great losses in so doing, but content to suffer them because the returns were so immensely greater. The Coast and Geodetic Survey, which in this field should have been the pioneer showing the way for commerce to reach each new enterprise, has, instead, been following impotently behind, charting dangers less from data obtained by its own surveys than from reports of vessels which have been wrecked on them*[15]

From the early history of the United States it was apparent that accurate nautical charts were needed for the development of the nation and its economy. As the nation grew in size so

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[13] Dawn Forsythe, 2017. "*Nautical Charts Contribute to Economic Growth and National Defense, 1807-1945"*, unpublished white paper, p.5. NOAA, National Ocean Service, Office of Coast Survey, April 20.

[14] Ibid.

[15] Ibid.

too did the demand for new and accurate charts to promote commerce and the transportation of needed goods. Charts were needed to enable ships to deliver cargoes and passengers safely.

The modern Office of Coast Survey continues this mission. The size of the United States territory has greatly increased from its beginning. Coast Survey is now responsible for charting a vast area of 95,000 miles of shoreline and 3.6 million square nautical mile of water representing the Exclusive Economic Zone of the United States.

Unlike the early days of charting in U.S. waters, the charting is now compiled and updated with information from many different sources. Coast Survey receives over 6,000 digital and hard copy chart source documents annually. Each is reviewed for its suitability for updating one or more raster nautical chart, NOAA ENC®, or U.S. Coast Pilot® products. Of these, about 18,000 separate chart compilations are assigned to be carried out by Coast Survey's federal employee and contract cartographers.

Of all the natural and manmade features depicted on NOAA nautical charts, the four types that change the most, and for which Coast Survey receives the most source material, are:

- Water depths and the identification of wrecks, rocks, and other obstructions – from NOAA's Hydrographic Surveys Division
- Depths within federally maintained channels – from the U.S. Army Corps of Engineers
- Delineation of shoreline – from NOAA's National Geodetic Survey
- Positions, types, and characteristics of aids to navigation (buoys, beacons, and navigational lights) – from the U.S. Coast Guard

These account for over 70% of the source applications assigned. The remaining source material is provided by a variety of other federal, state and local government agencies, national and international regulatory organizations, private companies, professional organizations, and private citizens.[16]

The nautical charts in U.S. waters can come from a number of providers of nautical chart products in U.S. waters but all of these either copy the NOAA OCS chart or use the NOAA data and add additional value-added information. The National Imagery and Mapping Agency, a part of the Department of Defense, compiles nautical charts from official NOAA charts with additional military information. These charts are intended for military use only.

- U.S. Army Corps of Engineers produces a set of paper charts for some of the navigable rivers in the United States. These are mostly compilations of their survey information.
- The British Admiralty compiles a set of paper charts covering the U.S. waters. These charts are based on the NOAA official chart but may differ in their interpretation.
- There are a number of Value Added Providers that take the NOAA chart compilation and repackage it with some additional information usually non-navigational information.

The important point is that, with the exception of navigable rivers that the Corps of Engineers charts, the NOAA nautical chart is the official U.S. nautical chart as recognized by the U.S. Coast Guard in their carriage regulations.

[16] https://nauticalcharts.noaa.gov/publications/docs/ENC-Transformation.pdf,

# APPENDIX B

## MAJOR U.S. PORTS

**Table B-1**

## DOMINATE U.S. EXPORT PORTS FOR CARGO VALUE DURING 2018

| | PORT NAME | TOTAL CARGO VALUE ($2018) | PERCENT OF TOTAL | CUMULATIVE PERCENT OF TOTAL |
|---|---|---|---|---|
| 1 | Total All Ports | 586,941,632,760 | 100.0% | |
| 2 | Houston, TX | 89,855,975,747 | 15.3% | 15.3% |
| 3 | Los Angeles, CA | 35,809,247,531 | 6.1% | 21.4% |
| 4 | Long Beach, CA | 34,109,886,357 | 5.8% | 27.2% |
| 5 | New York, NY | 34,006,598,652 | 5.8% | 33.0% |
| 6 | New Orleans, LA | 31,544,089,116 | 5.4% | 38.4% |
| 7 | Savannah, GA | 27,055,319,023 | 4.6% | 43.0% |
| 8 | Charleston, SC | 25,925,245,802 | 4.4% | 47.4% |
| 9 | Norfolk-Newport News, VA | 24,457,635,540 | 4.2% | 51.6% |
| 10 | Corpus Christi, TX | 23,229,720,775 | 4.0% | 55.5% |
| 11 | Oakland, CA | 19,399,870,170 | 3.3% | 58.8% |
| 12 | Baltimore, MD | 16,769,275,153 | 2.9% | 61.7% |
| 13 | Gramercy, LA | 16,568,968,507 | 2.8% | 64.5% |
| 14 | Beaumont, TX | 15,928,190,323 | 2.7% | 67.2% |
| 15 | Port Everglades, FL | 12,634,392,692 | 2.2% | 69.4% |
| 16 | Newark, NJ | 10,800,849,435 | 1.8% | 71.2% |
| 17 | Miami, FL | 9,811,905,183 | 1.7% | 72.9% |
| 18 | Port Arthur, TX | 9,567,583,178 | 1.6% | 74.5% |
| 19 | Lake Charles, LA | 9,175,221,572 | 1.6% | 76.1% |
| 20 | Baton Rouge, LA | 8,890,499,877 | 1.5% | 77.6% |
| 21 | Tacoma, WA | 8,874,083,311 | 1.5% | 79.1% |
| 22 | Texas City, TX | 8,080,182,016 | 1.4% | 80.5% |
| 23 | Freeport, TX | 7,867,305,511 | 1.3% | 81.8% |
| 24 | Seattle, WA | 7,721,627,497 | 1.3% | 83.2% |
| 25 | Norfolk/Mobile/Charleston (confidentiality place holder - not a real location) | 7,298,384,645 | 1.2% | 84.4% |
| 26 | Jacksonville, FL | 6,474,406,237 | 1.1% | 85.5% |
| 27 | Wilmington, NC | 5,281,285,347 | 0.9% | 86.4% |
| 28 | Brunswick, GA | 5,182,038,426 | 0.9% | 87.3% |
| 29 | Portland, OR | 5,101,663,039 | 0.9% | 88.2% |
| 30 | San Juan, PR | 4,882,811,908 | 0.8% | 89.0% |
| 31 | Mobile, AL | 4,718,893,542 | 0.8% | 89.8% |

## ESTIMATED GROSS BENEFITS PROVIDED BY NAVIGATIONAL CHARTS IN THE UNITED STATES

| | | | | |
|---|---|---|---|---|
| 32 | Philadelphia, PA | 4,111,595,572 | 0.7% | 90.5% |
| 33 | Anchorage, AK | 3,787,909,443 | 0.6% | 91.1% |
| 34 | Kalama, WA | 3,202,943,991 | 0.5% | 91.7% |
| 35 | Pascagoula, MS | 3,191,377,287 | 0.5% | 92.2% |
| 36 | Longview, WA | 2,892,254,816 | 0.5% | 92.7% |
| 37 | Wilmington, DE | 2,862,012,064 | 0.5% | 93.2% |
| 38 | Chester, PA | 2,785,562,923 | 0.5% | 93.7% |
| 39 | Galveston, TX | 2,690,832,414 | 0.5% | 94.1% |
| 40 | Vancouver, WA | 2,253,953,571 | 0.4% | 94.5% |
| 41 | Morgan City, LA | 2,088,225,824 | 0.4% | 94.9% |
| 42 | West Palm Beach, FL | 1,871,483,017 | 0.3% | 95.2% |
| 43 | San Francisco, CA | 1,780,206,092 | 0.3% | 95.5% |
| 44 | Richmond, CA | 1,651,474,169 | 0.3% | 95.8% |
| 45 | Tampa, FL | 1,567,911,861 | 0.3% | 96.1% |
| 46 | Aberdeen-Hoquiam, WA | 1,462,292,406 | 0.2% | 96.3% |
| 47 | Champlain-Rouses Point, NY | 1,389,847,023 | 0.2% | 96.5% |
| 48 | Boston, MA | 1,260,898,552 | 0.2% | 96.8% |
| 49 | Anacortes, WA | 1,238,928,328 | 0.2% | 97.0% |
| 50 | Buffalo-Niagara Falls, NY | 1,140,089,204 | 0.2% | 97.2% |

**Table B-2**

## DOMINATE U.S. EXPORT PORTS FOR CARGO WEIGHT DURING 2018

| | PORT NAME | TOTAL CARGO WEIGHT (KILOGRAMS) | PERCENT OF TOTAL | CUMULATIVE PERCENT OF TOTAL |
|---|---|---|---|---|
| 1 | Total All Ports | 786,043,992,328 | 100.0% | |
| 2 | Houston, TX | 118,075,775,262 | 15.0% | 15.0% |
| 3 | Los Angeles, CA | 79,457,538,164 | 10.1% | 25.1% |
| 4 | Long Beach, CA | 54,508,444,925 | 6.9% | 32.1% |
| 5 | New York, NY | 52,500,927,223 | 6.7% | 38.7% |
| 6 | New Orleans, LA | 43,784,272,381 | 5.6% | 44.3% |
| 7 | Savannah, GA | 31,189,208,922 | 4.0% | 48.3% |
| 8 | Charleston, SC | 27,133,413,663 | 3.5% | 51.7% |
| 9 | Norfolk-Newport News, VA | 26,323,008,816 | 3.3% | 55.1% |
| 10 | Corpus Christi, TX | 25,457,378,795 | 3.2% | 58.3% |

## ESTIMATED GROSS BENEFITS PROVIDED BY NAVIGATIONAL CHARTS IN THE UNITED STATES

| | | | | |
|---|---|---|---|---|
| 11 | Oakland, CA | 22,240,385,881 | 2.8% | 61.2% |
| 12 | Baltimore, MD | 21,687,608,287 | 2.8% | 63.9% |
| 13 | Gramercy, LA | 20,029,954,843 | 2.5% | 66.5% |
| 14 | Beaumont, TX | 17,300,224,823 | 2.2% | 68.7% |
| 15 | Port Everglades, FL | 15,697,714,725 | 2.0% | 70.7% |
| 16 | Newark, NJ | 14,398,095,498 | 1.8% | 72.5% |
| 17 | Miami, FL | 13,366,212,437 | 1.7% | 74.2% |
| 18 | Port Arthur, TX | 13,152,976,666 | 1.7% | 75.9% |
| 19 | Lake Charles, LA | 12,473,644,287 | 1.6% | 77.4% |
| 20 | Baton Rouge, LA | 12,313,873,404 | 1.6% | 79.0% |
| 21 | Tacoma, WA | 11,836,812,223 | 1.5% | 80.5% |
| 22 | Texas City, TX | 11,272,551,854 | 1.4% | 82.0% |
| 23 | Freeport, TX | 10,327,207,951 | 1.3% | 83.3% |
| 24 | Seattle, WA | 9,199,337,055 | 1.2% | 84.4% |
| 25 | Norfolk/Mobile/Charleston (confidentiality place holder - not a real location) | 8,955,771,473 | 1.1% | 85.6% |
| 26 | Jacksonville, FL | 8,167,952,087 | 1.0% | 86.6% |
| 27 | Wilmington, NC | 8,057,844,636 | 1.0% | 87.6% |
| 28 | Brunswick, GA | 6,564,880,289 | 0.8% | 88.5% |
| 29 | Portland, OR | 5,199,571,747 | 0.7% | 89.1% |
| 30 | San Juan, PR | 4,203,507,763 | 0.5% | 89.7% |
| 31 | Mobile, AL | 4,105,947,240 | 0.5% | 90.2% |
| 32 | Philadelphia, PA | 4,087,739,039 | 0.5% | 90.7% |
| 33 | Anchorage, AK | 3,975,060,088 | 0.5% | 91.2% |
| 34 | Kalama, WA | 3,937,968,431 | 0.5% | 91.7% |
| 35 | Pascagoula, MS | 3,644,923,913 | 0.5% | 92.2% |
| 36 | Longview, WA | 3,094,321,070 | 0.4% | 92.6% |
| 37 | Wilmington, DE | 2,760,864,512 | 0.4% | 92.9% |
| 38 | Chester, PA | 2,693,314,891 | 0.3% | 93.3% |
| 39 | Galveston, TX | 2,587,120,430 | 0.3% | 93.6% |
| 40 | Vancouver, WA | 2,488,497,344 | 0.3% | 93.9% |
| 41 | Morgan City, LA | 2,479,300,840 | 0.3% | 94.2% |
| 42 | West Palm Beach, FL | 2,451,281,613 | 0.3% | 94.5% |
| 43 | San Francisco, CA | 2,421,502,426 | 0.3% | 94.9% |
| 44 | Richmond, CA | 2,357,719,216 | 0.3% | 95.2% |
| 45 | Tampa, FL | 2,336,857,838 | 0.3% | 95.5% |
| 46 | Aberdeen-Hoquiam, WA | 1,871,219,156 | 0.2% | 95.7% |
| 47 | Champlain-Rouses Point, NY | 1,863,032,368 | 0.2% | 95.9% |

| | | | | |
|---|---|---|---|---|
| 48 | Boston, MA | 1,828,269,832 | 0.2% | 96.2% |
| 49 | Anacortes, WA | 1,529,900,388 | 0.2% | 96.4% |
| 50 | Buffalo-Niagara Falls, NY | 1,526,966,208 | 0.2% | 96.5% |

**Table B-3**

## DOMINATE U.S. IMPORT PORTS FOR CARGO VALUE DURING 2018

| | PORT NAME | TOTAL CARGO VALUE ($2018) | PERCENT OF TOTAL | CUMULATIVE PERCENT OF TOTAL |
|---|---|---|---|---|
| | Total All Ports | 1,175,270,204,136 | 100.0% | |
| 1 | Los Angeles, CA | 260,973,553,744 | 22.2% | 22.2% |
| 2 | Newark, NJ | 152,138,512,782 | 12.9% | 35.2% |
| 3 | Long Beach, CA | 74,940,216,636 | 6.4% | 41.5% |
| 4 | Savannah, GA | 74,070,190,172 | 6.3% | 47.8% |
| 5 | Houston, TX | 69,007,112,112 | 5.9% | 53.7% |
| 6 | Norfolk-Newport News, VA | 49,081,040,428 | 4.2% | 57.9% |
| 7 | Charleston, SC | 46,686,332,066 | 4.0% | 61.8% |
| 8 | Baltimore, MD | 42,855,058,688 | 3.6% | 65.5% |
| 9 | Tacoma, WA | 40,090,990,895 | 3.4% | 68.9% |
| 10 | Oakland, CA | 29,858,578,465 | 2.5% | 71.4% |
| 11 | New Orleans, LA | 21,679,430,165 | 1.8% | 73.3% |
| 12 | Seattle, WA | 20,836,032,323 | 1.8% | 75.1% |
| 13 | Philadelphia, PA | 20,512,505,059 | 1.7% | 76.8% |
| 14 | Jacksonville, FL | 19,195,090,856 | 1.6% | 78.4% |
| 15 | Miami, FL | 15,839,982,743 | 1.3% | 79.8% |
| 16 | Brunswick, GA | 13,129,747,930 | 1.1% | 80.9% |
| 17 | Mobile, AL | 12,429,853,444 | 1.1% | 82.0% |
| 18 | Port Everglades, FL | 11,760,790,254 | 1.0% | 83.0% |
| 19 | Port Arthur, TX | 11,660,146,175 | 1.0% | 84.0% |
| 20 | Wilmington, DE | 10,951,415,150 | 0.9% | 84.9% |
| 21 | New York, NY | 9,632,301,210 | 0.8% | 85.7% |
| 22 | Boston, MA | 9,221,604,801 | 0.8% | 86.5% |
| 23 | Port Hueneme, CA | 8,861,299,508 | 0.8% | 87.2% |

| | | | | |
|---|---|---|---|---|
| 24 | Providence, RI | 8,748,511,767 | 0.7% | 88.0% |
| 25 | Richmond, CA | 8,414,321,109 | 0.7% | 88.7% |
| 26 | San Juan, PR | 7,333,022,812 | 0.6% | 89.3% |
| 27 | Corpus Christi, TX | 7,149,662,732 | 0.6% | 89.9% |
| 28 | Chester, PA | 6,873,782,468 | 0.6% | 90.5% |
| 29 | Portland, OR | 6,799,825,994 | 0.6% | 91.1% |
| 30 | Morgan City, LA | 6,470,168,793 | 0.6% | 91.7% |
| 31 | San Diego, CA | 6,154,703,742 | 0.5% | 92.2% |
| 32 | Lake Charles, LA | 5,806,584,923 | 0.5% | 92.7% |
| 33 | El Segundo, CA | 5,567,150,801 | 0.5% | 93.1% |
| 34 | Carquinez Strait, CA | 4,922,781,009 | 0.4% | 93.6% |
| 35 | Gramercy, LA | 4,666,558,577 | 0.4% | 94.0% |
| 36 | Wilmington, NC | 4,516,748,390 | 0.4% | 94.3% |
| 37 | Martinez, CA | 3,899,706,639 | 0.3% | 94.7% |
| 38 | San Francisco, CA | 3,701,250,555 | 0.3% | 95.0% |
| 39 | Honolulu, HI | 3,671,068,467 | 0.3% | 95.3% |
| 40 | Galveston, TX | 3,667,996,021 | 0.3% | 95.6% |
| 41 | Freeport, TX | 3,662,710,298 | 0.3% | 95.9% |
| 42 | Perth Amboy, NJ | 3,627,549,940 | 0.3% | 96.2% |
| 43 | Pascagoula, MS | 3,118,172,793 | 0.3% | 96.5% |
| 44 | Baton Rouge, LA | 3,044,145,989 | 0.3% | 96.8% |
| 45 | Beaumont, TX | 2,745,060,564 | 0.2% | 97.0% |
| 46 | Vancouver, WA | 2,416,308,211 | 0.2% | 97.2% |
| 47 | Panama City, FL | 2,364,736,227 | 0.2% | 97.4% |
| 48 | Tampa, FL | 2,110,264,684 | 0.2% | 97.6% |
| 49 | Portland, ME | 2,094,851,606 | 0.2% | 97.8% |
| 50 | Bellingham, WA | 1,991,453,433 | 0.2% | 97.9% |

**Table B-4**

## DOMINATE U.S. IMPORT PORTS FOR CARGO WEIGHT DURING 2018

| | PORT NAME | TOTAL CARGO WEIGHT (KILOGRAMS) | PERCENT OF TOTAL | CUMULATIVE PERCENT OF TOTAL |
|---|---|---|---|---|
| | Total All Ports | 663,739,178,165 | 100.0% | |
| 1 | Houston, TX | 63,167,596,234 | 9.5% | 9.5% |
| 2 | Newark, NJ | 56,211,245,692 | 8.5% | 18.0% |

## ESTIMATED GROSS BENEFITS PROVIDED BY NAVIGATIONAL CHARTS IN THE UNITED STATES

| | | | | |
|---|---|---|---|---|
| 3 | Los Angeles, CA | 52,671,095,869 | 7.9% | 25.9% |
| 4 | New Orleans, LA | 35,240,662,857 | 5.3% | 31.2% |
| 5 | Long Beach, CA | 26,987,261,199 | 4.1% | 35.3% |
| 6 | Port Arthur, TX | 26,043,059,579 | 3.9% | 39.2% |
| 7 | Wilmington, DE | 20,894,405,721 | 3.1% | 42.4% |
| 8 | Philadelphia, PA | 19,956,787,289 | 3.0% | 45.4% |
| 9 | Savannah, GA | 19,167,625,123 | 2.9% | 48.3% |
| 10 | Gramercy, LA | 18,661,948,073 | 2.8% | 51.1% |
| 11 | Mobile, AL | 17,478,865,026 | 2.6% | 53.7% |
| 12 | Corpus Christi, TX | 17,392,756,728 | 2.6% | 56.3% |
| 13 | Lake Charles, LA | 14,468,734,485 | 2.2% | 58.5% |
| 14 | Morgan City, LA | 13,098,904,976 | 2.0% | 60.5% |
| 15 | Baltimore, MD | 12,863,192,638 | 1.9% | 62.4% |
| 16 | Charleston, SC | 12,594,135,908 | 1.9% | 64.3% |
| 17 | Richmond, CA | 12,150,567,193 | 1.8% | 66.1% |
| 18 | El Segundo, CA | 11,724,870,246 | 1.8% | 67.9% |
| 19 | Norfolk-Newport News, VA | 11,151,637,617 | 1.7% | 69.6% |
| 20 | Seattle, WA | 8,457,698,434 | 1.3% | 70.9% |
| 21 | Boston, MA | 8,385,208,577 | 1.3% | 72.1% |
| 22 | Martinez, CA | 7,979,808,857 | 1.2% | 73.3% |
| 23 | Pascagoula, MS | 7,086,295,217 | 1.1% | 74.4% |
| 24 | Tampa, FL | 7,061,634,025 | 1.1% | 75.5% |
| 25 | Oakland, CA | 6,840,658,238 | 1.0% | 76.5% |
| 26 | Jacksonville, FL | 6,747,736,202 | 1.0% | 77.5% |
| 27 | Freeport, TX | 6,746,840,183 | 1.0% | 78.5% |
| 28 | Port Everglades, FL | 6,667,429,496 | 1.0% | 79.5% |
| 29 | Honolulu, HI | 6,559,113,138 | 1.0% | 80.5% |
| 30 | Baton Rouge, LA | 6,552,830,497 | 1.0% | 81.5% |
| 31 | Beaumont, TX | 6,273,801,409 | 0.9% | 82.5% |
| 32 | Tacoma, WA | 5,983,377,690 | 0.9% | 83.4% |
| 33 | San Juan, PR | 5,784,599,175 | 0.9% | 84.2% |
| 34 | Perth Amboy, NJ | 5,351,081,581 | 0.8% | 85.0% |
| 35 | Chester, PA | 4,875,873,261 | 0.7% | 85.8% |
| 36 | San Francisco, CA | 4,831,218,780 | 0.7% | 86.5% |
| 37 | New York, NY | 4,566,697,864 | 0.7% | 87.2% |
| 38 | Ponce, PR | 4,320,063,172 | 0.7% | 87.8% |
| 39 | Texas City, TX | 4,143,676,238 | 0.6% | 88.5% |
| 40 | Providence, RI | 3,982,471,648 | 0.6% | 89.1% |
| 41 | Miami, FL | 3,898,898,569 | 0.6% | 89.6% |

| | | | | |
|---|---|---|---|---|
| 42 | Bellingham, WA | 3,710,119,115 | 0.6% | 90.2% |
| 43 | Detroit, MI | 3,430,619,782 | 0.5% | 90.7% |
| 44 | Carquinez Strait, CA | 3,376,290,074 | 0.5% | 91.2% |
| 45 | Port Canaveral, FL | 3,355,831,094 | 0.5% | 91.7% |
| 46 | Portland, ME | 3,248,530,258 | 0.5% | 92.2% |
| 47 | Wilmington, NC | 3,021,866,639 | 0.5% | 92.7% |
| 48 | Chicago, IL | 2,746,023,575 | 0.4% | 93.1% |
| 49 | Port Manatee, FL | 2,725,783,835 | 0.4% | 93.5% |
| 50 | Christiansted, VI | 2,625,862,088 | 0.4% | 93.9% |

**Table B-5**

| 2016 VESSEL TRANSITS (CPT DATA) | | | | | | |
|---|---|---|---|---|---|---|
| TOTAL DOCKED AND THROUGH TRAFFIC | | | | 3,991,481 | | |
| **COUNT** | **PORT NAME** | **YEAR PORTS® INSTALLED** | **STATE** | **2016 TOTAL VESSEL TRANSITS** | **PERCENT OF TOTAL** | **CUMULATIVE PERCENT** |
| 1 | Corpus Christi | 2018 | TX | 358,723 | 9.0% | 9.0% |
| 2 | New York | 1994 | NY | 315,072 | 7.9% | 16.9% |
| 3 | South Louisiana, Port of (including St. Rose and Destrehan) | 2009 | LA | 196,080 | 4.9% | 21.8% |
| 4 | Houston | 1996 | TX | 182,707 | 4.6% | 26.4% |
| 5 | Avondale / Good Hope | 2009 | LA | 161,553 | 4.0% | 30.4% |
| 6 | Gramercy | 2009 | LA | 157,511 | 3.9% | 34.4% |
| 7 | Baton Rouge | 2009 | LA | 156,065 | 3.9% | 38.3% |
| 8 | Plaquemines, Port of | 2009 | LA | 143,242 | 3.6% | 41.9% |
| 9 | Galveston & Bolivar | 1996 | TX | 141,019 | 3.5% | 45.4% |
| 10 | New Orleans (Including Port Sulphur) | 2009 | LA | 125,056 | 3.1% | 48.5% |
| 11 | San Francisco | 1995 | CA | 103,072 | 2.6% | 51.1% |
| 12 | Norfolk Harbor /Hampton Roads | 2003 | VA | 94,250 | 2.4% | 53.5% |
| 13 | St. Louis | | MO | 92,472 | 2.3% | 55.8% |
| 14 | Newport News | 2003 | VA | 86,721 | 2.2% | 58.0% |
| 15 | Chicago | | IL | 74,445 | 1.9% | 59.8% |

## ESTIMATED GROSS BENEFITS PROVIDED BY NAVIGATIONAL CHARTS IN THE UNITED STATES

| | | | | | | |
|---|---|---|---|---|---|---|
| 16 | Port Arthur | 2010 | TX | 55,571 | 1.4% | 61.2% |
| 17 | Louisville | | KY | 52,510 | 1.3% | 62.5% |
| 18 | Mackinac Island | | MI | 50,083 | 1.3% | 63.8% |
| 19 | Mobile | 2007 | AL | 44,154 | 1.1% | 64.9% |
| 20 | Detour City | | MI | 38,911 | 1.0% | 65.9% |
| 21 | Wilmington | | NC | 38,351 | 1.0% | 66.8% |
| 22 | Oakland | 1995 | CA | 35,567 | 0.9% | 67.7% |
| 23 | Port Fourchon | 2015 | LA | 32,565 | 0.8% | 68.5% |
| 24 | Lake Charles/Cameron | 2009 | LA | 31,718 | 0.8% | 69.3% |
| 25 | Portland | | ME | 26,365 | 0.7% | 70.0% |
| 26 | Peoria | | IL | 26,141 | 0.7% | 70.6% |
| 27 | Beaumont | 2010 | TX | 25,243 | 0.6% | 71.3% |
| 28 | Seattle | | WA | 23,476 | 0.6% | 71.9% |
| 29 | Morgan City | 2015 | LA | 23,207 | 0.6% | 72.5% |
| 30 | San Pablo Bay | | CA | 21,613 | 0.5% | 73.0% |
| 31 | Long Beach | 2001 | CA | 21,451 | 0.5% | 73.5% |
| 32 | Wilmington | 2002 | DE | 20,085 | 0.5% | 74.0% |
| 33 | Matagorda | 2017 | TX | 19,820 | 0.5% | 74.5% |
| 34 | Los Angeles | 2001 | CA | 19,664 | 0.5% | 75.0% |
| 35 | San Diego | | CA | 19,054 | 0.5% | 75.5% |
| 36 | Portland | 2005 | OR | 17,629 | 0.4% | 75.9% |
| 37 | Jacksonville/Mayport | 2014 | FL | 17,498 | 0.4% | 76.4% |
| 38 | Philadelphia | 2002 | PA | 16,936 | 0.4% | 76.8% |
| 39 | Alameda | 1995 | CA | 16,845 | 0.4% | 77.2% |
| 40 | Marcus Hook | 2002 | PA | 15,101 | 0.4% | 77.6% |
| 41 | New Castle | 2002 | DE | 14,498 | 0.4% | 78.0% |
| 42 | Tacoma | 2004 | WA | 13,981 | 0.4% | 78.3% |
| 43 | New London/Groton | 2012 | CT | 13,498 | 0.3% | 78.7% |
| 44 | Camden-Gloucester | 2002 | NJ | 13,130 | 0.3% | 79.0% |
| 45 | Newark | 1994 | NJ | 12,044 | 0.3% | 79.3% |
| 46 | Richmond | 1995 | CA | 11,644 | 0.3% | 79.6% |
| 47 | Texas City | 1996 | TX | 11,633 | 0.3% | 79.9% |
| 48 | Charleston | 2013 | SC | 11,114 | 0.3% | 80.1% |
| 49 | Everglades | 2018 | FL | 10,619 | 0.3% | 80.4% |

## ESTIMATED GROSS BENEFITS PROVIDED BY NAVIGATIONAL CHARTS IN THE UNITED STATES

| | | | | | | |
|---|---|---|---|---|---|---|
| 50 | Vancouver | 2005 | WA | 9,705 | 0.2% | 80.7% |
| 51 | Paulsboro | 2002 | NJ | 9,595 | 0.2% | 80.9% |
| 52 | Chester | 2002 | PA | 9,561 | 0.2% | 81.1% |
| 53 | Empire/Venice | 2009 | LA | 9,405 | 0.2% | 81.4% |
| 54 | Baltimore | 2003 | MD | 9,134 | 0.2% | 81.6% |
| 55 | Kalama | 2005 | WA | 8,885 | 0.2% | 81.8% |
| 56 | Freeport | | TX | 7,946 | 0.2% | 82.0% |
| 57 | Fajardo | | PR | 7,869 | 0.2% | 82.2% |
| 58 | Cruz Bay | | VI | 7,432 | 0.2% | 82.4% |
| 59 | Boca Grande | | FL | 6,974 | 0.2% | 82.6% |
| 60 | Longview | 2005 | WA | 6,726 | 0.2% | 82.7% |
| 61 | Pascagoula/Moss Point | 2008 | MS | 6,633 | 0.2% | 82.9% |
| 62 | Detroit | | MI | 6,618 | 0.2% | 83.1% |
| 63 | Sabine Pass | 2010 | TX | 6,587 | 0.2% | 83.2% |
| 64 | Rockland | | ME | 6,554 | 0.2% | 83.4% |
| 65 | Memphis | | TN | 6,473 | 0.2% | 83.6% |
| 66 | Savannah | 2016 | GA | 6,408 | 0.2% | 83.7% |
| 67 | Tampa | 1991 | FL | 5,693 | 0.1% | 83.9% |
| 68 | Algonac | | | 5,650 | 0.1% | 84.0% |
| 69 | Carquinez Strait | | CA | 5,430 | 0.1% | 84.2% |
| 70 | Selby | | CA | 5,430 | 0.1% | 84.3% |
| 71 | San Juan | | PR | 5,370 | 0.1% | 84.4% |
| 72 | Miami | 2018 | FL | 5,277 | 0.1% | 84.6% |
| 73 | Toledo-Sandusky | | OH | 5,124 | 0.1% | 84.7% |
| 74 | Honolulu | | HI | 5,070 | 0.1% | 84.8% |
| 75 | Kalama | | WA | 4,789 | 0.1% | 84.9% |
| 76 | Boston | | MA | 4,655 | 0.1% | 85.0% |
| 77 | Anacortes | 2010 | WA | 4,564 | 0.1% | 85.2% |
| 78 | Huntsville | | AL | 4,364 | 0.1% | 85.3% |
| 79 | West Palm Beach | | FL | 4,069 | 0.1% | 85.4% |
| 80 | Astoria | 2005 | OR | 3,966 | 0.1% | 85.5% |
| 81 | Juneau | | AK | 3,847 | 0.1% | 85.6% |
| 82 | Port Lavaca | | TX | 3,816 | 0.1% | 85.7% |
| 83 | New Haven | 2004 | CT | 3,614 | 0.1% | 85.8% |

## ESTIMATED GROSS BENEFITS PROVIDED BY NAVIGATIONAL CHARTS IN THE UNITED STATES

| | | | | | | |
|---|---|---|---|---|---|---|
| 84 | Ketchikan | | AK | 3,573 | 0.1% | 85.8% |
| 85 | Gloucester City | 2002 | NJ | 3,532 | 0.1% | 85.9% |
| 86 | Washington | 2003 | DC | 3,532 | 0.1% | 86.0% |
| 87 | Naval Sub Base, Kings Bay | | GA | 3,461 | 0.1% | 86.1% |
| 88 | Perth Amboy | | NJ | 3,431 | 0.1% | 86.2% |
| 89 | Petersburg | | AK | 3,416 | 0.1% | 86.3% |
| 90 | Pensacola | | FL | 3,404 | 0.1% | 86.4% |
| 91 | Sault Ste Marie | 2001 | MI | 3,016 | 0.1% | 86.4% |
| 92 | Soo Locks | 2001 | MI | 3,016 | 0.1% | 86.5% |
| 93 | Anchorage | 2002 | AK | 2,741 | 0.1% | 86.6% |
| 94 | Everett | | WA | 2,634 | 0.1% | 86.7% |
| 95 | Albany | | NY | 2,632 | 0.1% | 86.7% |
| 96 | Coos Bay | | OR | 2,607 | 0.1% | 86.8% |
| 97 | Duluth | | MN | 2,577 | 0.1% | 86.8% |
| 98 | Greenville | | SC | 2,545 | 0.1% | 86.9% |
| 99 | Port Canaveral | | FL | 2,451 | 0.1% | 87.0% |
| 100 | Beaufort-Morehead City | | NC | 2,380 | 0.1% | 87.0% |

# APPENDIX C

## BACKGROUND FOR ONE-INCH CHANGE IN DEPTH ESTIMATES

**ESTIMATED GROSS BENEFITS PROVIDED BY NAVIGATIONAL CHARTS IN THE UNITED STATES**

1 Metric Ton = 2,204.6 lbs

## Wheat

Price of Wheat = $5.25/bushel
Source: http://www.quotewheat.com/ Wheat Quote Updated Jan-06-11

1 bushel of wheat weighs approximately 60 lbs
Source: Wheat Foods council web site http://www.wheatfoods.org/AboutWheat-wheat-facts/Index.htm

Panamax Bulk Carrier Ship Long Tons/inch draft = 160 average = 358,400 lbs. Source: Captain John Betz, Los Angeles Pilots December, 2010.

Bushels/1" draft = 5,973.3 bushels
Calculation: 358,400 lbs/inch draft ÷ 60 lbs/bushel

Value of Wheat = $31,360
Calculations: 5,973.3 bushels × $5.25/bushel

How many loaves of white bread would this make:

> One bushel of wheat weighs approximately 60 pounds.
> One bushel of wheat yields approximately 42 pounds of white flour.
> One bushel of wheat yields approximately 60 pounds of whole-wheat flour.

Source:
http://wiki.answers.com/Q/How_many_pounds_of_wheat_does_it_take_to_make_one_pound_of_flour#ixzz1AffSsWO7

Calculation: (42 lbs white flour ÷ 60 lbs raw wheat) × 358,400 lbs wheat = 250,880 lbs white flour.

Approximately 2 cups of flour per loaf of white bread.
Source: http://wiki.answers.com/Q/How_much_flour_in_a_one_pound_loaf_of_bread

Weight of 2 cups of flour = 2 × 4.75oz/cup = 9.5 oz ÷ 16oz/lb = 0.59375 lbs/loaf white bread
Source: http://www.preparedpantry.com/how-to-measure-flour-convert-cups-ounces.aspx

# loaves white bread / 1 inch draft = 422,535 loaves bread
(250,880 lbs white flour/1 inch draft ÷ 0.59375 lbs/loaf bread)

EMPLOYMENT: U.S. = 950,600 agricultural workers producing grain. (2008)
Source: http://www.bls.gov/oco/cg/cgs001.htm

**ESTIMATED GROSS BENEFITS PROVIDED BY NAVIGATIONAL CHARTS IN THE UNITED STATES**

## Corn

Panamax Bulk Carrier Ship Long Tons/inch draft = 160 average = 358,400 lbs Source: Captain John Betz, Los Angeles Pilots December, 2010.

1 bushel of corn weighs approximately 56 lbs
Source: http://www.unc.edu/~rowlett/units/scales/bushels.html

Price of Corn (shelled) = $6.02/bushel
Source: http://www.quotecorn.com/ Corn Quote Updated Jan-06-11 3:19 PM

Bushels/1” draft = 6,400 bushels
Calculation: 358,400lbs/inch draft ÷ 56lbs/bushel

Value of Corn = $38,528
Calculations: 6,400 bushels × $6.02/bushel

EMPLOYMENT: U.S. = 950,600 agricultural workers producing grain. (2008)
Source: http://www.bls.gov/oco/cg/cgs001.htm

## Soybeans

Panamax Bulk Carrier Ship Long Tons/inch draft = 160 average = 358,400 lbs Source: Captain John Betz, Los Angeles Pilots December, 2010.

1 bushel of soybeans weighs approximately 60 lbs
Source: http://www.unc.edu/~rowlett/units/scales/bushels.html

Price of Soybeans = $13.78/bushel
Source: http://www.quotesoybeans.com/ Soybeans Quote Updated Jan-06-11 3:19 PM

Bushels/1” draft = 5,973.3 bushels
Calculation: 358,400lbs/inch draft ÷ 60lbs/bushel

Value of Soybeans = $82,312
Calculations: 5,973.3 bushels × $13.78/bushel

EMPLOYMENT: U.S. = 950,600 agricultural workers producing grain. (2008)
Source: http://www.bls.gov/oco/cg/cgs001.htm

**ESTIMATED GROSS BENEFITS PROVIDED BY NAVIGATIONAL CHARTS IN THE UNITED STATES**

## Beef

2009 U.S. exported 1.868 billion pounds beef
Source: USDA web site http://www.ers.usda.gov/news/BSECoverage.htm

Price of beef = $1.5877/lb (Choice 1 Carcass weight 600 – 900 lbs)
Source: USDA report http://www.ams.usda.gov/mnreports/nw_ls410.txt

Food items like beef are carried in refrigerated cargo ships
Source: http://www.globalsecurity.org/military/systems/ship/break-bulk-reefer.htm

Panamax Bulk Carrier Ship Long Tons/inch draft = 160 average = 358,400 lbs Source: Captain John Betz, Los Angeles Pilots December, 2010.

Beef (lbs)/1 inch of draft = 358,400 lbs

Value of beef/1 inch draft = $569,032
Calculation: (358,400lbs × 1.5877/lb)

EMPLOYMENT: U.S. 860,600 involve in animal production
Source: http://www.bls.gov/oco/cg/cgs001.htm

## Chevy Volt

Weight = 3,500 lbs
http://www.chevy-volt.net/chevrolet-volt-weight-details.htm

Cost = $40,280 Manufacturers Suggested Retail Price (msrp)
Source: http://usnews.rankingsandreviews.com/cars-trucks/Chevrolet_Volt/

Ship Vehicle Carrier - ALLIANCE CHARLESTON TPC 61.92
Calculation: (61.92TPC × 2204.6 lbs/metric ton) × 2.54 cm/inch = 346,732 lbs/inch of draft

# of cars per inch draft = 346,732 lbs/inch draft ÷ 3,500 lbs/car = 99 (99.07 rounded down)

Value of cars for 1 inch draft = 99 cars/inch × $40,280/car = $3,987,720

Employment: 91,960 (GM employs 209,000 people worldwide of which 44% are North American employees)
Source: http://www.numberof.net/number-of-gm-employees/

# OTHER VEHICLES

Ford F150
Weight = 4,803 lbs
Source: http://www.fordf150.net/2010/2010-ford-f150-specifications.php

Price - $36,777 (average)
Source : http://consumerguideauto.howstuffworks.com/all-ford-f-150s.htm

Ship Vehicle Carrier - ALLIANCE CHARLESTON TPC 61.92
Calculation: (61.92TPC × 2204.6 lbs/metric ton) × 2.54 cm/inch = 346,732 lbs/inch of draft

# of trucks per inch of draft = 346,732 lbs/inch draft ÷ 4,803 lbs/truck = 72 (72.19 rounded down)

Value of trucks for 1 inch draft = 72 trucks × $36,777/truck = $2,647,944

Employees = 45,000 in U.S.
Source: http://answers.yahoo.com/question/index?qid=20081119141833AAb71i9

John Deere Tractor
John Deere 6140 Tractor weight = 9,390 lbs,
John Deere 6140 Tractor price = $66,747
Source: Call to John Deere Customer Service Department 1/11/2011

Ship Vehicle Carrier - ALLIANCE CHARLESTON TPC 61.92
Calculation: (61.92TPC × 2204.6 lbs/metric ton) × 2.54 cm/inch = 346,732 lbs/inch of draft

# of Tractors/inch of draft = 36 (36.9 rounded down)
Calculation 346,732 lbs/inch of draft ÷ 9,390 lbs/tractor)

Value of Tractors = 36 × $66,747 = $2,402,892

John Deere has Headquarters and manufacturing facilities in Illinois, Iowa, Wisconsin, Kansas, North Carolina, Georgia, Louisiana, and California.
Source:
http://www.deere.com/en_US/compinfo/media/pdf/publications/jd_journal/journal_no_vu_2002.pdf

Caterpillar 950H Wheel Loader

Panamax Bulk Carrier Ship Long Tons/inch draft = 160 average = 358,400 lbs Source: Captain John Betz, Los Angeles Pilots December, 2010.

Price: $229,000.00
Source: Milton CAT Equipment Dealer
http://www.equipmenttraderonline.com/find/listing/2010-CATERPILLAR-950H-97802699

Weight: 28,500 lbs
Source: Richie Specs
http://www.ritchiespecs.com/specification?type=construction+equipment&category=Wheel+Loader&make=Caterpillar&model=950&modelid=91545

# of Caterpillar 950H Wheel Loader per inch of draft = 12 (12.58 rounded down) vehicles (358,400 lbs/inch of draft ÷ 28,500 lbs/vehicle)

Value of Cargo (Caterpillar 950H Wheel Loaders) = (12 × $229,000.00/vehicle) = $2,748,000

The 950H was manufactured in the USA, with a K5K serial number prefix
Source: http://www.ritchiewiki.com/wiki/index.php/Caterpillar_950H_Wheel_Loader

Caterpillar is the world's largest manufacturer of wheel loaders. The medium size (MWL) and large size (LWL) are designed at their Aurora, Illinois facility. Medium wheel loaders are manufactured at: Aurora, Illinois. Large wheel loaders are manufactured exclusively in the United States on three separate assembly lines at Aurora, Illinois. Caterpillar still has four major plants in the Peoria area: the Mapleton Foundry, where diesel engine blocks and other large parts are cast; the East Peoria factory, which has assembled Caterpillar tractors for over 70 years; the Mossville engine plant, built after World War II; and the Morton parts facility. As of December 31, 2009, Caterpillar employed 93,813 persons of whom 43,251 are located in the United States.
Source: http://en.wikipedia.org/wiki/Caterpillar_Inc

## Athletic Shoes Calculation

Typical Panamax Container Ship 4,300 TEU's Long Tons/inch draft = 104 Source: Captain John Betz, Los Angeles Pilots December, 2010.

40 foot shipping container interior dimensions and weight – length 39.5ft, width 7.7 ft, height 7.8ft, empty weight 8,380 lbs. Source: Wikipedia (http://en.wikipedia.org/wiki/Intermodal_container).

Shoe boxes are stacked in a shipping box. Shipping boxes are double stacked on a pallet.
Shipping Box: box dimensions 60” long, 39” wide, 45” high, weight 23 lbs (based on weight of S-4684 ) Pallet H-1618 fits box S-4684, weight 60 lbs Pallet 6” high
Source: Uline Shipping Supply Specialists, (http://www.uline.com/BL_430/350-Lb-Test-Double-Wall-Boxes)

Athletic Shoe boxes – Measured 4 boxes at Foot Locker – Average box size
13” long, 8.5” wide, 5” high , weight shoe box and packing material without shoes 4oz
Source: MacFarland measurement Foot Locker, December 23, 2010.

Athletic Shoe Weight – average 16 oz/shoe Source: Tennis Company (http://www.tenniscompany.com/shoes_weight_comparison.html)

Price Athletic shoes = Average $ 92
Nike Tennis $120 - $64 = $92 Average
Source: Nike web site (http://store.nike.com/us/en_us/?&wfp=true#l=shop,pwp,c-1+100701/f-12001/hf-10002+4294967109/t-Men's_Tennis_Shoes/ipp-48/pn-1)
New Balance $120 - $78 = $99 Average
Source: New Balance web site (http://www.shopnewbalance.com/category.asp?type=MNFTTC)
Reebok $130 - $40 = $85 Average
Source: Reebok web site (http://www.reebok.com/US/mens/footwear )

CALCULATION: # pairs of shoes
http://www.shopnewbalance.com/category.asp?type=MNFTTC per shipping box = 189 (packed 7 x 3 x 9high)

CALCULATION: Loaded weight per shipping box 425 lbs (2 lbs (shoes) + 0.25lbs (packing)) x 189 boxes/shipping box)

CALCULATION: Number of shipping boxes per container = 28 boxes per container (packed 7 long x 2 wide x 2 tall)

CALCULATION: Number of shoe pairs per container (189 pair/shipping box x 28 boxes/container) = 5292 pairs of athletic shoes

CALCULATION: Weight of loaded container
Weight of Shoes – 425 lbs/shipping box x 28 boxes/container = 11,900 lbs
Weight of Shipping boxes – 28 boxes x 23lbs/box = 644 lbs
Weight of Pallets (first layer only) – 14 x 60 = 840 lbs
Weight of Empty Container = 8,380 lbs
TOTAL WEIGHT LOADED CONTIANER = 21,764 lbs

CALCULATION: # of containers to reduce draft of ship 1”

(104 long tons x 2240 lbs/long ton) ÷ 21,764 lbs/container = 11 containers (10.7 rounded to 11) containers

CALCULATION: # of pairs of shoes to reduce ship draft by 1 inch = 58,212
(11 containers x 189 pairs of shoes/box × 28 boxes/container = 58,212)
CALCULATION: Value of athletic shoes = $5,355,504 ($92/pair shoes x 58,212 pairs of shoes)

How Many Miles Can Be Run With 58,212 Pairs of Running Shoes?

The generally accepted consensus is runners will require a new pair of running shoes every 300-500 miles. Source: The Runners Guide - http://www.therunnersguide.com/howlongrunningshoeslast/

Calculation: # of Miles Run = 58,212 pairs of shoes × 400 miles (average of 300-500 mile spread) = 23,284,800 miles. This is the equivalent of 48.7 round trips between the Earth and the Moon.

Distance from Earth to Moon = 238,857 miles Source: Universe Today
http://www.universetoday.com/38128/distance-from-earth-to-moon/

## Laptop Computer Calculation

Typical Panamax Container Ship 4,300 TEU's Long Tons/inch draft = 104 Source: Captain John Betz, Los Angeles Pilots December, 2010.

40 foot shipping container dimensions and weight – interior length 39.5ft, width 7.7 ft, height 7.8ft, empty weight 8,380 lbs. Source: Wikipedia (http://en.wikipedia.org/wiki/Intermodal_container).

Shipping Box: box dimensions 57" long, 46" wide, 36" high, weight 23 lbs (based on weight of S-4684 )
Pallet H-1618 fits box S-4684, weight 60 lbs Pallet 6" high
Source: Uline Shipping Supply Specialists, (http://www.uline.com/BL_430/350-Lb-Test-Double-Wall-Boxes)

Dell Latitude E5510 Laptop Computer Boxes (with computer inside/13.5 inch screen) – shipping dimensions: 19" long, 18" wide, 9" high, with a shipping weight of 14 lbs.
Source: Robert Gillium, Information Systems Division, CO-OPS/NOS/NOAA, December, 2010.

**ESTIMATED GROSS BENEFITS PROVIDED BY NAVIGATIONAL CHARTS IN THE UNITED STATES**

Price of Dell Latitude E5510 Laptop Computer = $894.00 (starting price without add-ons or discounts)
Source: Dell web site. http://www.dell.com/us/business/p/latitude-e5510/pd?refid=latitude-e5510&baynote_bnrank=1&baynote_irrank=0&~ck=baynoteSearch

CALCULATION: # of laptop computers per shipping box = 30 (packed 3 long x 5 wide x 2 high)

CALCULATION: Loaded weight per shipping box = 443 lbs (30 computers x 14 lbs/computer + 23 lbs/shipping box)

CALCULATION: Number of shipping boxes per container = 32 boxes (packed 8 long x 2 wide x 2 tall + layer of 6" tall pallets on bottom layer)

CALCULATION: Number of laptop computers per container = 960 (30 computers/shipping box x 32 shipping boxes/container)

CALCULATION: The weight of the loaded container:

32 shipping boxes x 443 lbs/ loaded shipping box = 14,176 lbs
16 pallets x 60 lbs/pallet = 960 lbs
Weight of Empty Container = 8,380 lbs
Total weight of loaded container = 23,516 lbs.

CALCULATION: # of containers to reduce draft of ship 1"
(104 long tons x 2240 lbs/long ton) ÷ 23,516 lbs/container = 10 containers (9.91 rounded to 10)

CALCULATION: # of laptop computers to reduce ship draft by 1" = 9,600 (960 computers/container x 10 containers)

CALCULATION: Value of computers = $8,582,400 ($894/computer x 9,600 computers)

CUPS of COFFEE Calculation

33oz coffee makes 240 – 270 (average 255) cups (6oz) Source: Maxwell House 33oz coffee container December, 2010.

Panamax Bulk Carrier Ship Long Tons/inch draft = 160 average = 358,400 lbs Source: Captain John Betz, Los Angeles Pilots December, 2010.

Price of raw coffee beans $2.1255/lb
Source New York Mercantile Exchange (NYMEX) December 29, 2010
http://www.cmegroup.com/trading/agricultural/softs/coffee.html

**ESTIMATED GROSS BENEFITS PROVIDED BY NAVIGATIONAL CHARTS IN THE UNITED STATES**

CALCULATION: 358400 lbs * 16oz/lb = 5,734,400 oz of coffee per 1” ship draft

CALCULATION: 5,734,400 oz X 7.727272 cups /oz of coffee = 44,311,268 6 oz cups of coffee / 1” ship draft

CALCULATION: Value of raw coffee beans = $761,779

LCD TV Calculation
55” Sony KDL 55EX500 Shipping Data dimensions 61”long, 9”wide, 34”tall, weight 81 lbs.
Source: Tiger Direct.Com Phone call with sales representative December 27, 2010.

Price Sony KDL 55EX500 retail non-discounted $1899.99
Source: Official Sony web site.
http://www.sonystyle.com/webapp/wcs/stores/servlet/ProductDisplay?catalogId=10551&storeId=10151&langId=-1&productId=8198552921666077656)

Typical Panamax Container Ship 4,300 TEU’s Long Tons/inch draft = 104 Source: Captain John Betz, Los Angeles Pilots December, 2010.

40 foot shipping container dimensions and weight – interior length 39.5ft, width 7.7 ft, height 7.8ft, empty weight 8,380 lbs. Source: Wikipedia (http://en.wikipedia.org/wiki/Intermodal_container).

TV boxes are stacked in a shipping box and placed on a pallet. Shipping boxes and pallets are double stacked.
Shipping Boxes 62” long, 45” deep, 36” high, pallet 6” high. Total empty weight 47 lbs.
Source: CS Packaging, Inc. customized box based on box AF584145 weight.

CALCULATION: # TVs per box = 5 (45”÷ 9”)

CALCULATION: # boxes that can be packed in a container: 7 long, 2 wide, 2 tall =
28 boxes per container
140 TVs per container

CALCULATION: weight of loaded container
TV weight = 140 TVs/container X 81 lbs/TV = 11,340 lbs

Weight of shipping boxes = 47lbs/box X 28boxes/container = 1316 lbs

Weight of empty shipping container = 8,380lbs
TOTAL WEIGHT LOADED CONTAINER = 21,036 lbs

CALCULATION: # Containers required to reduce ship draft by 1”

(104 long tons X 2,240 lbs/long ton) ÷ 21,036 lbs/loaded container = 11 containers
CALCULATION: # TVs required to reduce ships draft by 1”

11 containers X 140 TVs/container = 1,540 TVs

CALCULATION: Value of TVs = $2,925,984.60

## Other Automobile Calculations

Toyota Prius III 2010

Typical Car Carrier Ship 200 meters Tons (long 2,240lbs) per inch (TPI) = 120 long tons/inch or 268,800 lbs/inch of draft
Source: Captain John Betz, Los Angeles Pilots January, 2011.

TOYOTA Prius 2010 weight = 3,042 lbs
Source: Toyota web site http://www.toyota.com/prius-hybrid/specs.html

Calculation: # vehicles to lower ships draft by 1 inch = 268,800 lbs (vessel TPI) ÷ 3,042 (vehicle weight) = 88.36 or 88 whole units
Need to round down to next whole unit.

88 Toyota Priuses per inch of draft

Retail value of 2010 Toyota Prius III = $23,800
Source: Toyota web site: http://www.toyota.com/prius-hybrid/trims-prices.html#/?view=showroom&vehicle=1

Calculation: Cargo Value = 88 Toyotas × $23,800 = $2,094,400

2011 Mercedes Benz S600

## ESTIMATED GROSS BENEFITS PROVIDED BY NAVIGATIONAL CHARTS IN THE UNITED STATES

Typical Car Carrier Ship 200 meters Tons (long 2,240lbs) per inch (TPI) = 120 long tons/inch or 268,800 lbs/inch of draft
Source: Captain John Betz, Los Angeles Pilots January, 2011.

Mercedes-Benz 2011 S600 weight = 4,950 lbs
Source: Mercedes-Benz web site http://www.mbusa.com/mercedes/vehicles/explore/specs/class-S/model-S600V

Retail Value of 2011 Mercedes-Benz S600 = $158,050
Source: Yahoo Autos web site http://autos.yahoo.com/2011_mercedes_benz_s_class/

Calculation: # Vehicles to lower ships draft 1 inch = 268,800 lbs (vessel TPI) ÷ 4,950 lbs/vehicle = 54.3 or 54 whole units Need to round down to next whole unit.

54 Mercedes-Benz S600 per inch of draft

Calculation: Cargo Value = 54 Mercedes × $158,050/vehicle = $8,534,700

Hyundai 2011 Sonata SE

Typical Car Carrier Ship 200 meters Tons (long 2,240lbs) per inch (TPI) = 120 long tons/inch or 268,800 lbs/inch of draft
Source: Captain John Betz, Los Angeles Pilots January, 2011.

Hundai Sonata SE
Weight = 3,199 lbs
Retail price + $ 22,595

Source: Hyundai web site http://www.hyundaiusa.com/sonata/specifications.aspx

Calculation: # Vehicles to lower ships draft 1 inch = 268,800 lbs (vessel TPI) ÷ 3,199 lbs/vehicle = 84.0 or 84 whole units Need to round down to next whole unit.

84 Hyundai 2011 Sonata SE per inch of draft

Calculation: Cargo Value = 84 Hyundai's × $22,595/vehicle = $1,897,980

# APPENDIX D

## 200 LARGEST CONTAINERSHIPS IN THE WORLD

# LARGEST CONTAINERSHIPS IN THE WORLD

| YEAR BUILT | VESSEL NAME | LENGTH (METERS) | LENGTH (FEET) | BEAM (METERS) | BEAM (FEET) | MAXIMUM TEUs | GROSS TONNAGE |
|---|---|---|---|---|---|---|---|
| 2017 | OOCL Hong Kong | 399.9 | 1,312 | 58.8 | 193 | 21,413 | 210,890 |
| 2017 | OOCL Germany | 399.9 | 1,312 | 58.8 | 193 | 21,413 | 210,890 |
| 2017 | OOCL Japan | 399.9 | 1,312 | 58.8 | 193 | 21,413 | 210,890 |
| 2017 | OOCL United Kingdom | 399.9 | 1,312 | 58.8 | 193 | 21,413 | 210,890 |
| 2017 | OOCL Scandinavia | 399.9 | 1,312 | 58.8 | 193 | 21,413 | 210,890 |
| 2018 | OOCL Indonesia | 399.9 | 1,312 | 58.8 | 193 | 21,413 | 210,890 |
| 2018 | *COSCO Shipping Universe* | 400.0 | 1,312.3 | 58.6 | 192 | 21,237 | 201,000 |
| 2018 | *CMA CGM Antoine de Saint Exupery* | 400.0 | 1,312.3 | 59.0 | 193.6 | 20,954 | 217,673 |
| 2018 | *CMA CGM Jean Mermoz* | 400.0 | 1,312.3 | 59.0 | 193.6 | 20,954 | 217,673 |

**ESTIMATED GROSS BENEFITS PROVIDED BY NAVIGATIONAL CHARTS IN THE UNITED STATES**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 2018 | *CMA CGM Louis Bleriot* | 400.0 | 1,312.3 | 59.0 | 193.6 | 20,954 | 217,673 |
| 2017 | *Madrid Maersk* | 399.0 | 1,309.1 | 58.6 | 192 | 20,568 | 214,286 |
| 2017 | *Munich Maersk* | 399.0 | 1,309.1 | 58.6 | 192 | 20,568 | 214,286 |
| 2017 | *Moscow Maersk* | 399.0 | 1,309.1 | 58.6 | 192 | 20,568 | 214,286 |
| 2017 | *Milan Maersk* | 399.0 | 1,309.1 | 58.6 | 192 | 20,568 | 214,286 |
| 2017 | *Monaco Maersk* | 399.0 | 1,309.1 | 58.6 | 192 | 20,568 | 214,286 |
| 2018 | *Marseille Maersk* | 399.0 | 1,309.1 | 58.6 | 192 | 20,568 | 214,286 |
| 2018 | *Manchester Maersk* | 399.0 | 1,309.1 | 58.6 | 192 | 20,568 | 214,286 |
| 2018 | *Murcia Maersk* | 399.0 | 1,309.1 | 58.6 | 192 | 20,568 | 214,286 |
| 2018 | *Manila Maersk* | 399.0 | 1,309.1 | 58.6 | 192 | 20,568 | 214,286 |
| 2018 | *Mumbai Maersk* | 399.0 | 1,309.1 | 58.6 | 192 | 20,568 | 214,286 |

## ESTIMATED GROSS BENEFITS PROVIDED BY NAVIGATIONAL CHARTS IN THE UNITED STATES

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 2018 | *Ever Golden* | 400.0 | 1,312.3 | 58.8 | 193 | 20,388 | 217,612 |
| 2018 | *Ever Goods* | 400.0 | 1,312.3 | 58.8 | 193 | 20,388 | 217,612 |
| 2018 | *Ever Genius* | 400.0 | 1,312.3 | 58.8 | 193 | 20,388 | 217,612 |
| 2018 | *Ever Given* | 400.0 | 1,312.3 | 58.8 | 193 | 20,388 | 217,612 |
| 2017 | *MOL Truth* | 399.0 | 1,309.1 | 58.0 | 190.3 | 20,182 | 210,691 |
| 2018 | *MOL Treasure* | 399.0 | 1,309.1 | 58.0 | 190.3 | 20,182 | 210,691 |
| 2017 | *MOL Triumph* | 400.0 | 1,312.3 | 58.8 | 193 | 20,170 | 210,678 |
| 2017 | *MOL Trust* | 400.0 | 1,312.3 | 58.8 | 193 | 20,170 | 210,678 |
| 2017 | *MOL Tribute* | 400.0 | 1,312.3 | 58.8 | 193 | 20,170 | 210,678 |
| 2017 | *MOL Tradition* | 400.0 | 1,312.3 | 58.8 | 193 | 20,170 | 210,678 |
| 2018 | *COSCO Shipping Taurus* | 399.8 | 1,312 | 58.7 | 193 | 20,119 | 194,864 |
| 2018 | *COSCO Shipping Gemini* | 399.9 | 1,312 | 58.7 | 193 | 20,119 | 194,864 |
| 2018 | *COSCO Shipping Virgo* | 399.9 | 1,312 | 58.7 | 193 | 20,119 | 194,864 |

**ESTIMATED GROSS BENEFITS PROVIDED BY NAVIGATIONAL CHARTS IN THE UNITED STATES**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 2018 | *COSCO Shipping Libra* | 399.7 | 1,311 | 58.7 | 193 | 20,119 | 194,864 |
| 2015 | *Barzan* | 400.0 | 1,312.3 | 58.6 | 192 | 19,870 | 195,636 |
| 2015 | *Al Muraykh* | 400.0 | 1,312.3 | 58.6 | 192 | 19,870 | 195,636 |
| 2015 | *Al Nefud* | 400.0 | 1,312.3 | 58.6 | 192 | 19,870 | 195,636 |
| 2015 | *Al Zubara* | 400.0 | 1,312.3 | 58.6 | 192 | 19,870 | 195,636 |
| 2016 | *Al Dahna* | 400.0 | 1,312.3 | 58.6 | 192 | 19,870 | 195,636 |
| 2016 | *Tihama* | 400.0 | 1,312.3 | 58.6 | 192 | 19,870 | 195,636 |
| 2016 | *MSC Diana* | 400.0 | 1,312.3 | 58.8 | 193 | 19,462 | 193,489 |
| 2016 | *MSC Ingy* | 400.0 | 1,312.3 | 58.8 | 193 | 19,462 | 193,489 |
| 2016 | *MSC Eloane* | 400.0 | 1,312.3 | 58.8 | 193 | 19,462 | 193,489 |
| 2016 | *MSC Mirjam* | 400.0 | 1,312.3 | 58.8 | 193 | 19,462 | 193,489 |
| 2017 | *MSC Rifaya* | 400.0 | 1,312.3 | 58.8 | 193 | 19,462 | 193,489 |
| 2017 | *MSC Leanne* | 400.0 | 1,312.3 | 58.8 | 193 | 19,462 | 193,489 |
| 2016 | *MSC Reef* | 398.4 | 1,307 | 59.1 | 194 | 19,437 | 194,308 |

**ESTIMATED GROSS BENEFITS PROVIDED BY NAVIGATIONAL CHARTS IN THE UNITED STATES**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 2016 | *MSC Jade* | 398.5 | 1,307 | 59.1 | 194 | 19,437 | 194,308 |
| 2016 | *MSC Ditte* | 398.5 | 1,307 | 59.1 | 194 | 19,437 | 194,308 |
| 2016 | *MSC Mirja* | 398.5 | 1,307 | 59.0 | 193.6 | 19,437 | 194,308 |
| 2016 | *MSC Erica* | 398.5 | 1,307 | 59.1 | 194 | 19,437 | 194,308 |
| 2017 | *MSC Tina* | 398.5 | 1,307 | 59.1 | 194 | 19,437 | 194,308 |
| 2016 | *MSC Anna* | 400.0 | 1,312.3 | 58.6 | 192 | 19,368 | 187,587 |
| 2017 | *MSC Viviana* | 400.0 | 1,312.3 | 58.6 | 192 | 19,368 | 187,587 |
| 2018 | *COSCO Shipping Aries* | 400.0 | 1,312.3 | 59.0 | 193.6 | 19,273 | 196,670 |
| 2018 | *COSCO Shipping Leo* | 400.0 | 1,312.3 | 59.0 | 193.6 | 19,273 | 196,670 |
| 2018 | *COSCO Shipping Capricorn* | 400.0 | 1,312.3 | 59.0 | 193.6 | 19,273 | 196,670 |
| 2018 | *COSCO Shipping Scorpio* | 400.0 | 1,312.3 | 59.0 | 193.6 | 19,273 | 196,670 |
| 2015 | *MSC Oscar* | 395.5 | 1,298 | 59.1 | 194 | 19,224 | 192,237 |
| 2015 | *MSC Oliver* | 395.5 | 1,298 | 59.1 | 194 | 19,224 | 192,237 |

**ESTIMATED GROSS BENEFITS PROVIDED BY NAVIGATIONAL CHARTS IN THE UNITED STATES**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 2015 | *MSC Zoe* | 395.5 | 1,298 | 59.1 | 194 | 19,224 | 192,237 |
| 2015 | *MSC Maya* | 395.5 | 1,298 | 59.1 | 194 | 19,224 | 192,237 |
| 2015 | *MSC Sveva* | 395.5 | 1,298 | 59.1 | 194 | 19,224 | 192,237 |
| 2015 | *MSC Clara* | 395.5 | 1,298 | 59.1 | 194 | 19,224 | 192,237 |
| 2014 | *CSCL Globe* | 399.7 | 1,311 | 58.7 | 193 | 18,982 | 187,541 |
| 2014 | *CSCL Pacific Ocean* | 399.7 | 1,311 | 58.7 | 193 | 18,982 | 187,541 |
| 2015 | *CSCL Indian Ocean* | 399.6 | 1,311 | 58.7 | 193 | 18,982 | 187,541 |
| 2015 | *CSCL Arctic Ocean* | 399.6 | 1,311 | 58.7 | 193 | 18,982 | 187,541 |
| 2015 | *CSCL Atlantic Ocean* | 399.6 | 1,311 | 58.6 | 192 | 18,982 | 187,541 |
| 2013 | *Mærsk Mc-Kinney Møller* | 399.0 | 1,309.1 | 59.0 | 193.6 | 18,340 | 194,849 |
| 2013 | *Majestic Mærsk* | 399.0 | 1,309.1 | 59.0 | 193.6 | 18,340 | 194,849 |
| 2013 | *Mary Mærsk* | 399.0 | 1,309.1 | 59.0 | 193.6 | 18,340 | 194,849 |
| 2013 | *Marie Mærsk* | 399.0 | 1,309.1 | 59.0 | 193.6 | 18,340 | 194,849 |

**ESTIMATED GROSS BENEFITS PROVIDED BY NAVIGATIONAL CHARTS IN THE UNITED STATES**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 2013 | *Madison Maersk* | 399.2 | 1,310 | 59.0 | 193.6 | 18,340 | 194,849 |
| 2013 | *Magleby Maersk* | 399.2 | 1,310 | 59.0 | 193.6 | 18,340 | 194,849 |
| 2014 | *Maribo Mærsk* | 399.2 | 1,310 | 59.0 | 193.6 | 18,340 | 194,849 |
| 2014 | *Marstal Mærsk* | 399.2 | 1,310 | 59.0 | 193.6 | 18,340 | 194,849 |
| 2014 | *Matz Mærsk* | 399.2 | 1,310 | 59.0 | 193.6 | 18,340 | 194,849 |
| 2014 | *Mayview Mærsk* | 399.0 | 1,309.1 | 59.0 | 193.6 | 18,340 | 194,849 |
| 2014 | *Merete Mærsk* | 399.2 | 1,310 | 59.0 | 193.6 | 18,340 | 194,849 |
| 2014 | *Mogens Mærsk* | 399.0 | 1,309.1 | 59.0 | 193.6 | 18,340 | 194,849 |
| 2014 | *Morten Mærsk* | 399.2 | 1,310 | 59.0 | 193.6 | 18,340 | 194,849 |
| 2014 | *Munkebo Mærsk* | 399.2 | 1,310 | 59.0 | 193.6 | 18,340 | 194,849 |
| 2014 | *Maren Mærsk* | 399.2 | 1,310 | 59.0 | 193.6 | 18,340 | 194,849 |
| 2015 | *Margrethe Mærsk* | 399.2 | 1,310 | 59.0 | 193.6 | 18,340 | 194,849 |

**ESTIMATED GROSS BENEFITS PROVIDED BY NAVIGATIONAL CHARTS IN THE UNITED STATES**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 2015 | *Marchen Mærsk* | 399.2 | 1,310 | 59.0 | 193.6 | 18,340 | 194,849 |
| 2015 | *Mette Mærsk* | 399.2 | 1,310 | 59.0 | 193.6 | 18,340 | 194,849 |
| 2015 | *Marit Mærsk* | 399.2 | 1,310 | 59.0 | 193.6 | 18,340 | 194,849 |
| 2015 | *Mathilde Mærsk* | 399.2 | 1,310 | 59.0 | 193.6 | 18,340 | 194,849 |
| 2015 | *CMA CGM Vasco de Gama* | 399.2 | 1,310 | 54.0 | 177.2 | 17,859 | 178,228 |
| 2015 | *CMA CGM Zheng He* | 399.2 | 1,310 | 54.0 | 177.2 | 17,859 | 178,228 |
| 2015 | *CMA CGM Benjamin Franklin* | 399.2 | 1,310 | 54.0 | 177.2 | 17,859 | 178,228 |
| 2006 | *Emma Mærsk* | 397.7 | 1,305 | 56.4 | 185 | 17,816 | 171,542 |
| 2006 | *Estelle Mærsk* | 397.7 | 1,305 | 56.4 | 185 | 17,816 | 170,794 |
| 2007 | *Eleonora Mærsk* | 398.9 | 1,309 | 56.4 | 185 | 17,816 | 171,542 |
| 2007 | *Evelyn Mærsk* | 397.7 | 1,305 | 56.4 | 185 | 17,816 | 171,542 |
| 2007 | *Ebba Mærsk* | 397.7 | 1,305 | 56.4 | 185 | 17,816 | 170,794 |

**ESTIMATED GROSS BENEFITS PROVIDED BY NAVIGATIONAL CHARTS IN THE UNITED STATES**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 2007 | *Elly Mærsk* | 398.9 | 1,309 | 56.4 | 185 | 17,816 | 171,542 |
| 2007 | *Edith Mærsk* | 397.7 | 1,305 | 56.4 | 185 | 17,816 | 171,542 |
| 2008 | *Eugen Mærsk* | 398.9 | 1,309 | 56.4 | 185 | 17,816 | 171,542 |
| 2015 | *CMA CGM Kerguelen* | 398.0 | 1,305.8 | 54.0 | 177.2 | 17,722 | 175,688 |
| 2015 | *CMA CGM Georg Forster* | 398.0 | 1,305.8 | 54.0 | 177.2 | 17,722 | 175,688 |
| 2015 | *CMA CGM Bougainville* | 398.0 | 1,305.8 | 54.0 | 177.2 | 17,722 | 175,688 |
| 2013 | *APL Temasek* | 397.9 | 1,305 | 51.0 | 167.3 | 17,274 | 167,658 |
| 2013 | *APL Changi* | 397.6 | 1,304 | 51.0 | 167.3 | 17,274 | 167,658 |
| 2014 | *MSC London* | 399.0 | 1,309.1 | 54.0 | 177.2 | 16,652 | 176,490 |
| 2014 | *MSC New York* | 399.0 | 1,309.1 | 54.0 | 177.2 | 16,652 | 176,490 |
| 2015 | *MSC Istanbul* | 399.0 | 1,309.1 | 54.0 | 177.2 | 16,652 | 176,490 |
| 2015 | *MSC Amsterdam* | 399.0 | 1,309.1 | 54.0 | 177.2 | 16,652 | 176,490 |
| 2015 | *MSC Hamburg* | 399.0 | 1,309.1 | 54.0 | 177.2 | 16,652 | 176,490 |

## ESTIMATED GROSS BENEFITS PROVIDED BY NAVIGATIONAL CHARTS IN THE UNITED STATES

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 2016 | *MSC Venice* | 399.0 | 1,309.1 | 54.0 | 177.2 | 16,652 | 176,490 |
| 2012 | *CMA CGM Marco Polo* | 396.0 | 1,299.2 | 53.5 | 176 | 16,020 | 175,343 |
| 2013 | *CMA CGM Alexander von Humboldt* | 396.0 | 1,299.2 | 53.5 | 176 | 16,020 | 175,343 |
| 2013 | *CMA CGM Jules Verne* | 396.0 | 1,299.2 | 53.5 | 176 | 16,020 | 175,343 |
| 2017 | *Maersk Hong Kong* | 353.0 | 1,158.1 | 53.5 | 176 | 15,262 | 153,744 |
| 2017 | *Maersk Horsburgh* | 353.0 | 1,158.1 | 53.5 | 176 | 15,262 | 153,153 |
| 2017 | *Maersk Honam* | 353.0 | 1,158.1 | 53.5 | 176 | 15,262 | 153,153 |
| 2017 | *Maersk Hidalgo* | 353.0 | 1,158.1 | 53.5 | 176 | 15,262 | 153,744 |
| 2018 | *Maersk Hanoi* | 353.0 | 1,158.1 | 53.5 | 176 | 15,262 | 153,153 |
| 2018 | *Maersk Hangzhou* | 353.0 | 1,158.1 | 53.5 | 176 | 15,262 | 153,153 |
| 2018 | *Maersk Hamburg* | 353.0 | 1,158.1 | 53.5 | 176 | 15,262 | 153,744 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 2018 | *Maersk Herrera* | 353.0 | 1,158.1 | 53.5 | 176 | 15,262 | 153,744 |
| 2014 | *Sajir* | 368.5 | 1,209 | 51.0 | 167.3 | 14,993 | 153,148 |
| 2014 | *Al Murabba* | 368.5 | 1,209 | 51.0 | 167.3 | 14,993 | 153,148 |
| 2015 | *Salahuddin* | 368.5 | 1,209 | 51.0 | 167.3 | 14,993 | 153,148 |
| 2015 | *Linah* | 368.5 | 1,209 | 51.0 | 167.3 | 14,993 | 153,148 |
| 2015 | *Al Nasriyah* | 368.5 | 1,209 | 51.0 | 167.3 | 14,993 | 153,148 |
| 2016 | *Al Dhail* | 368.4 | 1,209 | 51.0 | 167.3 | 14,993 | 153,148 |
| 2016 | *Al Mashrab* | 368.0 | 1,207.3 | 51.0 | 167.3 | 14,993 | 153,148 |
| 2016 | *Al Jasrah* | 368.4 | 1,209 | 51.0 | 167.3 | 14,993 | 153,148 |
| 2016 | *Umm Qarn* | 368.0 | 1,207.3 | 51.0 | 167.3 | 14,993 | 153,148 |
| 2017 | *Afif* | 368.4 | 1,209 | 51.0 | 167.3 | 14,993 | 153,148 |
| 2017 | *Al Jmeliyah* | 368.0 | 1,207.3 | 51.0 | 167.3 | 14,993 | 153,148 |
| 2017 | *COSCO Shipping Himalayas* | 366.0 | 1,200.8 | 51.3 | 168 | 14,568 | 154,300 |

## ESTIMATED GROSS BENEFITS PROVIDED BY NAVIGATIONAL CHARTS IN THE UNITED STATES

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 2017 | *COSCO Shipping Kilimanjaro* | 366.0 | 1,200.8 | 51.3 | 168 | 14,568 | 154,300 |
| 2018 | *COSCO Shipping Alps* | 366.0 | 1,200.8 | 51.3 | 168 | 14,568 | 154,300 |
| 2018 | *COSCO Shipping Denali* | 366.0 | 1,200.8 | 51.3 | 168 | 14,568 | 154,300 |
| 2018 | *COSCO Shipping Andes* | 366.0 | 1,200.8 | 51.3 | 168 | 14,568 | 154,300 |
| 2018 | *Tenreach* | 366.0 | 1,200.8 | 48.0 | 157.5 | 14,508 | 141,514 |
| 2018 | *Goodreach* | 366.0 | 1,200.8 | 48.0 | 157.5 | 14,508 | 153,000 |
| 2018 | *Fanreach* | 366.0 | 1,200.8 | 48.0 | 157.5 | 14,508 | 153,000 |
| 2018 | *Canreach* | 366.0 | 1,200.8 | 48.0 | 157.5 | 14,508 | 153,000 |
| 2016 | *Triton* | 369.0 | 1,210.6 | 51.0 | 167.3 | 14,424 | 148,386 |
| 2016 | *Titan* | 369.0 | 1,210.6 | 51.0 | 167.3 | 14,424 | 148,386 |
| 2016 | *Talos* | 369.1 | 1,211 | 51.0 | 167.3 | 14,424 | 148,386 |
| 2016 | *Taurus* | 369.1 | 1,211 | 51.0 | 167.3 | 14,424 | 148,386 |

## ESTIMATED GROSS BENEFITS PROVIDED BY NAVIGATIONAL CHARTS IN THE UNITED STATES

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 2016 | *Theseus* | 369.1 | 1,211 | 51.0 | 167.3 | 14,424 | 148,386 |
| 2017 | *CMA CGM G. Washington* | 366.0 | 1,200.8 | 48.2 | 158 | 14,414 | 140,872 |
| 2017 | *CMA CGM A. Lincoln* | 366.0 | 1,200.8 | 48.2 | 158 | 14,414 | 140,872 |
| 2017 | *CMA CGM T. Jefferson* | 366.0 | 1,200.8 | 48.2 | 158 | 14,414 | 140,872 |
| 2017 | *CMA CGM T. Roosevelt* | 366.0 | 1,200.8 | 48.2 | 158 | 14,414 | 140,872 |
| 2017 | *CMA CGM J. Adams* | 366.0 | 1,200.8 | 48.2 | 158 | 14,414 | 140,872 |
| 2018 | *CMA CGM J. Madison* | 366.0 | 1,200.8 | 48.2 | 158 | 14,414 | 140,872 |
| 2018 | *YM Wellbeing* | 366.0 | 1,200.8 | 51.0 | 167.3 | 14,220 | 145,000 |
| 2016 | *YM Window* | 368.0 | 1,207.3 | 51.0 | 167.3 | 14,198 | 145,136 |
| 2016 | *YM Width* | 368.0 | 1,207.3 | 51.0 | 167.3 | 14,198 | 145,136 |
| 2016 | *YM Welcome* | 368.0 | 1,207.3 | 51.0 | 167.3 | 14,198 | 145,136 |
| 2015 | *YM Wish* | 368.0 | 1,207.3 | 51.0 | 167.3 | 14,080 | 144,651 |
| 2015 | *YM World* | 368.0 | 1,207.3 | 51.0 | 167.3 | 14,080 | 144,651 |

**ESTIMATED GROSS BENEFITS PROVIDED BY NAVIGATIONAL CHARTS IN THE UNITED STATES**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 2015 | *YM Wellhead* | 368.0 | 1,207.3 | 51.0 | 167.3 | 14,080 | 144,651 |
| 2015 | *YM Wondrous* | 368.0 | 1,207.3 | 51.0 | 167.3 | 14,080 | 144,651 |
| 2015 | *YM Winner* | 368.0 | 1,207.3 | 51.0 | 167.3 | 14,080 | 144,651 |
| 2015 | *YM Witness* | 368.0 | 1,207.3 | 51.0 | 167.3 | 14,080 | 144,651 |
| 2015 | *YM Wholesome* | 368.0 | 1,207.3 | 51.0 | 167.3 | 14,080 | 144,651 |
| 2015 | *YM Wellness* | 368.0 | 1,207.3 | 51.0 | 167.3 | 14,080 | 144,651 |
| 2015 | *YM Worth* | 368.0 | 1,207.3 | 51.0 | 167.3 | 14,080 | 144,651 |
| 2015 | *YM Warmth* | 368.0 | 1,207.3 | 51.0 | 167.3 | 14,080 | 144,651 |
| 2017 | *YM Wind* | 368.0 | 1,207.3 | 51.0 | 167.3 | 14,078 | 145,136 |
| 2017 | *YM Wreath* | 368.0 | 1,207.3 | 51.0 | 167.3 | 14,078 | 145,136 |
| 2010 | *CSCL Star* | 366.1 | 1,201 | 51.2 | 168 | 14,074 | 150,853 |
| 2011 | *CSCL Venus* | 366.1 | 1,201 | 51.2 | 168 | 14,074 | 150,853 |
| 2011 | *CSCL Jupiter* | 366.1 | 1,201 | 51.2 | 168 | 14,074 | 150,853 |
| 2011 | *CSCL Mercury* | 366.1 | 1,201 | 51.2 | 168 | 14,074 | 150,853 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 2011 | *CSCL Mars* | 366.1 | 1,201 | 51.2 | 168 | 14,074 | 150,853 |
| 2011 | *CSCL Saturn* | 366.1 | 1,201 | 51.2 | 168 | 14,074 | 150,853 |
| 2012 | *CSCL Uranus* | 366.0 | 1,200.8 | 51.2 | 168 | 14,074 | 150,853 |
| 2012 | *CSCL Neptune* | 366.0 | 1,200.8 | 51.2 | 168 | 14,074 | 150,853 |
| 2009 | *MSC Danit* | 365.5 | 1,199 | 51.3 | 168 | 14,028 | 153,092 |
| 2009 | *MSC Camille* | 365.5 | 1,199 | 51.3 | 168 | 14,028 | 153,092 |
| 2010 | *MSC Sonia* | 365.6 | 1,199 | 51.3 | 168 | 14,028 | 153,092 |
| 2010 | *MSC Melatilde* | 365.6 | 1,199 | 51.3 | 168 | 14,028 | 153,092 |
| 2010 | *MSC Paloma* | 365.5 | 1,199 | 51.3 | 168 | 14,028 | 153,092 |
| 2016 | *NYK Blue Jay* | 364.2 | 1,195 | 50.6 | 166 | 14,026 | 144,285 |
| 2016 | *NYK Ibis* | 364.2 | 1,195 | 50.6 | 166 | 14,026 | 144,285 |
| 2016 | *NYK Eagle* | 364.2 | 1,195 | 50.6 | 166 | 14,026 | 144,285 |
| 2016 | *NYK Crane* | 364.2 | 1,195 | 50.6 | 166 | 14,026 | 144,285 |
| 2017 | *NYK Hawk* | 364.2 | 1,195 | 50.6 | 166 | 14,026 | 144,277 |

## ESTIMATED GROSS BENEFITS PROVIDED BY NAVIGATIONAL CHARTS IN THE UNITED STATES

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 2017 | *NYK Falcon* | 364.2 | 1,195 | 50.6 | 166 | 14,026 | 144,277 |
| 2017 | *NYK Swan* | 364.2 | 1,195 | 50.6 | 166 | 14,026 | 144,277 |
| 2017 | *NYK Owl* | 364.2 | 1,195 | 50.6 | 166 | 14,026 | 145,253 |
| 2018 | *NYK Wren* | 364.2 | 1,195 | 50.6 | 166 | 14,026 | 145,251 |
| 2018 | *ONE Stork* | 364.2 | 1,195 | 50.6 | 166 | 14,026 | 145,251 |
| 2018 | *ONE Aquila* | 364.2 | 1,195 | 50.6 | 166 | 14,026 | 145,647 |
| 2010 | *MSC Savona* | 365.8 | 1,200 | 51.3 | 168 | 14,000 | 153,115 |
| 2010 | *MSC Alexandra* | 365.8 | 1,200 | 51.3 | 168 | 14,000 | 153,115 |
| 2010 | *MSC Genova* | 365.8 | 1,200 | 51.3 | 168 | 14,000 | 153,115 |
| 2010 | *MSC La Spezia* | 365.8 | 1,200 | 51.3 | 168 | 14,000 | 153,115 |
| 2010 | *MSC Livorno* | 365.8 | 1,200 | 51.3 | 168 | 14,000 | 153,115 |
| 2010 | *MSC Rosa M* | 365.8 | 1,200 | 51.3 | 168 | 14,000 | 153,115 |
| 2011 | *MSC Bari* | 365.8 | 1,200 | 51.3 | 168 | 14,000 | 153,115 |
| 2011 | *MSC Teresa* | 365.8 | 1,200 | 51.3 | 168 | 14,000 | 153,115 |

**ESTIMATED GROSS BENEFITS PROVIDED BY NAVIGATIONAL CHARTS IN THE UNITED STATES**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 2011 | *MSC Taranto* | 365.8 | 1,200 | 51.3 | 168 | 14,000 | 153,115 |
| 2011 | *MSC Ravenna* | 365.8 | 1,200 | 51.3 | 168 | 14,000 | 153,115 |
| 2012 | *MSC Clorinda* | 365.8 | 1,200 | 51.2 | 168 | 14,000 | 153,115 |
| 2012 | *MSC Deila* | 365.8 | 1,200 | 51.3 | 168 | 14,000 | 153,115 |
| 2012 | *MSC Valeria* | 365.8 | 1,200 | 51.3 | 168 | 14,000 | 153,115 |

Source: https://en.wikipedia.org/wiki/List_of_largest_container_ships, Accessed October 20, 2018.

# APPENDIX E

## DATA BASES AND DATA TOOLS EMPLOYED IN THE ANALYSIS

**ESTIMATED GROSS BENEFITS PROVIDED BY NAVIGATIONAL CHARTS IN THE UNITED STATES**

Several major data bases were employed in this study:

**A.** United States Department of Commerce, Census Bureau's USA Trade® Online;
**B.** United States Department of Transportation's Maritime Administration (MARAD);
**C.** United States Army Corps of Engineers' (USACE) National Navigation Operation and Maintenance Performance Evaluation and Assessment System (NNOMPEAS);
**D.** United State Coast Guard's Automatic Identification System (AIS) network;
**E.** Congressional Budget Office's Discount Rate, CBO's Circular No. A-94, Appendix B;
**F.** United States Department of Commerce, Bureau of Economic Analysis Gross Domestic Product (GDP) Deflator;
**G.** United States Army Corps of Engineers' (USACE) Channel Portfolio Tool (CPT);
**H.** United States Coast Guard's Boating Accident Report Data Base (BARD);
**I.** United States Coast Guard's Marine Information for Safety and Law Enforcement (MISLE); and,
**J.** National Oceanic and Atmospheric Administration's, Office of Coast Survey Dangers to Navigation.

## A. United States Department of Commerce, Census Bureau's USA Trade® Online

Provided by the U.S. Census Bureau's Foreign Trade Division, USA Trade Online is the official source of U.S. Import and Export statistics.[17] The database provides current and cumulative U.S. export and import data on more than 9,000 export commodities and 17,000 import commodities by county. Individual movements are theoretically available in the International Harmonized System Code (IHS)[18] and the North American Industry Classification

[17] A total of 390 ports are identified and further summarized into one of 44 districts. In addition, 74 airport locations are identified Many of these did not have reported international traffic. An additional location Norfolk/Mobile/Charleston" was created to report cumulative tonnages from numerous locations where confidentiality concerns prevents individual port reporting. In addition, a large number of inland ports reside on inland waterways (e.g., river, lake, or canal) which may or may not be connected to the ocean. The term is also employed to refer to dry ports that are extensions of seaports usually connected by rail to the docks. As of 2014, a total of 43 inland ports had been established. Source: *American Journal of Transportation*, Issue 642, February 13, 2017.

[18] The U.S. International Trade Commission maintains the Harmonized Tariff Schedule of the U.S. covering international traffic.

System (NAICS)[19] codes, at the 10- and 6-digit levels of granularity, respectively.[20]

Goods are initially classified under IHS that describes and measures the characteristics of goods traded. Combining trade into approximately 140 export and 140 import end-use categories makes it possible to examine goods according to their principal uses. These categories are used as the basis for computing the seasonal and working-day adjusted data. These adjusted data are then summed to the six end-use aggregates for publication.[21] These data are provided to the Bureau of Economic Analysis, from the U.S. Census Bureau, for use in the Balance of Payments and the National Income and Product Accounts.

Individual data elements available include:[22]

- **Container Shipping Weight (CWT)**
  Represents the gross weight in kilograms of shipments made by surface vessel, including the weight of moisture content, wrappings, dunnage, crates, boxes, and containers (other than cargo vans and similar substantial outer containers). In some instances, shipments between the United States and countries abroad enter or depart through Canada or

[19] The NAICS was developed by the Office of Management and Budget in 1997 to classify business establishments for the purpose of collecting, analyzing and publishing statistical data on the U.S. economy.

[20] The statistics include both government and non-government shipments by vessel into and out of the U.S. foreign trade zones, the 50 states, District of Columbia and Puerto Rico. The statistics exclude postal and military shipments.

[21] The Census Bureau is bound by the provisions of Title 13, United States Code, Section 301(g) to protect the confidentiality of the export data it collects and make the information available only when the Secretary of Commerce's delegate, the Director of the Census Bureau, determines that withholding of information would be contrary to the national interest. Such determination is conditioned on the recipient agency implementing appropriate data safeguards and agreeing to use such data solely for the purposes authorized by the Census Bureau Director. Typically, these purposes are either statistical or for enforcing U.S. export laws and regulations. The regulatory provisions regarding the confidentiality of export information are found in Title 15, Code of Federal Regulations, Part 30, Section 30.60. Information detailing the names of importers, shippers, consignees and other manifest data is not released by the Census Bureau. Manifest data are collected and disclosed by the U.S. Customs and Border Protection (CBP) in accordance with Title 19, United States Code. Section 103.31(a) allows accredited representatives of the press collect manifest data at every port of entry.

[22] In addition to vessel and container data, weight and cargo values are also provided for air shipments.

Mexico. Such shipments are recorded under the method of transportation by which they enter or depart the United States regardless of the method of transportation between Canada or Mexico and the country of origin or destination.

- **Container Value (CV)**

  The nominal value of goods that enter or leave the country by container. In some instances, shipments between the United States and countries abroad enter or depart through Canada or Mexico. Such shipments are recorded under the method of transportation by which they enter or depart the United States regardless of the method of transportation between Canada or Mexico and the country of origin or destination.

- **Total Shipping Weight (SWT)**

  Represents the gross weight in kilograms of shipments made by surface vessel and air, including the weight of moisture content, wrappings, dunnage, crates, boxes, and containers (other than cargo vans and similar substantial outer containers). In some instances, shipments between the United States and countries abroad enter or depart through Canada or Mexico. Such shipments are recorded under the method of transportation by which they enter or depart the United States regardless of the method of transportation between Canada or Mexico and the country of origin or destination.

- **Vessel Shipping Weight (VWT)**

  Represents the gross weight in kilograms of shipments made by deep sea vessels of all types (e.g., dry bulk, ro-ro, tank, container, etc.) including the weight of moisture content, wrappings, dunnage, crates, boxes, and containers (other than cargo vans and similar substantial outer containers). In some instances, shipments between the United States and countries abroad enter or depart through Canada or Mexico. Such shipments are recorded under the method of transportation by which they enter or depart the United States regardless of the method of transportation between Canada or Mexico and the country of origin or destination.

- **Vessel Value (VV)**

  The nominal value of goods that enter or leave the country by surface vessels of all types (e.g., dry bulk, ro-ro, tank, container, etc.) In some instances, shipments between the United States and countries abroad enter or depart through Canada or Mexico. Such shipments are recorded under the method of transportation by which they enter or depart the United States regardless of the method of transportation between Canada or Mexico and the country of origin or destination.

This database is utilized as the primary source of inventory carrying cost calculations of average cargo value per kilogram (later converted to short tonnage) for all types of vessels.

Subtracting fully cellular container data that is provided separately from all vessel data provides an estimate for all other types of vessels (e.g., dry bulk, tank, general and Ro-Ro).[23] While individual ship types (e.g., tank, dry bulk, ro-ro, etc.) are not specifically identified in the USA Trade Online database, more granular analysis of commodities which are typically unique to certain ships (e.g., finished automobiles and trucks in ro-ro vessels) might be teased from the data to a certain degree. For example, the 2-digit IHS Code *(87 – Vehicles other than railway or tramway rolling stock, and parts and accessories thereof)* is of too high a level of aggregation to identify specific commodities by vessel type as container traffic is employed in over 70 of the 79 six-digit HS commodity groups.[24] However, as USA Trade Online database also provides up to 6-digit IHS definition, it is possible to infer traffic carried by tanker (e.g., crude, processed petroleum products and Liquefied Natural Gas (LNG)) and Ro-Ro (finished vehicles) vessels. The remainder of traffic groups bulk with general vessel traffic.

While it could be advantageous to identify cargo costs by individual type of vessel, sufficient data (e.g., cargo weight and cargo value) may not be publicly available for all desired combinations of size and vessel type. Employing data from the longer 2003 to 2018 period suggests that the overall average weight of an imported Twenty-foot Equivalent Unit (TEU)[25]

[23] The database also provides cargo value and weight associated with air shipments.

[24] The *Harmonized Commodity Description and Coding System* (e.g. the IHS is an internationally standardized system of names to classify traded products. For example, IHS 8703.24 and 8703.23 are the codes for finished motor vehicles.

[25] The twenty-foot equivalent unit (often TEU or tee) is an inexact unit of cargo capacity often used to describe the capacity of container ships and container terminals.[1] It is based on the volume of a 20-foot-long (6.1 m) intermodal container, a standard-sized metal box that can be easily transferred between different modes of transportation, such as ships, trains and trucks. (Rowlett 2000) There is a lack of standardization in regard to height, ranging between 4 feet 3 inches (1.30 m) and 9 feet 6 inches (2.90 m), with the most common height being 8 feet 6 inches (2.59 m). Also, it is common to designate 45-foot (13.7 m) containers as 2 TEU, rather than 2.25 TEU. Refer to:

across the entire U.S. was 8.0 short tons (7.3 metric tonnes) while exported TEUs averaged 10.7 short tons (9.7 metric tons) reflecting the difference in commodities imported (e.g., apparel) versus commodities exported (e.g., machinery).[26] The weighted average for imports and exports was 9.0 short tons (8.2 metric tonnes).[27]

### B. United States Department of Transportation's Maritime Administration (MARAD)

The United States Department of Transportation's Maritime Administration (MARAD) annually reports a number of trade statistics on imported and exported cargo. While not including any commodity specification when identified by port district, data on (metric) tonnage and cargo value (in nominal U.S. dollars) is provided in its *U.S. Waterborne Foreign Trade by U.S. Customs Districts* for the years 2003 to 2017.[28] In addition, U.S. Customs Ports provide data on international containerized cargo in their U.S. Waterborne Foreign Container Trade.[29] Vessel tonnage based on the number of TEUs it is carrying can be estimated from these MARAD databases for both import and export traffic.

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http://en.wikipedia.org/wiki/Twenty-foot_equivalent_unit.

[26] This is reflective of the types of commodities being imported versus exported in containers. Imports in 2019 were typically higher weight items such as furniture parts motor vehicle parts, bananas, seats, tires, etc.. Exports in 2019 were dominated by paper waste and scrap, primary polymers of ethylene, ferrous waster and scrap, wood pulp, soybeans, etc.

[27] Use of this period allowed incorporation of at least one full business cycle as the last recession ran from December 2007 to June 2009.

[28] Source: U.S. Department of Transportation, Maritime Administration. Accessed February 22, 2019.

[29] Data is provided from the Port Import Export Reporting Service (PIERS) provided by the Journal of Commerce /UBM Global Trade. Data is collected from vessel manifests and bills of lading. The data covers loaded containers only.

While MARAD container cargo value is not listed, total imported and exported (metric) tonnage is provided, as is the number of imported and exported TEUs. This facilitates estimation of average container weight. Coupled with known overall value of container from USA Trade Online data, it is possible to estimate cargo value per TEU. As cargo ships are generally characterized by the number of TEUs they carry, total cargo value by size of vessel can be estimated.

## C. United States Army Corps of Engineers' (USACE) National Navigation Operation and Maintenance Performance Evaluation and Assessment System (NNOMPEAS)

NNOMPEAS is a USACE tool for estimating marine transportation costs and performing economic analyses on USACE waterway projects. It is the standard source for all marine transportation cost data and is employed as the basis for considering the benefits of proposed USACE projects**.** (Refer to Figure E-1)

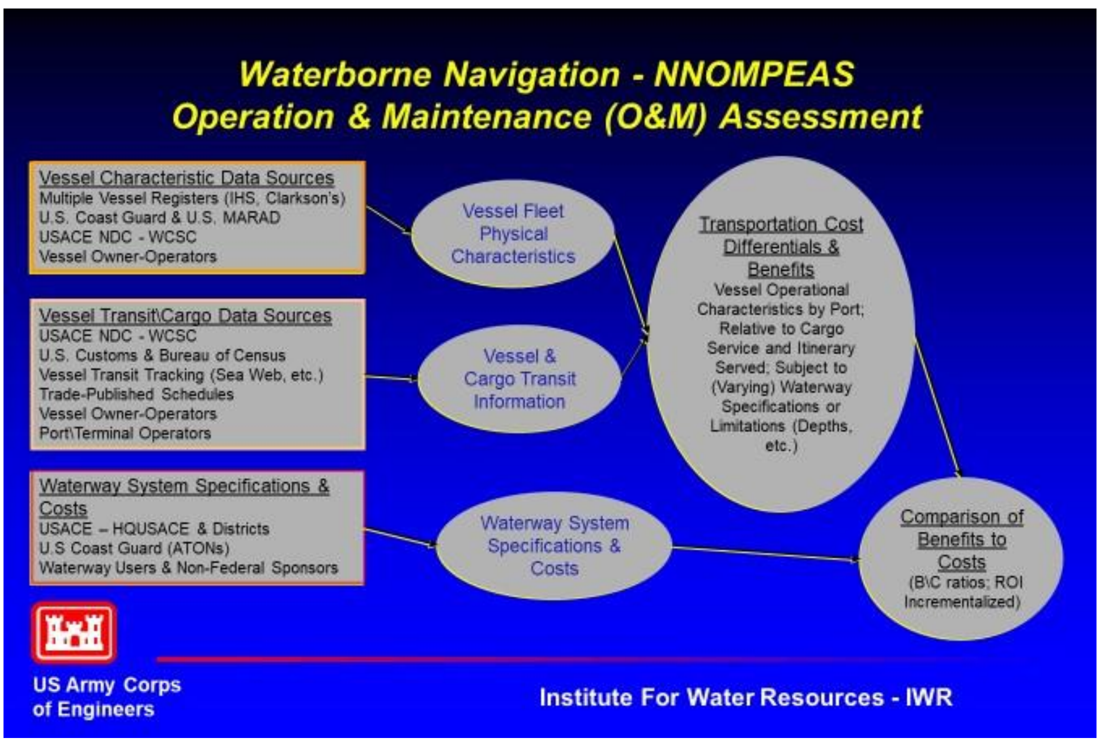
The USACE has regularly evaluated and compiled aggregated vessel operating costs (VOCs, deep draft, and shallow-draft) since before the 1960s for use in measurement of economic benefits for waterway system improvements for inland and coastal harbors and supporting channel or waterway systems. VOCs, as employed by USACE, is not equivalent to shipping rates and are compiled on an Economic Resource Cost (ERC) basis (as opposed to only financial or accounting costs) considered consistent with general directives of the Water Resource Council (WRC) for associated civil works evaluation and with conceptual principles of welfare economics applicable to the assessment of public investment for civil engineering works.

## ESTIMATED GROSS BENEFITS PROVIDED BY NAVIGATIONAL CHARTS IN THE UNITED STATES

In the circumstance of USACE, such investment of civil works for harbors and waterways are intended to support betterments or efficiencies for facilitation of the nation's economy and waterborne trade (hence the context of NED or national economic development that one encounters throughout USACE guidance regarding economic evaluation of water resources development projects considered within the agency's jurisdiction for evaluation, construction, and ongoing operation). Aggregated VOCs are not rates nor are they explicitly financial or accounting costs due to the differences in amortization of base capital asset acquisition (i.e., the hull) and allowances for profit (whether short-term volatile or long-term normalized), though both rates and profits are sometimes evaluated for studies to explain behavior in the market or in industry practice.

**Figure E-1**

**USACE NNOMPEAS DATA FLOW**



## ESTIMATED GROSS BENEFITS PROVIDED BY NAVIGATIONAL CHARTS IN THE UNITED STATES

NNOMPEAS is constructed from a large number of variables (e.g., vessel length, breadth, draft, engine horsepower, crew, distance traveled, cost of fuel, engine fuel efficiency, the diameter of the propeller, etc.), all of which affect the costs of operating the vessel. It does not include profit margin, market pricing decisions, competitive pricing strategies, etc. Actual vessel operating and transportation costs are highly sensitive and not shared by marine transportation companies for competitive reasons.[30] Alternatively, the best data available are outputs from the detailed NNOMPEAS model. This gives the USACE a more stable platform upon which to make comparisons across multiple years without having to consider the competitive elements of cost and volatility of rates.

Cost data is comprised of highly sensitive information that could be used to give a company, port, or even a nation a competitive advantage. Therefore, the information derived from NNOMPEAS and much of the information used as input to the NNOMPEAS model is restricted to access and use for authorized application by USACE to the assessment of civil works projects with limited allowances for support of other Federal entities consistent with requirements for safeguarding and appropriate use of respective data and estimates. Hence, only USACE staffers have direct access to NNOMPEAS. Fortunately, USACE staff has shown an overwhelming willingness to assist NOAA in its investigations where sufficient safeguards for the data can be put in place.

NNOMPEAS combines data from four sources:

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[30] As they are market driven by a wide-variety of influences, vessel rates are not uniformly representative of vessel operating costs and tend to be significantly more volatile.

## ESTIMATED GROSS BENEFITS PROVIDED BY NAVIGATIONAL CHARTS IN THE UNITED STATES

1. Lloyd's Register of Ships (LRS) SEAWEB.[31] LRS provides information on vessel characteristics (vessel type, size class, physical dimensions, capacities, and speed), while SEAWEB provides information on vessel itinerary for estimation of vessel transit distances over time or period of service.

2. USACE Institute for Water Resources (IWR) \ Navigation Data Center (NDC) – Waterborne Commerce Statistics Center (WCSC) Statistics.

3. Vessel information is broken down by individual vessel name and identification by IMO\LRS number, tonnage handled, and transit draft, prior and post port information where available.
   a. PIERS[32] (Port Import\Export Research service), which contains information on nature of cargo, cargo weight, and origins\destinations of cargo as well as to some extent vessel itinerary.
   b. Available information on project specifications from port series investigations.
   c. Estimated vessel-operating costs per unit of time as assembled by IWR.

4. Computerized\GIS generated voyage distance tables reconciled with traditional rhumb line heading and course plots for transit as well as great distance calculators respective of ocean and waterway boundaries.[33]

5. The evolving TEC (Topographic Engineering Center) project database on project specifications for depth and available information from condition surveys.

The vessel service data includes information about the frequency of service, route, or itinerary (with particular attention to time at sea or in service for cargo forwarding and transport),

[31] An extensive ship database covering over 200,000 ships over 100 gross tons (GT). A gross ton is a nonlinear vessel's overall internal volume. One ton is equal to 40 cubic feet. Refer to: https://ihsmarkit.com/products/sea-web-vessel-search.html Over time, Lloyds was acquired by IHS Fairplay. On November 30, 2020 was acquired by S&P Global.

[32] A proprietary product of the Journal of Commerce.

[33] A rhumb line is an arc crossing all meridians of longitude at the same angle (i.e., a path with constant bearing as measured relative to true or magnetic north.)

type of vessel, and corresponding costs per unit of time relative to the general mode of operation, vessel physical specifications for cargo capacity by weight and volume, and cargo carried by weight.

Vessel characteristics fields extracted from IWR's vessel operating costs are merged with Lloyd's Register of Ships (LRS) and other electronic databases with transit and tonnage records from WCSC (with cross-matching and tabulation performed via either the International Maritime Organization (IMO) vessel identification number or Lloyd's Registry number, or the USCG's vessel identification number), the resulting composite database(s) gives most of the information needed to estimate cargo unit cost trade-offs relative to vessel capacity utilization, transit draft and available waterway depth.

In addition to vessel cost, the NNOMPEAS system has an emissions application for provision of volume estimates of several emissions (e.g., CO, $CO_2$, $NO_x$, $SO_x$, $CH_4$, $NH_3$, $PM_{2.5}$, $PM_{10}$, ROG) which are based on variables such as fuel type used, engine type and size, vessel speed, etc.[34] Finally, lightweight and deadweight figures for each vessel, along with the estimated weight of stores (fuel, water, crew, food, etc.), permit the calculation of cargo-carrying capacity.

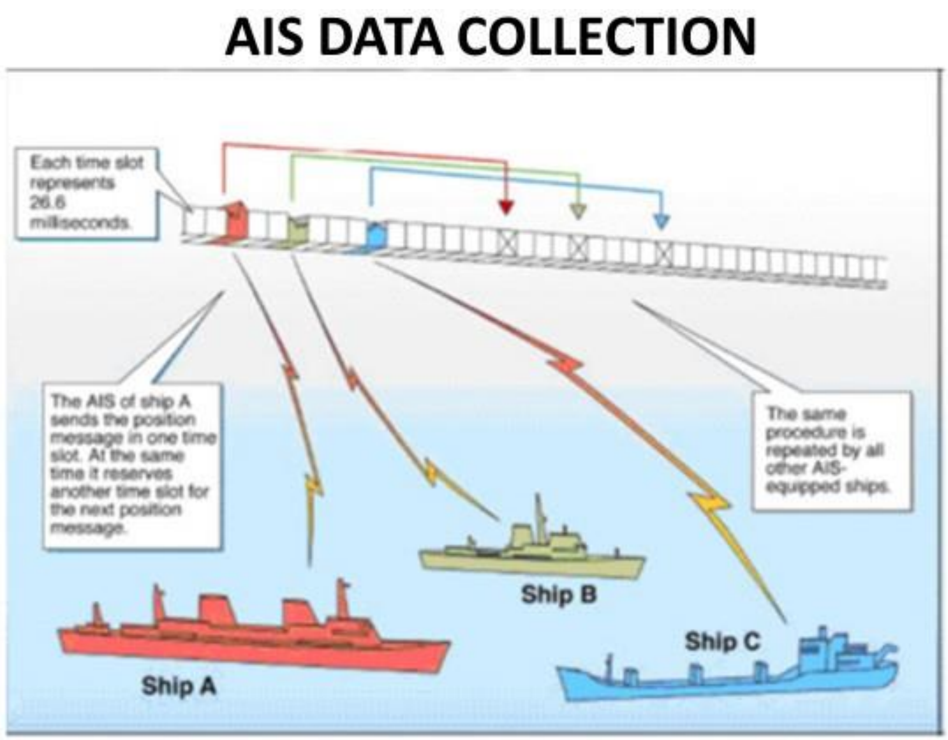
**D. United State Coast Guard's Automatic Identification System (AIS) network**

Regulation 19 of Safety of Life at Sea (SOLAS) Chapter V – *Carriage requirements for shipborne navigational systems and equipment* – identifies navigational equipment that must be

[34] The Environmental Protection Agency (EPA) has approved the process and end estimations of pollutant emissions the in the NNOMPEAS model.

carried on board ships. These requirements are based on the type of ship (e.g., tank, passenger, etc.) In 2000, the International Maritime Organization (IMO) adopted a new requirement (as part of a revised new Chapter V) for all ships to carry AIS capable of providing information about the ship to other ships and to coastal authorities automatically.[35] Refer to Figure E-2.

**Figure E-2**




Source: USCG

The regulation requires AIS to be fitted aboard all ships of 300 gross tons and greater engaged on international voyages, cargo ships of 500 gross tons and greater not engaged on international voyages and all passenger ships regardless of size.[36] The requirement became

[35] Refer to International Maritime Organization (IMO) website on AIS transponders. http://www.imo.org/OurWork/Safety/Navigation/Pages/AIS.aspx

[36] While AIS is a ship-to-ship collision avoidance system that facilitates communication of vessel position, speed and other data via a Very High Frequency (VHF) virtual data link, the Nationwide Automatic Identification System

effective for all ships by December 31, 2004.[37]

AIS data has been used in the following applications:

- **Collision Avoidance**
  AIS was developed by the IMO technical committees as a technology to avoid collisions among large vessels at sea that are not within range of shore-based systems.

- **Fishing Fleet Monitoring and Control**
  AIS is widely used by national authorities to track and monitor the activities of their national fishing fleets. AIS enables authorities to reliably and cost effectively monitor fishing vessel activities along their coast line, typically out to a range of 60 miles (depending on location and quality of coast-based receivers/base stations) with supplementary data from satellite-based networks.

- **Aids to Navigation**
  The AIS Aids to Navigation (A to N) product standard was developed with the ability to broadcast the positions and names of objects other than vessels, such as navigational aid and marker positions and dynamic data reflecting the marker's environment (e.g., currents and climatic conditions).

- **Search and Rescue**
  For coordinating on-scene resources of a marine search and rescue (SAR) operation, it is imperative to have data on the position and navigation status of other ships in the vicinity.

- **Accident Investigation**

(NAIS) (begun in 2004) monitors, consolidates and disseminates AIS data on vessels operating in or approaching US waters to the United States Coast Guard, US Navy and other government agencies. NAIS is used to improve an understating of issues that could impact the economy, national security, safety and the environment.

[37] The regulation applies to ships built on or after 1 July 2002 and to ships engaged on international voyages constructed before 1 July 2002, according to the following timetable: (1) passenger ships, not later than 1 July 2003; (2) tankers, not later than the first survey for safety equipment on or after 1 July 2003; and (3) ships, other than passenger ships and tankers, of 50,000 gross tonnage and upwards, not later than July 1, 2004.

AIS information received by the Vessel Traffic Management System (VTMS) is important for accident investigation since it provides accurate historical data on time, identity, GPS-based position, compass heading, course over ground, speed (by log/SOG), and rates of turn, rather than the less accurate information provided by radar.[38]

- **Fleet and Cargo Tracking**
  Internet disseminated AIS can be used by fleet or ship managers to keep track of the global location of their ships. Cargo dispatchers or the owners of goods in transit can track the progress of cargo and anticipate arrival times in port.

- **Regulatory Compliance**
  With the ability to monitor ship speed and location, it is possible to identify cooperation with management measures or compliance with regulations concerning alternative, restricted or conditionally restricted areas of operation.

AIS data is available in two levels of periodicity: (1) every two to 10 seconds depending on a vessel's speed underway; and, (2) every three minutes while a vessel is at anchor; and, every six minutes for data not as variable across time.

Data reported every two to ten seconds when underway and every three minutes at anchor includes:

- The vessel's Maritime Mobile Service Identity (MMSI) – a unique nine-digit identification number.
- Navigation status – "at anchor", "under way using engine(s)", "not under command", etc.
- Rate of turn – right or left, from 0 to 720 degrees per minute
- *Speed over ground* – 0.1-knot (0.19 km/h) resolution from 0 to 102 knots (189 km/h)
- Positional accuracy:
  Longitude – to 0.0001 minutes
  Latitude – to 0.0001 minutes
- *Course over ground* – relative to true north to 0.1°

[38] VTMS is a real-time control system for harbors and coastal surveillance. It provides active monitoring and navigational advice for vessels particularly in busy and confined waterways.

- True heading – 0 to 359 degrees (for example from a gyro compass)
- True bearing at own position. 0 to 359 degrees
- Coordinated Universal Time (UTC) Seconds – The seconds field of the UTC time when these data were generated. A complete timestamp is not present.

Data reported every 6 minutes includes:

- IMO ship identification number – a seven-digit number that remains unchanged upon transfer of the ship's registration to another country
- Radio call sign – international radio call sign, up to seven characters, assigned to the vessel by its country of registry
- Name – 20 characters to represent the name of the vessel
- Type of ship/cargo
- Dimensions of ship – to nearest meter
- Location of positioning system's (e.g., GPS) antenna on board the vessel – in meters aft of bow and meters port or starboard
- Type of positioning system – such as GPS, DGPS or LORAN-C.
- Draught of ship – 0.1 meter to 25.5 meters[39]
- Destination – max. 20 characters
- ETA (estimated time of arrival) at destination – month/date hour: minute
- High precision time request, a vessel can request other vessels provide a high precision UTC time and date stamp. *NOTE: This data element is optional.*

The Department of the Interior's Bureau of Ocean Energy Management (BOEM) and the National Oceanic and Atmospheric Administration (NOAA) have worked jointly to repurpose and make available some of the most important records from the U.S. Coast Guard's national network of AIS receivers. The AIS data available contained records for years 2009 through 2020.

For this study, 2017 point and track AIS data was obtained from the Vessel Traffic data page at the MarineCadastre.gov website (2018 data for Hawaii). Alaska 2017 AIS data not

[39] Vessel immersed draughts are often not reliably reported in automated systems such as AIS and the estimation of immersed draught may or may not include allowances for trim and squat depending on how or whether draught measurements are assessed in the static condition.

available in the Marine Cadastre site were obtained by request from the Marine Exchange of Alaska (MXAK) – a non-profit organization.[40] The Marine Cadastre AIS data represents 17 of the most important fields from the original AIS record. The data shows all vessels that the land-based antennas received, with the exception of certain law enforcement and military vessels that are excluded. Records are filtered to a one minute rate and formatted in zipped, monthly files by Universal Transverse Mercator (UTM) zones.

Data reported every 1 minute includes:

- The Vessel's Maritime Mobile Service Identity (MMSI) – a Unique 8-digit Identification Number.
- Full UTC Date and Time (YYYY-MM-DD-HH-MM-SS)
- Latitude in Decimal Degrees
- Longitude in Decimal Degrees
- Speed Over Ground (SOG) in Knots
- Course Over Ground (COG) in Degrees
- True Heading Angle in degrees
- Vessel Name as Shown on the Station Radio License
- International Maritime Organization (IMO) Vessel Identification Number
- Call Sign as Assigned by FCC
- Vessel Type as Defined in NAIS Specifications
- Navigation Status as Defined by the COLREGS
- Length of Vessel According to NAIS Specifications
- Width of Vessel According to NAIS Specifications
- Draft Depth of Vessel According to NAIS Specifications
- Cargo Type According to NAIS Specifications and Codes
- Class of AIS Transceiver

From these AIS information, employing an ArcGIS software application, individual vessel transit segments were summarized to estimate overall vessel trip average transit speeds.

[40] Refer to (https://www.mxak.org/).

This was the same database employed in an earlier study currently underway to estimate reduced vessel transit speeds' biological impact.[41] From this data, differences in transit speed were applied by transit distance to estimate augmented cargo (inventory) carrying costs and non-fuel vessel operating costs due to the added time to traverse greater distances.[42] Vessel transits grouped by vessel type arriving to individual ports based on dominant commodity carried were examined. From this group inventory values by vessel type (mainly cargo, tankers, and passenger) and displacement grouping were developed and ultimately a measure of how many extra vessels would be needed to move just one foot less of currently transported materials. The data was used as well to look into how close in general traffic of vessel tracks are from dangers to navigation.

### E. Congressional Budget Office's Discount Rate (CBO's Circular No. A-94, Appendix B

The General Accountability (nee Accounting) Office (GAO) revised its discount rate policy in 1983 (GAO 1983).[43] At that time, GAO employed a rate based on the Treasury borrowing rate for all types of discounting problems, including those related to public investment, regulatory, lease-purchase, and asset divestiture decisions. In 1991 this was refined

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[41] Rockwood, R. Cotton, Jeff Adams, Greg Silber and Jaime Jahncke. 2020. *"Estimating Effectiveness of Speed Reduction Measures for Decreasing Whale Strike Mortality In a High-Risk Region"*, White Paper currently under review. This analysis estimated reductions in whale mortality resulting from lower transit speeds.

[42] Simply the cargo value (per tonne) multiplied by the number of added hours in transit by the opportunity cost of capital as defined by the commercial paper rate (CPR). Commercial paper is often employed as an unsecured short-term loan by a corporation to finance inventories and receivables.

[43] U.S. General Accounting Office (GAO), Project Manual, Washington, D.C., 1983, pages 17-18. The GAO Human Capital Reform Act changed the GAO's name in 2004. Refer to: Walker, David M. (July 19, 2004). "GAO Answers the Question: What's in a Name?, *Roll Call*

to state that the "base case discount rate should be the interest rate for marketable Treasury debt with maturity comparable to the program being evaluated. Sensitivity analysis should also be employed to address issues such as differing expectations about inflation and interest rates, private sector opportunity costs, and intergenerational effects of policies on human life."[44]

The Congressional Budget Office (CBO) annually distributes its discount rates through Circular No. A-94, Appendix C.[45] As this study employed vessel movements reported in AIS during 2019, the nominal rate of 3.4 percent specified for an ten-year analysis was selected.

### F. United States Department of Commerce, Bureau of Economic Analysis Gross Domestic Product (GDP) Deflator

In this analysis, all databases report cargo value in terms of nominal dollars representing the value of the dollar at the time (year) it was reported. Over time, inflation can increase the level of nominal dollars and artificially enhance the perceived value of cargo transported. The Gross Domestic Product (GDP) calculated by the U.S. Department of Commerce's Bureau of Economic Analysis, is the monetary value of all the finished goods and services produced within a county's borders. It is calculated on both a quarterly and annual basis with annual calculation being the most often used in removing the impact of inflation from across years.

Nominal and real (inflation-adjusted) monetary data for the years 2003 through 2019 is delineated in Table E-1. While 2019 dollars were selected for this illustration, data from any year can be chosen as the "base" year of the analysis., use of 2019 might make it easier for readers to comprehend.

[44] GAO, "Discount Rate Policy", Office of the Chief Economist, May 1991, Chapter I, Overview.

[45] Revised November 2018.

**Table E-1**

**GROSS DOMESTIC PRODUCT DEFLATOR**
**(NOTE: Recession lasted from December 2007 through June 2009)**

| YEAR | NOMINAL GDP (Trillions of Dollars) | REAL GDP (Billions of Chained 2012 Dollars) | CHANGE IN REAL GDP (Over Prior Year) | REAL GDP INDEX (2019 = 100) |
|---|---|---|---|---|
| 2003 | $11.5 | $13,879.1 | 2.9% | 1.37 |
| 2004 | $12.3 | $14,406.4 | 3.8% | 1.32 |
| 2005 | $13.1 | $14,912.5 | 3.5% | 1.28 |
| 2006 | $13.9 | $15,338.3 | 2.9% | 1.24 |
| 2007[46] | $14.5 | $15,626.0 | 1.9% | 1.22 |
| 2008 | $14.7 | $15,604.7 | -0.1% | 1.22 |
| 2009 | $14.4 | $15,208.8 | -2.5% | 1.25 |
| 2010 | $15.0 | $15,598.8 | 2.6% | 1.22 |
| 2011 | $15.5 | $15,840.7 | 1.6% | 1.20 |
| 2012 | $16.2 | $16,197.0 | 2.3% | 1.18 |
| 2013 | $16.7 | $16,495.4 | 1.8% | 1.16 |
| 2014 | $17.4 | $16,899.8 | 2.5% | 1.13 |
| 2015 | $18.1 | $17,386.7 | 3.0% | 1.10 |
| 2016 | $18.6 | $17,659.2 | 1.7% | 1.08 |
| 2017 | $19.4 | $18,050.7 | 2.3% | 1.05 |
| 2018 | $20.5 | $18,566.4 | 3.0% | 1.02 |
| 2019 | $21.4 | $19,072.7 | 2.2% | 1.00 |
| 2020[47] | $20.9 | $18,422.5 | -3.5% | 0.97 |

Source: US Department of Commerce, Bureau of Economic Analysis.

## G. United States Army Corps of Engineers' (USACE) Channel Portfolio Tool (CPT)

The CPT developed by Dr. Ken Mitchell of the United States Army Corps of Engineers (USACE) has been employed in several previous analyses most notably several benefit assessments of PORTS®. Data on vessel transits is currently available from 2008 through 2016.

In essence, the CPT is a method to transform raw data involving water transportation into

[46] Recession lasted from December 2007 to June 2009. Source: National Bureau of Economic Research.

[47] Recession lasted between February 2020 to April 2020. Source: National Bureau of Economic Research.

tabular and graphic representations of activity. Containing data on channel depth, commodity transported, vessel depth, cargo value, cargo weight, cargo type (container versus non-container), ship type (dry cargo barge, liquid barge, tanker, towboat, rafted logs, etc.) and ship direction, it is possible to review actual movements and how those movements might be at risk owing to channel constraints[48]. Central to the value of CPT is its ability to uniquely assess traffic by river or channel segment and provide summary origin or destination data without double counting ship passing, tonnages or values of cargo.

The CPT is a web-based decision-support package developed within the USACE Coastal Inlets Research Program (CIRP) for determining the extent to which Corps-maintained navigation channel depths are utilized by commercial shipping. The CPT uses the proprietary, dock-level tonnage database maintained by the USACE's Waterborne Commerce Statistics Center (WCSC). A live web version of CPT is presently available to registered Federal government personnel.[49] Under Federal law, companies operating vessels must report domestic waterborne commerce movements to the Army Corps of Engineers. The data collected includes the type, weight, type, and value of the cargo, and movements and dockings of the vessel, and the location and depth of the channels.[50] The data is collated to the channel and channel reach (subset of a channel) level and to the five-digit commodity code level.

The commodity code structure is unique to the USACE and does not translate well to

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[48] Non-container traffic included tank, dry bulk, Roll On – Roll Off (RO-RO), general and combination carriers.

[49] Access and registration can be found at http://www.cpt.usace.army.mil/

[50] Cargo value is supplied to the USACE by the Department of the Census. Under the January 2015 Memorandum of Understanding between the two agencies, cargo value cannot be made available to users outside of the USACE owing to data confidentiality concerns. Hence, cargo value is obtained from the USA Trade® Online data base.

other more commonly used codes like the Harmonized System (HS) Commodity Code system. The USACE stores its commodity code data to five digits. While not as detailed as the Census Bureau's seven-digit commodity data the CPT data is detailed enough for nearly all research.

The projects are an assemblage of channels that are themselves collection of segments referred to as "reaches". The hierarchy then goes from the large area project to the more site-specific channel to the very specific location of the reach. Ports are defined as a collection of associated reaches and channels that lead to and encompass a port facility.

The CPT provides decision makers and researchers with relevant data concerning commercial shipping activity that is supported by Corps dredging activities. CPT conducts nearest-neighbor matching of WCSC's Master Docks database with a spatial network representing Corps-maintained channels and waterways. Entries in the tonnage database are routed from origin to destination docks through this network using well-established shortest-path logic. The cumulative statistics for tons, dollar value, vessel draft, commodity types and traffic types are then compiled for each individual reach (channel segment) in the network. The web-based CPT interface provides a straightforward means of querying and filtering the resulting data to suit user specifications, such as tonnage totals transiting at depths most vulnerable to shoaling.

The CPT output can be selected from a large number of options to enable the researcher to focus on specific aspects of vessel and commodity movements. A particularly important option is that which enables one to compile the data on vessel movements within a certain number of feet from the channel bottom. Present channel conditions and historical shoaling rates are compared to the draft profile to determine the amount of cargo that is directly impacted by channel shoaling conditions.

## H. United States Coast Guard's Boating Accident Report Data Base (BARD)

The USCG has the legal responsibility to collect, analyze, and publish recreational boating accident data and statistical information for the fifty states, five U.S. territories, and the District of Columbia. Federal law requires the operator – or owner to file a boating accident report with the State reporting authority when, as a result of an occurrence that involves a boat or its equipment:

- A person dies;
- A person disappears from the vessel under circumstances that indicate death or injury;
- A person is injured and requires medical treatment beyond first aid;
- Damage to vessels and other property totals $2,000 (lower amounts in some states and territories) or more; or,
- The boat is destroyed.

Annually, the USCG compiles statistics on reported recreational boating accidents referred as the Boating Accident Report Database (BARD). These statistics are derived from accident reports that are filed by the owners / operators of recreational vessels involved in accidents. The fifty states, five U.S. territories and the District of Columbia submit accident report data to the USCG for inclusion in the annual Boating Statistics publication and the USCG boating recreational accident database. While the USCG has maintained the boating accident data for almost two decades it hasn't been until 2005 that the data can be considered reliable from all states and territories.

The database contains information on:

- Year – of the accident
- State – in which accident took place
- Water – name of the body of water the accident occurred in
- City – nearest city or town
- County – name of the county nearest the accident
- Additional Location Information – a more exact descriptor of the location
- Dead – number of deaths attributed to the accident
- Injuries – number of injuries attributed to the accident
- Damage – damage estimate
- Cause 1 – major result from accident (e.g. grounding, collision[51], flooding, etc.)
- Cause 2 – major reason directly leading to the accident
- Cause 3-5 – issues leading up to the accident. Cause 3 issues are more significant to the accident than are those for Causes 4 and 5.

## I. United States Coast Guard's Marine Information for Safety and Law Enforcement (MISLE)

The Marine Casualty and Pollution Database contain data related to commercial marine casualty investigations reportable under 46 C.F.R. 4.03 and pollution investigations reportable under 33 C.F.R. 153.203. [52] The data reflect information collected by U.S. Coast Guard personnel concerning vessel and waterfront facility accidents and marine pollution incidents throughout the United States and its territories. Containing over 10 years of data in the new format, in December 2001, the U.S. Coast Guard transitioned from the Marine Safety

[51] In this database allisions were not separately identified but included with collisions.

[52] The marine casualty reporting requirements are in 46 CFR 4.03, but that rule exempts vessels covered by 33 CFR 1783.51, which are recreational vessels. The USCG office of Boating Safety works with the various state agencies that have jurisdiction over recreational boating to ensure accurate record keeping on recreational boating accidents.

Information System (MSIS) to the Marine Information for Safety and Law Enforcement (MISLE) information system. The redesigned system better supports the collection and analysis of data. In this analysis, data involving monetary damages related to vessels, cargo, facilities and other were joined with instances of injuries and deaths.[53] A second database covering 2005 to 2017 was formed which contained instances of water pollution. In the latter analysis releases from fixed facilities (e.g., docks, platforms, etc.) were analyzed along with losses from ships, barges, tugs, etc. the theory being that PORTS® information involving tides, currents and temperature could help speed locating and remediating such spills.[54]

Based on location, a number of socio-economic data fields were added from NOAA's Coastal Services Center (CSC)'s ENOW (Economics: National Ocean Watch) database and the USACE's RECONS (Economics: Regional Economic System) database at the county level. Data from adjacent counties to port locations was also added. Finally, using ArcGIS, the "operational area" of each port was identified using a "lasso" technique where industry experts reviewed port maps and identified the relative jurisdictional area of each port.

## K. National Oceanic and Atmospheric Administration's, Office of Coast Survey Dangers to Navigation.

A danger to navigation is considered to be any natural feature (e.g., shoal, boulder, reef, rock outcropping) as well as any cultural feature (e.g., wreck, obstruction, pile) which pose an imminent danger to the mariner.. All features with depths of 11 fathoms (66 feet) or less in navigable waters are evaluated and

[53] MISLE data is presented to the public as a series of 10 files which contain 1,532,668 records as of January 8, 2013.

[54] Overall, the database provides details on over 1,100,000 vessels and 54,000 facilities.

charted as potential dangers to navigation.

Dangers to Navigation (DTON) may include:

- Natural or cultural features, either submerged or visible, that pose an imminent danger to surface navigation based on hydrographer’s knowledge of the survey area, vessel traffic, and existing cartographic product;
- Uncharted or inadequately charted clearances for bridges and overhead cables or pipelines;
- Uncharted aid to navigation, unless temporary in nature or repositioned frequently;
- An aid to navigation located off station, is damaged to the extent that it does not serve its intended purpose or its characteristics are incorrectly charted; or,
- Elevated pipelines.

DTONs do not cause undue clutter in relation to other soundings or features on the nautical chart. Dangers that are too complex to be adequately identified as discrete features are depicted as area features.

For this study, an extraction was written to obtain a Lines-Points-Areas Dangers to Navigation Geodatabase. The objects (DTONs) were first extracted from the largest scale ENCs (Band 6). Then extracted from the Band 5 ENCs. Anywhere a Band 6 ENCs overlapped with the Band 5 the objects in that overlap area extracted from the Band 5 were deleted. This process was repeated through the scales (Band 6 and 5 areas deleted Band 4 objects and so on) to ensure no duplication of objects. A set of simplified attributions were written for each extracted object based on several extraction rules.

## DATA TOOLS FOR STUDY

### A. ArcGIS

ArcGIS, developed by Environmental Systems Research Institute (ESRI), is a geographic information system (GIS) for working with maps and geographic information. It is used for: creating and using maps; compiling geographic data; analyzing mapped information; sharing and discovering geographic information; using maps and geographic information in a range of applications; and managing geographic information in a database.

For this study, ArcMap and ArcGIS Pro were used to manipulate geodatabases (i.e. AIS Point and Tracks, DTONs, Aids to Navigation, Port Locations, MISLE accidents, etc.) using several appropriate geoprocessing tools, and to view/review the data along other layers (i.e. raster charts, aids to navigation, etc.).

Working with NOAA's Office of Coast Survey (OCS) and Center for Operational Oceanographic Products and Services (CO-OPS), individual accident and pollution cases categorized by the USCG by latitude and longitude were associated with areas of nautical charting and installation of PORTS® instrumentalities.

**B. Statistical Analysis System (SAS)**

SAS is a statistical software suite developed by SAS Institute that can mine, alter, manage and retrieve data from a variety of sources and perform statistical analysis on it. SAS programs have DATA steps, which retrieve and manipulate data, and PROC steps, which analyze the data. Data sets are organized into tables with rows called "observations" and columns called "variables". The PROC step consists of PROC statements that call upon named procedures. There are more than 300 named procedures and each one contains a substantial body of programming and statistical work. SAS macros are pieces of code or variables that are coded once and referenced to perform repetitive tasks.

For this study, SAS was used to manipulate most of all datasets (including geo-databases), sometimes in combination, to produce statistical summaries and report the results in EXCEL tables.

## REFERENCES

Rowlett, Russ. 2000. *"How Many, A Dictionary of Units of Measurement",* University of North Carolina, Chapel Hill.

# APPENDIX F

## CALCULATION OF MORTALITY AND MORBIDITY COSTS

## MORBIDITY AND MORTALITY

In performing analysis of their programs, many Federal agencies have sought to identify these values through two methodologies: (1) Quality-adjusted life year (QALY); and, (2) Value of Statistical Life Year (VSLY). Merrill (2017) observed that the Federal Government in promulgating new regulations often estimate the value of lives in order to assess if the benefits of the proposal outweigh its costs.

Reportedly developed by health economists Cundell and McCartney in 1956 QALY is often employed in cost-utility analysis to calculate the ratio of cost to QALY saved for a particular health care intervention. This is then employed to allocate healthcare resources, with an intervention with a lower cost to QALY saved (incremental cost effectiveness) ratio ("ICER") being preferred over an intervention with a higher ratio.[55] QALY is a measure of the value of health outcomes developed by Cundell and McCartney in 1956. Since health is a function of length of life and quality of life, the QALY was developed as an attempt to combine the value of these attributes into a single index number. The basic idea underlying the QALY is simple: it assumes that a year of life lived in perfect health is worth one QALY (one Year of Life × one Utility value = one QALY) and that a year of life lived in a state of less than this perfect health is worth less than one. In order to determine the exact QALY value, it is sufficient to multiply the utility value associated with a given level of health by the years lived in that state of health. QALYs are consequently expressed in terms of "years lived in perfect health": half a year lived in perfect health is equivalent to 0.5 QALYs (0.5 years × 1 Utility), the same as one year of life lived in a situation with utility 0.5 (e.g. bedridden) (one year × 0.5 Utility). QALYs can then be incorporated with medical costs to arrive at a final common denominator of cost/QALY. This parameter can be employed to develop a cost-

[55] Refer to: http://en.wikipedia.org/wiki/Quality-adjusted_life_year

effectiveness analysis of any treatment.[56]

Value of a Statistical Life Year (VSLY) employed in this analysis represents another methodology to view the risks that people are voluntarily willing to take and how much they must be paid for taking them Mankiw (2012). The willingness to pay to avoid the risk of a fatal injury increases proportionally with growing risk.[57] If, for instance, each member of a population of a hundred thousand were willing to pay $50 on average for a one in one hundred thousand decrease in his risk of dying during the next year, the corresponding Value per Statistical Life (VSL) would be $50×100,000 or $5 million.

The value per statistical life year (VSLY) is an approach for adjusting VSL estimates to reflect differences in remaining life expectancy and involves calculating the value of each year of life extension. Because the degree of life extension is usually closely related to the age of the affected individuals[58], VSLY is often interpreted as an approach for adjusting VSL to reflect age differences.[59] It is generally derived by applying simple assumptions to VSL estimates based on the

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[56] A problem of the QALY calculation relies on the numerical nature of its constituent parts. The appropriateness of the QALY arithmetical operation is compromised by the essence of the utility scale: while life-years are expressed in a ratio scale with a true zero, the utility is an interval scale where 0 is an arbitrary value for being dead. In order to be able to obtain coherent results, both scales would have to be expressed in the same units of measurement. See Prieto (2003), Schlander (2007) and Mortimer (2007).

[57] Refer to: US Department of Transportation. 2015. "Revised Departmental Guidance 2014: Treatment of the Value of Preventing Fatalities and Injuries in Preparing Economic Analyses", June 17. https://www.transportation.gov/sites/dot.gov/files/docs/VSL2015_0.pdf

[58] Other researchers (e.g., Muller et al. 2011) have suggested varying VSL based on age and have employed up to 19 age groups in their analysis of the population at risk due to pollution.

[59] The relationship between VSL and VSLY may be clarified by recognizing that any change in an individual's mortality risk can be described by a corresponding shift in her survival curve, which can be summarized by the expected number of lives saved (as a function of time or within a specified time period) or by the expected number of life-years saved. An individual's willingness to pay (WTP) for a shift in her survival curve can be summarized by her average VSL or VSLY for that change. Economic theory suggests that both VSL and VSLY may depend on the individual's initial survival curve, characteristics of the shift, and individual characteristics such as health and income. Neither VSL nor VSLY is likely to be constant across changes in mortality risk. Therefore, accurate valuation requires the use of scenario-specific values. The choice between VSL and VSLY summary measures is largely one of convenience. Refer to: Hammitt

work of Schelling et al. (1968) and Moore and Viscusi (1988). VSL estimates have varied over time. Tables F-1 and F-2

**Table F-1**

## EXAMPLES OF PREVIOUS VSL ESTIMATES

| AUTHORS (YEARS) | PUBLICATION DATES OF UNDERLYING STUDIES | AS REPORTED (DOLLAR YEAR) | INFLATED TO CONSTANT 2019 DOLLARS |
|---|---|---|---|
| Miller (2000) | 1974 - 1990 | $3.7 million (1995) | $6.6 million |
| Mrozek & Taylor (2002) | 1974 – 1995 | 1.5 to $2.5 Million (1998) | $2.4 to $4.0 million |
| Viscusi & Aldy (2003) | 1974 – 2000 | $5.5 to $7.6 Million (2000) | $8.0 to 11.0 million |
| Kochi et al. (2006) | 1974 – 2002 | $8.9 Million (2000) | $12.9 million |

Source: Bosworth et al. *"The Value of a Statistical Life: Economics and Politics",* Table 1, Page 12

(2007) and http://reep.oxfordjournals.org/content/1/2/228.abstract

**Table F-2**

## SUMMARY OF FEDERAL AGENCY LIFE VALUATION PROCESSES

| AGENCY | DOLLAR VALUE PER YEAR Millions of US Dollars (Study Year) | ADJUSTED TO 2017 DOLLARS (Millions of US Dollars)[60] | METHOD (VSLY or QALY) | ANNUALLY ADJUSTED? (If so, how?) | COMMENTS |
|---|---|---|---|---|---|
| U.S. Environmental Protection Agency | $2.3 (1996)<br>$7.4 (2006)<br>$7.9 (2008)<br>$9.1 (2011)<br>$9.7 (2013)<br>$10.0 (2016) | $3.8<br>$8.8<br>$8.6<br>$10.4<br>$10.7<br>$10.2 | N/A | Yes<br>- Inflation using GDP deflator<br>- Real income growth (either CPI or GDP)<br>- Income elasticity (0.50) | Emphasizes importance of consistency and challenge of communication; working to change to Value of Risk Reduction |
| Consumer Product Safety Administration | $5.4 (2008)<br>$8.7 (2014) | $6.3<br>$9.3 | | | |
| Pipeline and Hazardous Materials Safety Administration | $6.2 (2008)<br>$6.7 (2018) | $7.6<br>$6.5 | | | |
| Federal Railroad Administration | $6.3 (2010)<br>$9.6 (2016) | $7.3<br>$9.8 | | | |
| Occupational Safety and Health Administration | $9.1 (2010) | $10.6 | | | |
| Mining Safety and Health Administration | $9.1 (2010) | $10.6 | VSLY | | |

[60] Employing overall Gross Domestic Product Deflator (GDP).

## ESTIMATED GROSS BENEFITS PROVIDED BY NAVIGATIONAL CHARTS IN THE UNITED STATES

| AGENCY | DOLLAR VALUE PER YEAR Millions of US Dollars (Study Year) | ADJUSTED TO 2017 DOLLARS (Millions of US Dollars) | METHOD (VSLY or QALY) | ANNUALLY ADJUSTED? (If so, how?) | COMMENTS |
|---|---|---|---|---|---|
| U.S. Department of Transportation | $6.2 (2011)<br>$9.1 (2013)<br>$9.4 (2015)<br>$9.6 (2016)[61] | $7.1<br>$10.0<br>$9.8<br>$9.8 | VSL and QALY - when applicable | Yes<br>- Inflation (CPI-U)<br>- Income Growth | VSL basis is from five-meta-analysis studies from 2000-2004. Updating the number to another base year involves use of both changes in real income and CPI. For example: 2015 VSL = Base Year VSL * (2015 CPI/Base Year CPI) * (2015 Real Incomes / Base Year Incomes) |
| U.S. Food & Drug Administration | $3.7 (1996)<br>$7.9 (2010)<br>$9.3 (2015)<br>$9.5 (2017) | $6.1<br>$9.2<br>$9.7<br>$9.5 | VSLY | Yes<br>- Inflation (GRP deflator)<br>- Not for income growth | Uses EPA's base VSL; uses VSLY more frequently than VSP (due to the characteristics of FDA's regulations) |
| U.S. Department of Homeland Security/Customs and Border Protection | $6.8 (2011) | $7.8 | | Yes (every time VSL is used for regulation):<br>- Inflation (CPI-U)<br>- Real income growth<br>- Income elasticity (0.47) | Established VSL in 2008 (had used EPA or DOT previous to that) |
| U.S. Department of Homeland Security/United States Coast Guard | $6.3 (2008) | $7.3 | | No | Uses Customs and Border Protection 2008 study as basis |

[61] Source: Moran, Molly J. 2016. "Guidance on Treatment of the Economic Value of a Statistical Life (VSL) in U.S. Department of Transportation Analysis – 2016 adjustment", U.S. Department of Transportation, Office of the Secretary of Transportation, August 8.

## ESTIMATED GROSS BENEFITS PROVIDED BY NAVIGATIONAL CHARTS IN THE UNITED STATES

| AGENCY | DOLLAR VALUE PER YEAR Millions of US Dollars (Study Year) | ADJUSTED TO 2017 DOLLARS (Millions of US Dollars) | METHOD (VSLY or QALY) | ANNUALLY ADJUSTED? (If so, how?) | COMMENTS |
|---|---|---|---|---|---|
| U.S. Department of Agriculture/Headquarters | $3.6 (1994)<br><br>$8.9 (2016) | $6.3<br><br>$8.9 | VSLY | | |
| U.S. Department of Agriculture / Economic Research Service | $6.9 (2003) | $9.0 | VSLY | Yes<br>- Inflation only | Does not apply for rulemaking; uses calculator that uses VSL as an input to calculate costs of food borne illnesses and pathogens. VSL=(P/$r$)[1-(1+$r$)$^{-1}$]<br>P = annual payment (VSLY);<br>$r$ = interest rate;<br>t = average life expectancy in years |
| U.S. Department of Agriculture / Food Safety Inspection Service | $3.6 (1994)<br><br>$5.0 (2000)<br><br>$8.9 (2016) | $6.3<br><br>$6.9<br><br>$9.1 | VSLY | Yes<br>- inflation only<br>- no formalized process | Used VSL directly or indirectly for 6 rules |
| National Oceanic and Atmospheric Administration | | | | | Working to learn more about VSL and how it may be applied at NOAA |
| U.S. Department of Energy / Headquarters and National Nuclear Security Agency | | | | | No official VSL; on occasion for radiation cases it uses NRC's dollar per person-rem nominal value of $2,000 / person-rem |

**ESTIMATED GROSS BENEFITS PROVIDED BY NAVIGATIONAL CHARTS IN THE UNITED STATES**

| AGENCY | DOLLAR VALUE PER YEAR Millions of US Dollars (Study Year) | ADJUSTED TO 2017 DOLLARS (Millions of US Dollars) | METHOD (VSLY or QALY) | ANNUALLY ADJUSTED? (If so, how?) | COMMENTS |
|---|---|---|---|---|---|
| Nuclear Regulatory Commission | $3.0 (1995)<br><br>$9.0 (2017) | $5.1<br><br>$9.0 | Neither; Uses Dollar per person-rem[62] ($1,000) | No | Uses Dollar per person-rem ($1,000) Actively working to update VSL and corresponding dollar per person-rem factor as well as establish systematic process for updating in the future |

Sources: U.S. Nuclear Regulatory Commission, 2012. *"Cost-Benefit Analysis – Value of Statistical Life Workshop Report*", Office of Nuclear Regulatory Research, Cost Table 2, Summary, page 9; W. Kip Viscusi, "The Value of Individual and Societal Risks to Life and Health", in the Handbook of the Economics of Risk and Uncertainty; U.S. Department of Transportation, 2015. *Guidance on Treatment of the Economic Value of a Statistical Life (VSL) in the U.S. Department of Transportation Analysis – 2015 Adjustment*, June 17; and, US Department of Transportation, 2016. *"Guidance on Treatment of the Economic Value of a Statistical Life (VSL) in the U.S. Department of Transportation Analyses – 2016 Adjustment"*, August 8.

[62] Represents the product of the average (radiation) dose per person times the number of persons exposed. Source: McCree, Victor M. 2017. "Proposed Revision to NUREG-1530, "Assessment of NCR's Dollar per Person-REM Conversion Factor Policy", January 30.

Another method employed to estimate the VSLY is by simply asking people (e.g., through questionnaires) how much they would be willing to pay for a reduction in the likelihood of dying, perhaps by purchasing safety improvements. These types of studies are referred to as stated preference studies[63]

Several Federal agencies delineated their methodologies to value lives at an interagency workshop.[64] From their discussions and presentations, it was learned that some agencies employed the VSLY approach while one utilized the QALY approach. When responses from that 2012 conference and later agency updates were adjusted to constant 2017 dollars[65], the VSL across agencies ranged from $6.5 million at the Pipeline and Hazardous Materials Safety Administration to $10.6 million at the Occupational Safety and Health Administration.[66]

Separately, Viscusi et al. (2003) and Viscusi (2005) observed a median VSL for U.S. workers of $6 and $7 million, respectively. These translate to about $7.8 million and $7.3 ($2017), respectively. In a later estimate, Kniesner et al. (2019) reported the mean estimate for a life was $13.1 million ($12.4 million in $2017).

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[63] A well-known problem with this method is the so-called "hypothetical bias", whereby people tend to overstate their valuation of goods and services.

[64] Interagency Regulatory Analysis Workshop: Cost-Benefit Analysis, Value of a Statistical Life, Hyatt Regency, Bethesda, March 19-20, 2012.

[65] The Gross Domestic Product was employed as the basis for conversion to constant (2017) dollars.

[66] Estimates by Muller (2011) ranged from $6.0 million in 2011 ($6.9 million in $2017) to $8.1 million by Holland in 2016 ($8.3 in $2017). Both studies also included sensitivity analyses that ranged from $2 to $10 (nominal) million and $8.1 to $10.8 (nominal) million, respectively.

Given the conservative nature of this analysis and the transportation-related nature of the injuries and deaths that could be reduced through timely accurate and complete use of more rigorous navigational data, the U.S. Department of Transportation's (DOT) 2017 figure of $9.8 million was selected.[67]

### B. Value of Injury Reduction

The measurement of the society's Willingness To Pay (WTP) to avoid catastrophic transportation accidents is based on a combination of the economic losses from the accidents and the broader societal values held in support of social justice and equity. In this context, the value of a life to a society cannot be fully represented by direct costs and lost earnings alone. This approach to assessing the value of life – also referred to as the "comprehensive" model – represents the values citizens themselves would assign to a reduced risk of death if they were purchasing the protection directly. This approach estimates accident costs in reference to the values attached to a broad array of costs – property damages, delays, fatalities involved in each reported accident, plus an estimated measure of Quality-Adjusted Life Years lost (QALY) for the injuries resulting from each accident. Using the QALY as an additional measure of the comprehensive cost of transportation-related accidents, the National Highway Transportation Safety Administration (NHTSA) has calculated the comprehensive accident costs through the

[67] In this analysis a constant $9.8 million was universally employed regardless of the victim's age. Other researchers (e.g., Muller et al. 2011) have suggested varying VSL based on age and have employed up to 19 age groups in their analysis of the population at risk due to pollution.

"Maximum Abbreviated Injury Scale" (MAIS).[68]

For estimating the WTP to avoid a severe transportation-related injury, the Office of the Secretary of Transportation (OST) calculated relationships between the MAIS indicating injury severity and the WTP value.[69] Table F-3 presents the estimated $2017 dollar cost of accidents by the degree of injury severity.

**Table F-3**

**VALUES FOR SOCIETAL WILLINGNESS
TO PAY TO AVERT INJURIES**

| DOT AIS SCALE FOR LEVEL OF SEVERITY | INJURY SEVERITY | FRACTION OF THE VSL OF AN AVERTED FATALITY[70] | VSL FOR AN AVERTED INJURY OR DEATH (2017 Dollars) |
|---|---|---|---|
| AIS 1 | Minor | 0.3 % | $29,400 |
| AIS 2 | Moderate | 4.7% | $460,600 |
| AIS 3 | Serious | 10.5% | $1,029,000 |
| AIS 4 | Severe | 26.6% | $2,606,800 |
| AIS 5 | Critical | 59.3% | $5,811,400 |
| AIS 6 | Not Survivable | 100.0% | $9,800,000[71] |

Source: U.S. Department of Transportation, 2016. "*Guidance on Treatment of the Economic Value of a Statistical Life (VSL) in the U.S. Department of Transportation Analysis – 2016 Adjustment*," August 8, Table 3. Also see Wolfe et al. (2020) Table 3.

[68] National Highway Transportation Safety Administration, *The Economic Impact of Motor Vehicle Crashes 2000*, May 2002; FHWA, "Treatment of Value of Life and Injuries in Preparing Economic Evaluation", January 8. 1993.

[69] The Department of Transportation refers to this scale as the "Abbreviated Injury Scale (AIS)".

[70] Refer to Table 2, Relative Disutility Factors by Injury Severity Level (MAIS) for Use With 3% or 7% Discount Rate, Page 10, U.S. Department of Transportation, 2016. *Guidance on treatment of the Economic Value of a Statistical Life (VSL) in the U.S. Department of Transportation Analysis – 2016 Adjustment*, August 8.

[71] Note: the total WTP values do not add up to $9.8 million due to the rounding of AIS fractions.

**ESTIMATED GROSS BENEFITS PROVIDED BY NAVIGATIONAL CHARTS IN THE UNITED STATES**

Prior to 2011, only the total number of injuries was reported in the MISLE database.[72] Of the nearly 1,500 events where the degree of injury was reported during 2011 to 2015, almost 13 percent were classified as "minor".[73] (Refer to Table F-4.) From this distribution, the overall expected average cost of injuries could be calculated. (Refer to Table F-5) Following this procedure, the average cost of an injury was estimated to be approximately $789,233 ($2017).

**Table F-4**

## DISTRIBUTION OF INJURY SEVERITY

| DOT AIS SCALE FOR LEVEL OF SEVERITY | USCG SCALE OF INJURIES | INJURY SEVERITY | NUMBER OF REPORTED INJURIES (2011 – 2015) Source: USCG | PERCENT OF TOTAL INJURY REPORTS |
|---|---|---|---|---|
| AIS 1 | 1 | Minor | 190 | 12.9% |
| AIS 2 | 2 | Moderate | 789 | 53.5% |
| AIS 3 | 3 | Serious | 363 | 24.6% |
| AIS 4 | 4 | Severe | 109 | 7.4% |
| AIS 5 | 5 | Critical | 24 | 1.6% |

Source: USCG MISLE Database

**Table F-5**

## ESTIMATION OF EXPECTED AVERAGE INJURY COST

| USCG SCALE OF INJURIES | INJURY SEVERITY | PERCENT OF TOTAL INJURY REPORTS | VSL FOR AN AVERTED INJURY (2017 Dollars) | PERCENT TIMES VSL (Column 3 * Column 4) (2017 Dollars) |
|---|---|---|---|---|
| 1 | Minor | 12.9% | $29,400 | $3,793 |
| 2 | Moderate | 53.5% | $460,600 | $246,421 |
| 3 | Serious | 24.6% | $1,029,000 | $253,134 |

[72] The USCG does not claim that its injury scale is identical to the AIS scale. The descriptions of the categorization levels in the CG and AIS are similar, such that the match-up in Table 21 provides a way to monetize injuries. This approach was used in the Inspection of Towing Vessel and other rulemakings.

[73] During this time, a total of 190 injuries were reported. Refer to Table 22.

| | | | | |
|---|---|---|---|---|
| 4 | Severe | 7.4% | $2,606,800 | $192,903 |
| 5 | Critical | 1.6% | $5,811,400 | $92,982 |
| | | | **EXPECTED COST:** | **$789,233** |

Source: United States Coast Guard MISLE database (2011 – 2017) and U.S. Department of Transportation, 2016. *Guidance on Treatment of the Economic Value of a Statistical Life (VSL) in the U.S. Department of Transportation Analysis – 2016 Adjustment*, August 8, Table 3.

# APPENDIX G

## EXAMPLES OF UNDERKEEL CLEARANCES (UKC) SPECIFIED IN PORT AUTHORITY OPERATIONAL PLANS

# SPECIFIED CLEARANCES AT MAJOR PORTS

| PORT LOCATION | MINIMUM UNDERKEEL CLEARANCE REQUIRED |
|---|---|
| San Diego, CA | 1 foot |
| Oakland, CA | 2 feet |
| San Francisco, CA | 2 feet |
| Richmond, CA | 2 feet |
| Martinez, CA | 2 feet |
| Stockton, CA | 2 feet |
| San Pablo Bay, CA | 2 feet |
| Carquinez Strait, CA | 2 feet |
| San Joaquin River, CA | 2 feet |
| Selby, CA | 2 feet |
| Crockett, CA | 2 feet |
| Redwood City, CA | 2 feet |
| Humboldt, CA | 2 feet |
| Los Angeles, CA | 3 feet |
| Long Beach, CA | 3 feet |
| Seattle, WA | 3 feet |
| Tacoma, WA | 3 feet |
| Anacortes, WA | 3 feet |
| Everett, WA | 3 feet |
| Blaine, WA | 3 feet |
| Bellingham, WA | 3 feet |
| Grays Harbor, WA | 3 feet |
| Port Townsend, WA | 3 feet |
| Olympia, WA | 3 feet |
| Point Roberts, WA | 3 feet |
| Port Hueneme, CA | 3.5 feet |

Source: Port Authority operational plans for respective ports effective in 2012.

# APPENDIX H

## SAN FRANCISCO, SAN PABLO AND SUISUN BAYS HARBOR SAFETY PLAN

**ESTIMATED GROSS BENEFITS PROVIDED BY NAVIGATIONAL CHARTS IN THE UNITED STATES**

Voted on and approved by the Harbor Safety Committee of the San Francisco Bay Region
June 14, 2012
Pursuant to the California Oil Spill and Prevention Act of 1990
Submitted by the Harbor Safety Committee of the San Francisco Bay Region
C/o Marine Exchange of the San Francisco Bay Region
505 Beach Street, Suite 300
San Francisco, California 94133-1131
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## UNDERKEEL CLEARANCE

Many of the navigation channels within the Bay are subject to shoaling because of the nature of the Bay system, which is more fully described in Chapter V, Surveys, Charts and Dredging. Accurate tidal information is essential in order to calculate required underkeel clearances for vessel transit. This is particularly critical in the Bay region where minimal clearances may occur in certain channels. The committee reiterates its support for "real time" accurate measurement of tides, such as the PORTS® system recommended in Chapter II, General Weather, Tides and Currents. Underkeel clearance is the distance between the deepest point on the vessel and the bottom of the channel in still water conditions. Tank vessels carrying oil or petroleum products as cargo should maintain minimum underkeel clearances as listed below. The underkeel clearances are minimum standards during normal, calm conditions. Masters and pilots should use prudent seamanship and should evaluate the need for additional clearance to accommodate squat rolling, listing, sink and pitch. The following are guidelines for underkeel clearance of tank vessels:

a. Tank vessels west of the Golden Gate Bridge: Ten percent (10%) of the vessel's draft.

b. Tank vessels under way east of the Golden Gate Bridge: Two feet (2).

c. Tank vessels at final approach to berth and at berth: Always afloat.

Regarding single hull tankers, on July 30, 1996, the Coast Guard published the Final Rule (33 CFR 157.455, effective November 27, 1996) on Operational Measures to Reduce Oil Spills for Existing Tank Vessels of 5,000 gross tons or more without double hulls. In part, the regulations require the Master to calculate the vessel's deepest navigational draft, the controlling depth of the waterway and the anticipated underkeel clearance. In addition, the Master and Pilot are to discuss the tanker's planned transit. The regulations can be found on the web in the Code of Federal Regulations at www.gpoaccess.gov. A Working Group was formed with representatives from the San Francisco Bar Pilots, Coast Guard, Port authorities and the maritime industry to evaluate the process of calculating, in a dynamic condition, underkeel clearances. The above guidelines on minimum clearances for the San Francisco Bay Area were established Captain of the Port. This is interpreted to be 2 feet for all commercial vessels.

# APPENDIX I

## CPT BACKGROUND AND
## PORT, PORTS® AND USACE CPT LOCATION
## CROSS-WALK DEFINITIONS
## AND
## USAGE PROCEDURES

**Table I-1**

## CPT PROJECT NAMES

(Puerto Rico) - Arecibo Harbor
(Puerto Rico) - Fajardo Harbor
(Puerto Rico) - Naturally Deep - SAJ
(Puerto Rico) - Ponce Harbor
(Puerto Rico) - Port Ensenada
(Puerto Rico) - San Juan Harbor
(Puerto Rico) Low Use - SAJ
(Puerto Rico) Mayaguez Harbor
Absecon Inlet
Adam's Bayou Channel
AIWW - NAO
AIWW - SAC
AIWW - SAJ
AIWW - SAS
AIWW - SAW
Alabama-Coosa Rivers
Alameda Point Channel, CA
Albermarle Sound
Allegheny River Improved Portion
Allegheny River Open Channel Portion
Alpena Harbor
Alsea Bay and River
Altamaha River
Amite River and Bayou Manchac
Anacortes Harbor
Anacostia River, DC
Anahuac Channel
Anchorage
Anclote River
Andrews River, MA
Annapolis Harbor
Apalachicola Bay
Apalachicola Chattahoochee and Flint Rivers
Appomattox River
Ashland Harbor
Ashland_WI
Ashley River
Ashtabula Harbor
Atchafalaya River
Atchafalaya River Morgan City to Gulf of Mexico
Atka Island
Atlantic Beach Channels
Avon Harbor
Back Creek
Back Creek, Anne Arundel County, MD
Bakers Haulover Inlet, FL
Baltimore Harbor
Bar Harbor
Barataria Bay Waterway
Barbers Point Harbor
Barkley Canal Cumberland and Tennesse Rivers
Barnegat Inlet, NJ
Bass Harbor
Bass River, MA

## ESTIMATED GROSS BENEFITS PROVIDED BY NAVIGATIONAL CHARTS IN THE UNITED STATES

Bastrop Bayou, TX
Baton Rouge Harbor-Devil's Swamp
Bay Ridge and Red Hook Channels
Bay River
Bayfield Harbor
Bayou Bernard
Bayou Boeuff
Bayou Bonfouca
Bayou Chico
Bayou Coden
Bayou Dupre
Bayou Galere
Bayou La Batre
Bayou Lacombe
Bayou Lafourche and Lafourche-Jump Waterway
Bayou Little Caillou
Bayou Plaquemine Brule
Bayou Segnette Waterway
Bayou Teche
Bayou Teche and Vermilion River
Bayou Terrebonne
Bayous La Loutre ST Malo and Yscloskey
Beaufort Harbor
Belfast Harbor
Belle River, MI
Bellingham Bay and Harbor
Beresford Creek, SC
Berkeley
Big Pigeon and Little Pigeon Bayous
Big Sandy Harbor
Biloxi Harbor
Bivalve, MD
Black River
Black River
Black Warrior and Tombigbee Rivers
Blackwater River
Blaine Harbor
Block Island Sound, RI
Blue Hill Bay, ME
Bodega Bay, CA
Bolles Harbor, MI
Bon Secour River
Bonum Creek, VA
Boothbay Harbor
Boston Harbor
Branford Harbor
Breton Bay
Bridgeport Harbor
Bristol Harbor
Broad Creek River
Broad Creek, MD
Broadwater Creek
Bronx River
Browns Creek
Brownsville
Brunswick Harbor
Buffalo Harbor
Bullocks Point Cove
Burlington Harbor, VT
Burns Harbor
Buttermilk Channel
Calcasieu River and Pass
Calumet Harbor and River
Calumet-Sag Channel

## ESTIMATED GROSS BENEFITS PROVIDED BY NAVIGATIONAL CHARTS IN THE UNITED STATES

Cambridge Harbor
Camden Harbor
Canapitsit Channel
Canaveral Harbor
Cape Charles City Harbor
Cape Cod Canal
Cape Fear River above Wilmington
Cape May Canal
Carquinez Strait
Carrabelle Harbor
Carters Creek
Caruthersville Harbor, MO
Casey's Pass Venice Inlet, FL
Cashie River
Cathlamet Bay, OR
Cathlamet Ferry Terminal, WA
Cedar Bayou
Centerville, MA
Channel Connecting Thoroughfare Bay with Cedar Bay
Channel from Back Sound to Lookout Bight
Channel from Naples to Gordon Pass and Big Marco Pass
Channel from Pamlico Sound to Rodanthe
Channel to Aransas Pass
Channel to Newport News
Channel to Palacios
Channel to Port Bolivar
Channel to Victoria
Channels in Lake St. Clair
Charleston Harbor
Charleston_OR
Charlevoix Harbor
Charlotte Harbor
Cheboygan Harbor
Cheesequake Creek
Chester River
Chetco River, OR
Chicago Harbor
Chicago River (Main and North Branch)
Chicago River (South Branch)
Chicago Sanitary and Ship Canal
Chickasaw Creek
Chincoteague Bay
Chincoteague Harbor
Chinook Channel
Chocolate Bayou
Choctawhatchee River
Choptank River
Chowan River
Claiborne County, Ms
Claiborne Harbor
Claiborne Harbor, MD
Clatskanie River
Clear Creek
Clearwater Pass
Clearwater River
Cleveland Harbor
Clinch River
Clinton Harbor, CT
Clinton River, MI
Coach Point, VA
Coan River
Cobscook Bay
Cold Spring Inlet
Colorado River and Flood discharge Channels

## ESTIMATED GROSS BENEFITS PROVIDED BY NAVIGATIONAL CHARTS IN THE UNITED STATES

Columbia and Lower Willamette Rivers
Columbia R. and Trib above Mcnary Lock and Dam to Kennewick
Columbia River above The Dalles Dam, WA to Mcnary Lock and Dam

Columbia River between Vancouver, WA and The Dalles, OR
Columbia River between Wenatchee and Kettle Falls
Columbia Slough
Coney Island Channel
Coney Island Creek
Conneaut Harbor
Connecticut River Below Hartford
Cook Inlet Shoals, AK
Coon Island
Cooper River, SC
Coos and Millicoma Rivers
Coos Bay
Coquille River, OR
Cordova Harbor
Corpus Christi Ship Channel
Corpus Christi, TX - Outer Bay
Corsica River
Cotuit Harbor, MA
Cow Bayou Channel, TX
Cowlitz River
Craig Harbor
Crescent City Harbor, CA
Criehaven Harbor, ME
Crisfield Harbor
Cross Rip Shoals, Nantucket Sound
Cross-Florida Barge Canal
Crystal River
Cumberland River Mouth to Nashville
Cumberland River Nashville
Cuttyhunk Harbor
Cypress Bayou and Waterway
Damariscotta River
Darien Harbor
Dauphin Island Bay
Deep Creek, Newport News, VA
Deep River
Deepwater (Buzzards Bay, MA)
Deepwater (Hawaiian Outer Islands)
Deepwater (Kauai Island)
Deepwater (Molokai Island)
Deepwater (Niihau Island)
Delaware Bay Waterway
Delaware River Between Philadelphia and Trenton
Delaware River, Philadelphia to the Sea
Dennis Creek
Depoe Bay, OR
Detour Harbor, MI
Detroit River
Devils Elbow
Dickinson Bayou
Dillingham Harbor
Dog and Fowl Rivers
Dorchester Bay
Double Bayou
Drum Inlet
Drummond Island
Dubuque Commercial Harbor, IA
Duck Island Harbor, CT
Duluth-Superior Harbor
Dunkirk Harbor

## ESTIMATED GROSS BENEFITS PROVIDED BY NAVIGATIONAL CHARTS IN THE UNITED STATES

East Boothbay Harbor
East Chester Creek
East Pass Channel from Gulf of Mexico to Choctawhatchee Bay
East Pearl River
East Rippowam River, CT
East River
East Rockaway Inlet
Eastern Bay
Echo Bay Harbor
Edenton Harbor
Edgartown Harbor
Edisto River
Egegik River
Elfin Cove Harbor
Elizabeth River
Elk and Little Elk Rivers
Elk River
Elk River Harbor
Elokomin Slough
Elvis Starh (Hickman) Harbor, KY
Emory River
Erie Harbor
Escambia and Conecuh R., Escambia Bay
Essex River
Everett Harbor and Snohomish River
Fairport Harbor
Fall River Harbor
Falmouth Harbor
Far Creek
Fernandina Harbor
Fire Island Inlet
Fishing Bay
Fishing Creek
FLA Intracoastal Waterway
Flushing Bay and Creek
Fly Creek
Folly River, SC
Fort Myers Beach
Fort Pierce Harbor
Frankfort Harbor
Franklin Canal
Freeport Harbor
Frenchmans Bay, ME
Freshwater Bayou
Ft. Gaines Channel, AL
Galveston Harbor and Channel
Georgetown Harbor
GIWW - MVN
GIWW - SAM
GIWW - SWG
GIWW Morgan City to Port Allen Route
Gladstone Harbor
Glen Cove Creek
Glen Cove Harbor
Gloucester Harbor
Goat Island, RI
Goose Creek
Gordon's Landing, VT
Goshen Creek, NJ
Gowanus Creek Channel
Grand Haven Harbor and Grand River
Grand Lagoon
Grand Marais Harbor
Grand Marais Harbor, MN

## ESTIMATED GROSS BENEFITS PROVIDED BY NAVIGATIONAL CHARTS IN THE UNITED STATES

Grays Harbor and Chehalis River
Grays Reef Passage
Grays River
Great Kills Harbor
Great Pee Dee River
Great Salt Pond
Great South Bay
Great Wicomico River
Green and Barren Rivers
Green Bay Harbor
Green Harbor, MA
Greenport Harbor
Greenville, Ms
Greenwich Bay
Greenwich Harbor
Gulf County Canal
Gulfport Harbor
Hammersley Inlet
Hammond Boat Basin, OR
Hampton Creek
Hampton Harbor, NH
Harbor Beach (Harbor of Refuge, Lake Huron)
Harbor of Refuge Block Island
Harbor of Refuge Nantucket
Harbor of Refuge Point Judith
Harlem River
Harwich Port, MA
Hatteras Channel, NC
Hay (West) Harbor
Helena Harbor, AR
Hempstead Harbor
Herring Bay and Rockhold Creek
Herring Creek, MD
Herring River, MA
Hilo Harbor
Hingham Bay and Harbor
Holland Harbor
Holston River
Homer
Honga River and Tar Bay
Honolulu Harbor
Hoonah Harbor
Hoquiam River
Horn Harbor
Hoskins Creek
Houma Navigation Canal
Housatonic River
Houston Ship Channel
Hudson River Channel
Hudson River, NY (Maint)
Humboldt Harbor
Humboldt Harbor and Bay
Huntington Beach, CA
Huron Harbor
Hyannis Harbor
Illinois Waterway
Ilwaco_WA
Indian River Inlet and Bay
Indian WW between Rehoboth Bay and Delaware Bay
Indiana Harbor
Innerharbor Navigation Canal
Ipswich Bay and River
Isle Au Haut
Isle of Shoals Harbor

## ESTIMATED GROSS BENEFITS PROVIDED BY NAVIGATIONAL CHARTS IN THE UNITED STATES

IWW Chincoteague Bay to Del Bay
IWW Deleware Bay to Chesapeake Bay
IWW, Delaware River to Chesapeake Bay
IWW-NAB
J Bennett Johnston Waterway
Jackson Creek, VA
Jacksonville Harbor
Jamaica Bay
James River (Below Richmond)
Japan
Johns Pass
Johnsons Bayou
Jones Inlet
Jonesport Harbor, ME
Juneau Harbor
Kahului Harbor
Kake Harbor
Kalaupapa Harbor
Kanawha River
Kaskaskia River
Kaunakakai Harbor
Kawaihae Harbor
Kelleys Island
Kenmore Navigation Channel, WA
Kennebec River, ME
Kennebunk River, ME
Kenosha Harbor
Kentucky River
Kewaunee, WI
Keweenaw Waterway
Keweenaw Waterway
Key West
Keyport Harbor
King Cove Lagoon
Knobbs Creek
Kodiak Harbor
Kuskokwim River
La Grange Bayou
La Pointe Harbor
La Quinta, TX
Lac la Belle
Lac La Belle Harbor
Lafayette River
Lagoon Pond
Lake Calumet
Lake Charlevoix
Lake Montauk Harbor
Lake Moultrie, SC
Lake Providence Harbor, LA
Lake River
Lake Washington
Lake Washington Ship Canal
Larchmont Harbor
Larkspur, CA
Leland Harbor
Lewis River
Little Harbor, NH
Little Kanawha River
Little River
Little River (Creek)
Little River Inlet
Little Wicomico River
Long Island Intracoastal Waterway
Longboat Pass

## ESTIMATED GROSS BENEFITS PROVIDED BY NAVIGATIONAL CHARTS IN THE UNITED STATES

Lorain Harbor
Los Angeles - Long Beach Harbors
Low Use - LRB
Low Use - LRL
Low Use - MVN
Low Use - MVP
Low Use - NAB
Low Use - NAE
Low Use - NAN
Low Use - NAO
Low Use - NAP
Low Use - NWK
Low Use - NWP
Low Use - NWS
Low Use - POA
Low Use - POH
Low Use - SAC
Low Use - SAJ
Low Use - SAM
Low Use - SAS
Low Use - SAW
Low Use - SPL
Low Use - SPN
Low Use - SWG
Lower Cedar Point, MD
Lower Mississippi River - MVK
Lower Mississippi River - MVM
Lower Mississippi River - MVN
Lower Thoroughfare, Wenona, MD
Lubec Channel
Ludington Harbor
Lynhaven Roads Inlet

Lynn Harbor
Mackay Creek
Madison Parish Port, LA
Malden River
Mamaroneck Harbor
Manasquan River, NJ
Manatee Harbor
Manatee River
Manhasset Bay
Manistee Harbor
Manistique Harbor
Manitowoc Harbor
Manns Harbor
Manteo (Shallowbag) Bay
Mantua Creek, NJ
Marquette Harbor
Matagorda Ship Channel
Matincus Harbor, ME
Mattaponi River
Mattituck Harbor
Maurice River
Mcclellan-Kerr Arkansas River Navigation - SWL
Mcclellan-Kerr Arkansas River Navigation - SWT
Melbourne Harbor
Memphis Harbor
Menemsha Creek, MA
Menominee Harbor and River
Mermentau River
Mermentau River, Bayous Nezpique and Des Cannes
Metlakatla Harbor
Miami Harbor
Miami River

## ESTIMATED GROSS BENEFITS PROVIDED BY NAVIGATIONAL CHARTS IN THE UNITED STATES

Michigan City Harbor
Middle River
Middle River and Dark Head Creek
Milford Harbor, CT
Milford Haven, VA
Mill Creek
Milwaukee Harbor
Minnesota River
Mispillion River
Mission Bay
Mississippi River Gulf Outlet
Mississippi River Gulf Outlet via Venice
Missouri River - MVS
Missouri River - NWK
Missouri River - NWO
Mobile
Mokelumne River
Monongahela River
Monroe, MI
Monterey Harbor
Moosabec Bar, ME
Morehead City Harbor
Moriches Inlet, NY
Morristown Harbor, NY
Morro Bay Harbor, CA
Moss Landing harbor, CA
Mouth of the Colorado River, TX
Mouth of Yazoo River
Mt Sinai, Long Island, NY
Multnomah Channel
Muskegon Harbor
Muskingum River
Mystic River, CT
Naknek River
Nansemond River
Nanticoke River
Nanticoke, MD
Nantucket Sound North Channel, MA
Napa River
Narrows of Lake Champlain
Naturally Deep - LRE
Naturally Deep (Prince William Sound)
Nawiliwili Harbor
Neah Bay
Neale Sound
Neponset River
Neuse River
New Bedford and Fairhaven Harbor
New Haven Harbor
New London Harbor
New Madrid Harbor, MO
New River
New River
New Rochelle Harbor
New York and New Jersey Channels
New York Harbor
New York State Barge Canal System
Newark Bay
Newburyport Harbor
Newport Bay Harbor
Newport Harbor
Newport News
Newtown Creek
Niagara Falls

## ESTIMATED GROSS BENEFITS PROVIDED BY NAVIGATIONAL CHARTS IN THE UNITED STATES

Niagara River
Niantic Bay and Harbor
Ninilchik Harbor
NJ Intracoastal Waterway
Nome
Nomini Bay, VA
Non-Project (Asharoken)
Non-Project (Back Creek, York Creek)
Non-Project (Back River)
Non-Project (Calvert County)
Non-Project (Camp Pendleton Harbor)
Non-Project (Cape Flattery)
Non-Project (Chatham Strait)
Non-Project (Clarence Strait)
Non-Project (Coasters Harbor)
Non-Project (Cutler Bay)
Non-Project (Dixon Entrance)
Non-Project (Drift River Platforms)
Non-Project (East Chicago, IN)
Non-Project (Eastport Harbor)
Non-Project (Eatons Neck, Long Island, NY)
Non-Project (El Segundo)
Non-Project (Ellwood)
Non-Project (Florida Power Corporation)
Non-Project (Frederick Sound)
Non-Project (Freeport Harbor)
Non-Project (French Broad and Little Pigeon Rivers)
Non-Project (Fripp Island)
Non-Project (Gary, IN)
Non-Project (Gowanus Canal)
Non-Project (Gravesend Bay)
Non-Project (Harris Creek)
Non-Project (Hiwassee River)
Non-Project (Hog Island Channel)
Non-Project (Holbrook Island)
Non-Project (Honaunau)
Non-Project (Hooper Strait)
Non-Project (Hull Creek)
Non-Project (Icy Strait)
Non-Project (Island of Kauai Other Ports)
Non-Project (Island of Maui Explosives Anchorage)
Non-Project (Island of Oahu)
Non-Project (Jones Creek)
Non-Project (Kailua Bay)
Non-Project (Kaumalapau)
Non-Project (Kewalo Basin)
Non-Project (Kivilina)
Non-Project (LA Offshore Oil Loop)
Non-Project (Lahaina)
Non-Project (Little Ogeechee River)
Non-Project (Long Beach, WA)
Non-Project (Long Island Sound at City Island)
Non-Project (Lynn Canal)
Non-Project (Maalaea)
Non-Project (Manele Bay Small Boat Harbor)
Non-Project (Marathon)
Non-Project (Marblehead Outer Harbor, OH)
Non-Project (Masonboro Inlet)
Non-Project (Mobjack Bay)
Non-Project (Narragansett Bay)
Non-Project (New Topsail Inlet)
Non-Project (Nikishka)
Non-Project (Noatak River)
Non-Project (Northville)

## ESTIMATED GROSS BENEFITS PROVIDED BY NAVIGATIONAL CHARTS IN THE UNITED STATES

Non-Project (Nuka Bay)
Non-Project (Oak Bluffs)
Non-Project (Oceanside)
Non-Project (Other Hawaiian Island Area Ports)
Non-Project (Other San Francisco Area Ports)
Non-Project (Oyster Bay)
Non-Project (Pearl Harbor)
Non-Project (Phoebus)
Non-Project (Pidgeon Industrial PK)
Non-Project (Pine Orchard)
Non-Project (Portland Canal)
Non-Project (Prudence Island)
Non-Project (Resurrection Bay)
Non-Project (Revillagigado Channel)
Non-Project (Roseland)
Non-Project (San Clemente Harbor)
Non-Project (San Francisco District Other Coastal Ports)
Non-Project (San Miguel Island)
Non-Project (Santa Monica)
Non-Project (Shallote River)
Non-Project (Shinnecock Canal)
Non-Project (Silver Bay, MN)
Non-Project (Smithtown Bay, Long Island, NY)
Non-Project (St. George River)
Non-Project (Stephens Passage)
Non-Project (Sumner Strait)
Non-Project (Tongass Narrrows)
Non-Project (Vineyard Sound)
Non-Project (Whittier Harbor)
Non-Project (Zion, IL)
Norfolk Harbor
North Carolina International Port, NC

Northeast (Cape Fear) River
Northeast Harbor
Northport Harbor
Norwalk Harbor
Noyo River, CA
Nueces Bay, TX
Oakland Harbor
Obion River
Occoquan Creek
Ocean City Harbor
Oconto Harbor
Ocracoke Channel, NC
Ocracoke Inlet
Ogdensburg Harbor, NY
Ohio River - LRH
Ohio River - LRL
Ohio River - LRP
Okeechobee Waterway
Old Harbor
Old River
Olympia Harbor
Onancock River
Ontonagon Harbor
Orange, TX
Oregon Slough
Osceola Harbor, AR
Oswego Harbor
Ouachita-Black River
Pagan River
Palm Beach Harbor
Pamlico and Tar Rivers
Pamlico River and Sound

## ESTIMATED GROSS BENEFITS PROVIDED BY NAVIGATIONAL CHARTS IN THE UNITED STATES

Pamunkey River
Panama City Harbor
Parish Creek
Pascagoula Harbor
Pascagoula River
Pass Christian Harbor
Pass Manchac
Patchogue River
Patchogue River, CT
Patuxent River
Pearl River
Peconic Bay and River
Peekskill Harbor, NY
Pelican Harbor
Penobscot River
Pensacola Harbor
Perdido Pass Channel
Perquimans River
Petaluma River
Petit Anse, Tigre and Carlin Bayous
Petoskey, MI
Piankatank River, VA
Plattsburgh, NY
Pleasant River, ME
Plymouth Harbor
Pocomoke River
Pollack Rip Shoals
Ponce De Leon Inlet
Port Alexander
Port Allen Harbor
Port Angeles Harbor
Port Aransas, TX
Port Arthur, TX
Port Chester Harbor
Port Clyde, ME
Port Everglades Harbor
Port Hueneme
Port Huron, MI
Port Isabel
Port Jefferson Harbor
Port Mansfield
Port of New York
Port of Richmond
Port Orford
Port Royal Harbor
Port ST Joe Harbor
Port Townsend Harbor
Port Washington Harbor
Portland Harbor
Portsmouth Harbor
Potomac River
Potomac River Virginia Channel
Potomac River Washington Channel
Prairie du Chien, WI
Presque Isle Township, MI
Providence River and Harbor
Provincetown Harbor
Puget Sound Deepwater - NWS
Queen's Creek, VA
Quillayute River
Quinby Creek
Racine Harbor
Racoon Creek, NJ
Rahway River

## ESTIMATED GROSS BENEFITS PROVIDED BY NAVIGATIONAL CHARTS IN THE UNITED STATES

Rancocas River, NJ
Rappahannock River
Raritan River
Raritan River to Arthur Kill Cut Off Channel
Red Wing Commercial Harbor, MN
Redondo Beach
Redwood City Harbor
Rice Creek
Richardson Bay, CA
Richmond Harbor
Richmond's Island Harbor, ME
Roanoke River
Rochester (Charlotte) Harbor
Rock Hall Harbor, MD
Rockland Harbor
Rockport
Rogers City, MI
Rogue River, OR
Rollinson Channel
Rosedale, Ms
Rouge River, MI
Roundout Harbor, NY
Royal River
Rudee Inlet
Rye Harbor, MA
Sabine-Neches Waterway
Sackets Harbor
Saco River, ME
Sacramento River
Sag Harbor
Saginaw River
Sakonnet Harbor, RI
Salem Harbor
Salem River
San Bernard River
San Diego Harbor
San Francisco Bay
San Francisco Harbor
San Joaquin River
San Pablo Bay and Mare Island Strait
San Rafael Creek
Sandusky Harbor
Sandy Hook Bay
Sandy Hook Bay at Leonardo
Santa Barbara Harbor
Santa Cruz Harbor
Santee River
Sasanoa River, ME
Saugerties Harbor, NY
Savannah Harbor
Savannah River below Augusta
Scarboro River, ME
Schulykill River
Scituate Harbor, MA
Scuppernong River
Searsport Harbor
Seattle Harbor
Seekonk River
Seldovia Harbor
Sergius and Whitestone Narrows
Severn River
Seward Harbor
Shark River
Sheboygan Harbor

## ESTIMATED GROSS BENEFITS PROVIDED BY NAVIGATIONAL CHARTS IN THE UNITED STATES

Shinnecock Inlet
Shipyard River
Shoal Harbor and Compton Creek
Shrewsbury River
Silver Lake Harbor
Sitka Harbor
Siuslaw River
Skagit River
Skagway Harbor
Skamokawa (Steamboat) Slough
Skamokawa Creek
Skipanon Channel
Slaughter Creek
Smith River
Smiths Creek (Pamlico County)
Smiths Creek (Wilmington)
Smyrna River, DE
Snake River
South Haven Harbor
South River
Southeast Missouri Port, MO
Southport Harbor
Southwest Harbor
ST Augustine Harbor
ST Johns River FL Jacksonville to Lake Harney
ST Lucie Inlet
ST Marks River
St Marys River GA and FL
ST Petersburg Harbor
ST Thomas Harbor
St. Alban's Harbor, VT
St. Catherines Sound
St. Clair River
St. Croix River
ST. Croix River
St. James (Beaver Island)
St. Joseph River
St. Josephs Harbor
St. Marys River
Stamford Harbor
Stonington Harbor, CT
Stonington Harbor, ME
Straits of Mackinac
Stumpy Point Bay
Sturgeon Bay and Lake Michigan Ship Canal
Suisun Bay Channel
Suisun Channel
Susquehanna River
Swinomish Channel
Tacoma Harbor
Taconite Harbor
Tampa
Tangier Channel
Tangier Sound
Tar Bay
Tarrytown Harbor, NY
Tchefuncte and Bogue Falaya Rivers
Tenants Harbor
Tennessee River
Tenn-Tom Waterway
Tensas River and Bayou Macon
Texas City Channel
Thames River
Thimble Shoal Channel

**ESTIMATED GROSS BENEFITS PROVIDED BY NAVIGATIONAL CHARTS IN THE UNITED STATES**

Three Mile Creek
Tickfaw Natalbany Ponchatoula and Blood Rivers
Tillamook Bay, OR
Tolchester Channel
Toledo Harbor
Tom's River, NJ
Tonawanda Harbor
Town Creek, SC
Town River
Townsend Inlet, NJ
Traverse City Harbor
Tred Avon River
Trent River
Tributary Arroyo Colorado
Trinity River Channel to Liberty
Twitch Cove
Two Harbors (Agate Bay)
Tyler's Beach, VA
Umpqua River
Unalaska Island
Upper Chipola River Mouth to Mariana
Upper Cooper River, SC
Upper Machodoc Creek
Upper Mississippi River - MVP
Upper Mississippi River - MVS
Upper Mississippi River -MVR
Upper Thoroughfare, Deal Island, MD
Urbanna Creek, VA
Valdez Harbor
Vicksburg, MS
Vineyard Haven Harbor
Vinton Waterway
Virgin Islands
Waccamaw River
Wake Island Harbor
Wallabout Channel
Warren River
Warroad Harbor
Warwick Cove
Waterway connecting Pamlico Sound and Beaufort Harbor
Waterway Connecting Port Townsend Bay and Oak Bay
Waterway connecting Swan Quarter Bay with Deep Bay
Waterway from Empire to Gulf of Mexico
Waterway from Intracoastal Waterway to Bayou Dulac
Waterway from Little Choptank
Waterway Norfolk VA to Sounds of NC
Watson Bayou
Waycake Creek
Wells Harbor, ME
West Bay, Osterville, MA
Westchester Creek
Westport Harbor and Saugatuck River
Westport Harbor, MA
Westport River
Westport Slough
Weymouth Back River
Weymouth Fore River
White River below Batesville
Wickford Harbor
Wicomico River (Eastern Shore)
Wicomico River (Western Shore)
Willamette River above Portland and Yamhill River
Willapa River and Harbor
Willoughby Channel

## ESTIMATED GROSS BENEFITS PROVIDED BY NAVIGATIONAL CHARTS IN THE UNITED STATES

Yukon River
Wilmington Harbor
Wilmington Harbor
Winona Commercial Harbor, MN
Winthrop Harbor
Wishkaw River, WA
Witchmere Harbor, MA
Withlacoochee River
Wolf and Jordan Rivers
Wolf River
Wood Island Harbor, ME
Woods Hole Channel
Wrangell Harbor
Wrangell Narrows
Wrights Creek
WW Indian River to Rehoboth Bay
Yaquina Bay and Harbor
Yaquina River
Yazoo River
Yellow Bend Port, LA
York River
Youghiogheny River
Youngs Bay and Youngs River

## ESTIMATED GROSS BENEFITS PROVIDED BY NAVIGATIONAL CHARTS IN THE UNITED STATES

## I. CPT USAGE PROCEDURES

### A. Use of the "Rollup" and "Docked" Features

The CPT data is very complex and unless the researcher is extremely careful it is very likely that vessel cargoes will be doubly counted yielding erroneous results. To avoid this CPT provides two tools the "Rollup" and "Docked" options. The CPT "Rollup" feature is essential for evaluating dredging work packages that cover more than a single reach or channel. Using this powerful feature, consolidated statements of commerce can be generated for entire areas with many channels and reaches. The central concept underlying CPT is that the USACE portfolio of maintained navigation channels and waterways is an interconnected transportation system. That is, waterborne traffic utilizing any one portion of the system likely also transits other portions during the course of its journey. Likewise, the impacts to waterborne commerce from the physical condition (i.e. channel controlling depth) of any given navigation channel are not isolated within just that channel; they are realized system wide, in all other portions of the waterway network through which transiting tonnage also travels. It is only by utilizing the "Rollup" feature of CPT that the analysis can avoid counting the same vessel cargo multiple times.

The "Docked" feature is also required in calculating data for a port. Only cargo that was being offloaded or loaded aboard a vessel was counted for the port. Cargo that remained aboard a vessel bound for another port was not counted in determining the value of marine transportation for that port.

## B. Port Definition in the CPT System

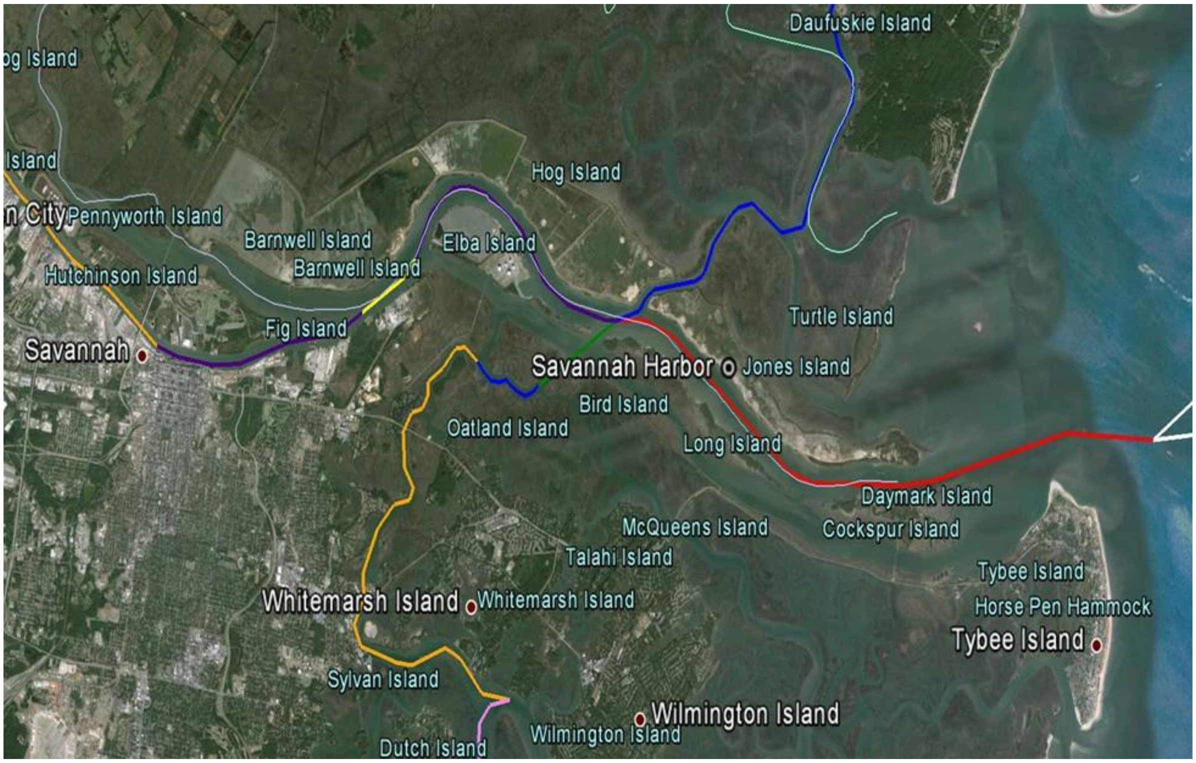
Calculating total system tonnage and value for ports using the CPT tools is not always straightforward. The Corps is interested in the use of channels and channel reaches in the USACE system. In some cases it is clear that one or a few channel reaches lead to a port so the sum of their activity can reasonably be considered the total activity for that port. Other ports are more complex and involve many channels and segments of channels. In other ports several ports lie in the same geographic area and the activity in the channel reaches have to be carefully separated to give accurate information at the port level. To assist the research effort, CPT offers a tool to export the selected projects, channels, and reaches to Google Earth so that the researcher can visually decide which channels to include in the analysis of the port. The definition of each of the ports is documented in the spreadsheet developed for this study.

### a. Example of a simple port

Figure G-1 illustrates The Port of Savannah that is defined as all the commercial traffic operating in this channel.

**Figure I-1**

**PORT OF SAVANNAH**




The Port of Savannah is defined as the shipping activity on the following channel reaches:

Savannah Harbor, GA (mile 00 to mile 10) 496900 (reach number)

Savannah Harbor, GA (mile 11 – 26) 497066

Savannah Harbor, GA (mile 11 – mile 26) 497033

Savannah River Below Augusta, GA (mile 26 – mile 203) 497120

Savannah River Below Augusta, GA (mile 26 – 2003) 497110

**b. Example of a complex port**

The Port of New York & New Jersey is defined as all the commercial traffic operating in these channels and reaches. (Refer to Figure G-2)

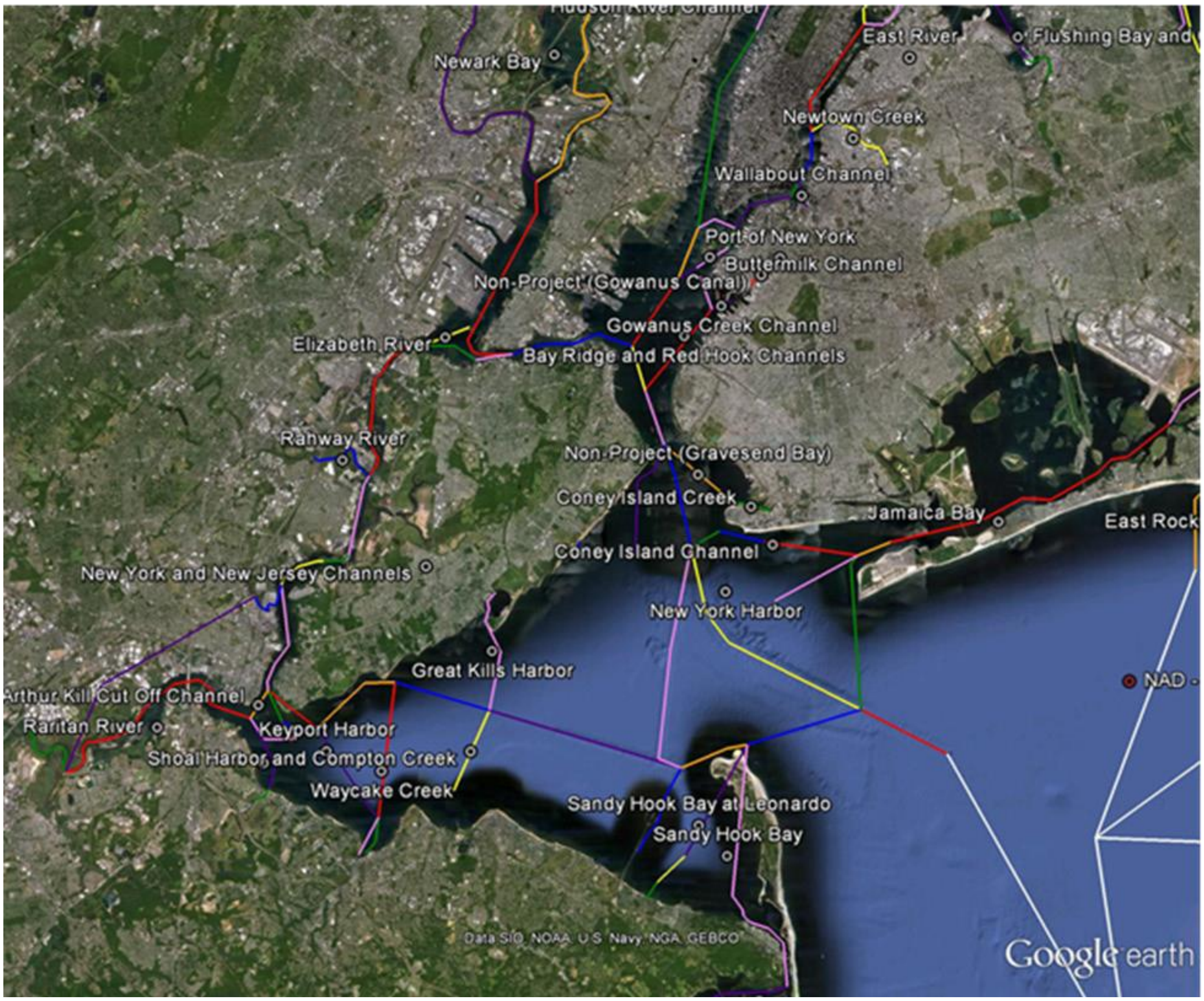
- Sandy Hook Bay
- Shrewsbury river
- Shoal Harbor and Compton Creek
- Raritan River
- New York and New Jersey Channels
- Newark Bay
- New York Harbor
- Jamaica Bay
- Bay Ridge & Redhook Channels
- Gowanus Creek Channel
- Buttermilk Channel
- East River
- Hudson River Channel
- Flushing Bay & Creek
- East Chester Creek

Each of the colored sections represents a separate channel reach. The port then is a collection of all the vessel activities and cargo carried on these reaches. The system looked at all data on vessels and cargoes involved in imports and exports to foreign nations, all coastwise vessel movements between U.S. ports via ocean routes, all internal movements via navigable rivers, as well as ferry movements.

In this study, The data for this study used only docked plus thru cargo, and only data that was first rolled up to avoid duplicate counting of cargoes.

**Figure I-2**

## PORT of NEW YORK and NEW JERSEY



# APPENDIX J

## MAPPING VALUE ADDED PROVIDERS

# CMORE - High-resolution seafloor maps for chart plotters.

**https://www.cmormapping.com/**


| CMOR Map Pak Simrad Go9 - 9" Display<br><br>$1,250.00 | CMOR Map Pak Simrad Go7 XSR - 7" Display<br><br>$850.00 |
|---|---|

## See It. Dive It. Fish It.

**CMOR Mapping's game-changing, high-resolution bathymetric imagery for Simrad, Lowrance, Raymarine, and Furuno chartplotters and Mercury VesselView displays brings the ocean floor into an entirely new level of focus for anglers and divers.**

## Complete Coverage

CMOR Mapping data comes from methodical surveys of the entire bottom with high-resolution echosounders — not point soundings and historical records.

## Unprecedented Detail

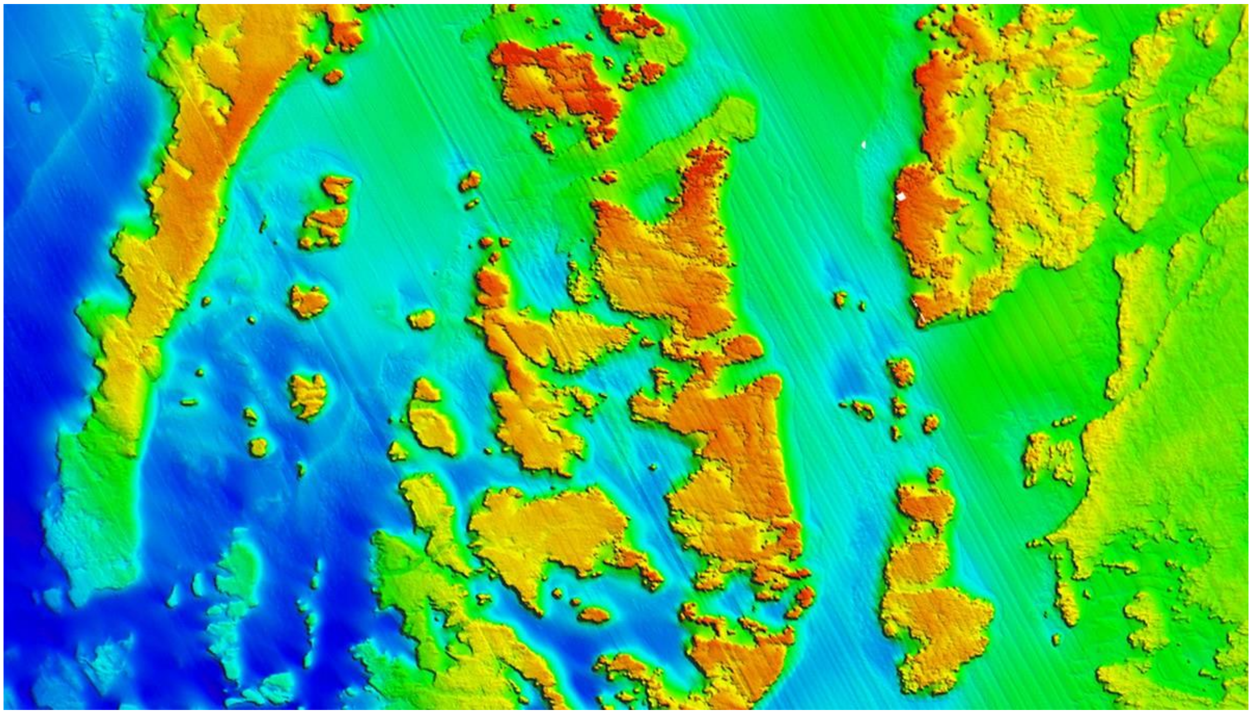
With resolution as high as 1 meter — meaning each pixel equals a square meter of bottom — we show you every ledge, coral head, and sunken culvert in unprecedented detail.

## Seamless Compatibility

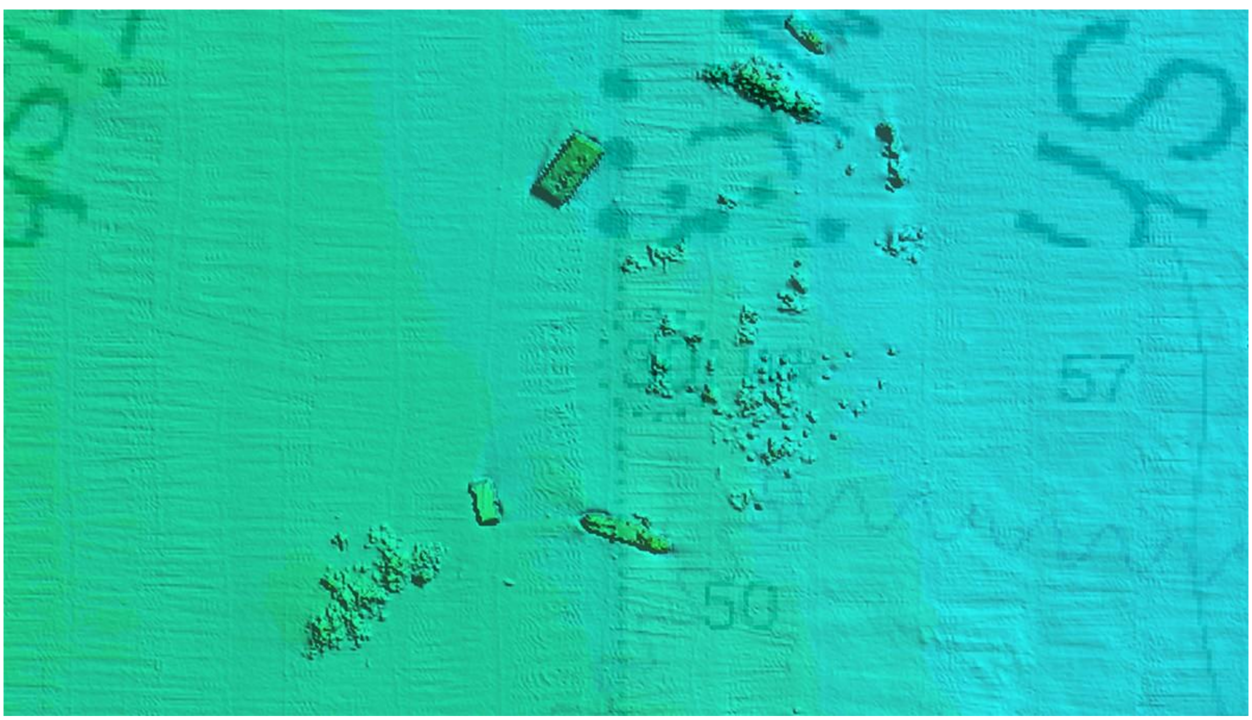
Just insert a CMOR Mapping card into your plotter and zoom in to see bathymetric imagery. Your vessel icon shows your exact location relative to bottom features.

## ESTIMATED GROSS BENEFITS PROVIDED BY NAVIGATIONAL CHARTS IN THE UNITED STATES

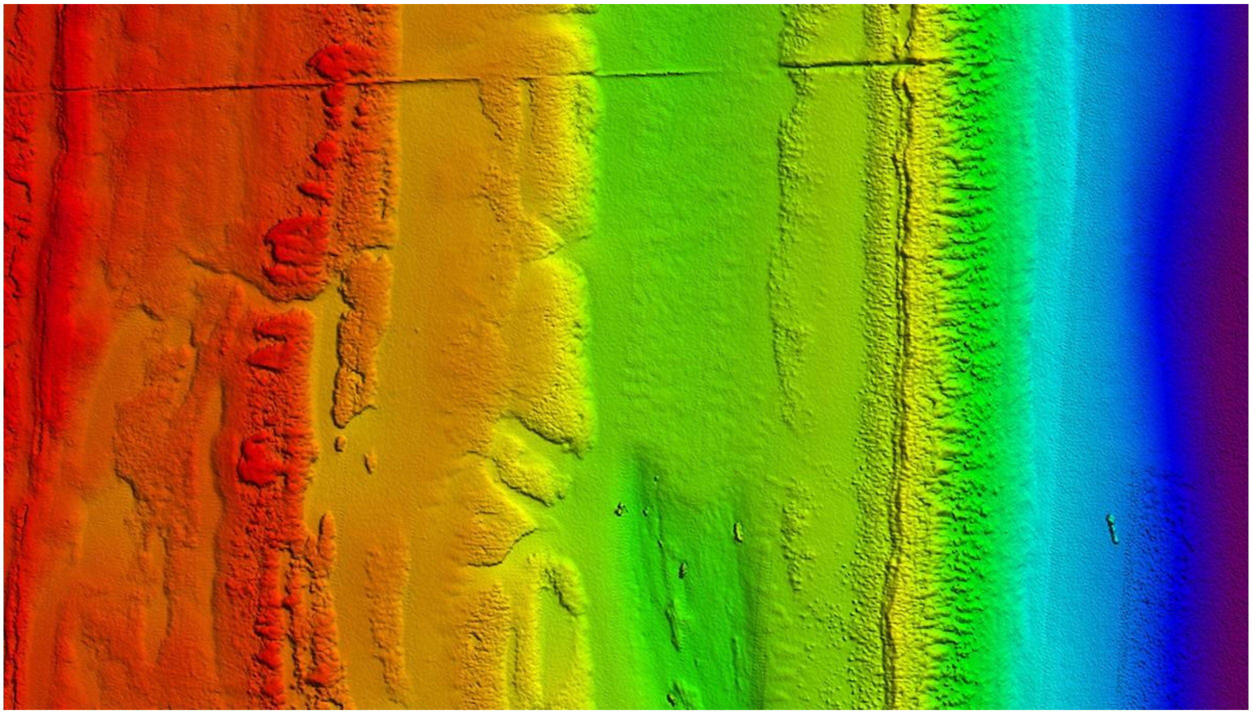

**CMORE Coverage**



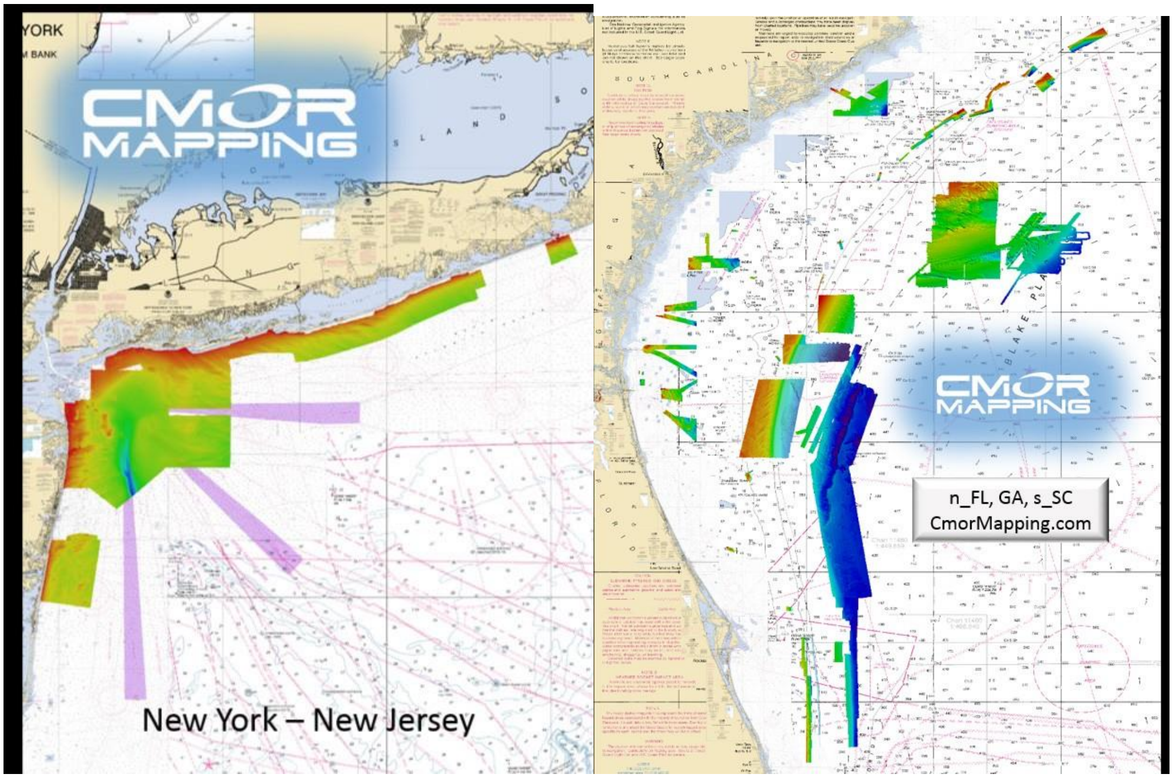
Extensive Reefs (Florida Middle Grounds CMOR Card)



Wrecks and Debris (Miami-Biscayne CMOR Card)



Wrecks and Outflow Pipe (Jensen Beach-N. Miami CMOR Card)




New York - New Jersey CMOR Card

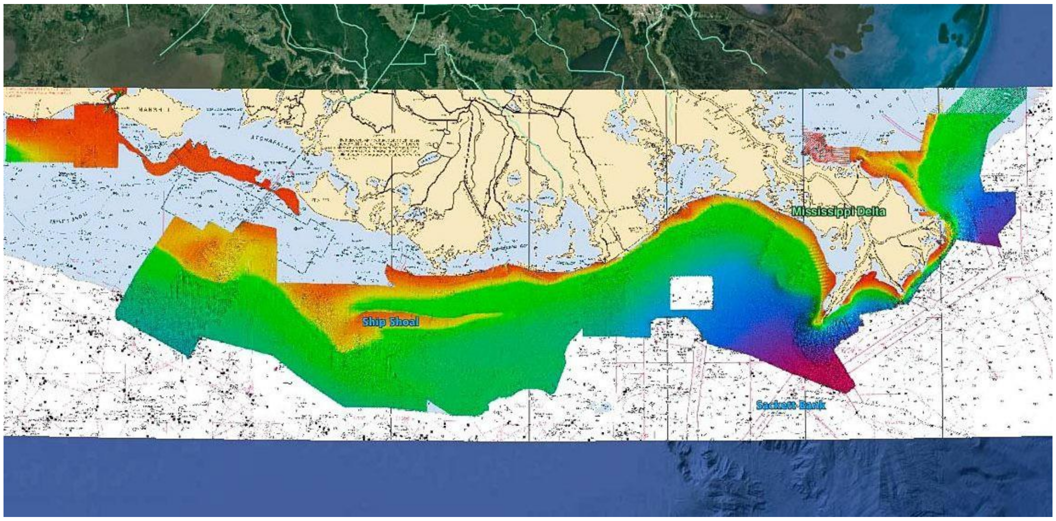
$700.00

North Florida, Georgia, and South Carolina CMOR Card

$700.00

## Strikelines

https://strikelines.com/3d-image-maps/




**3D Louisiana Nearshore**

$199 – $449

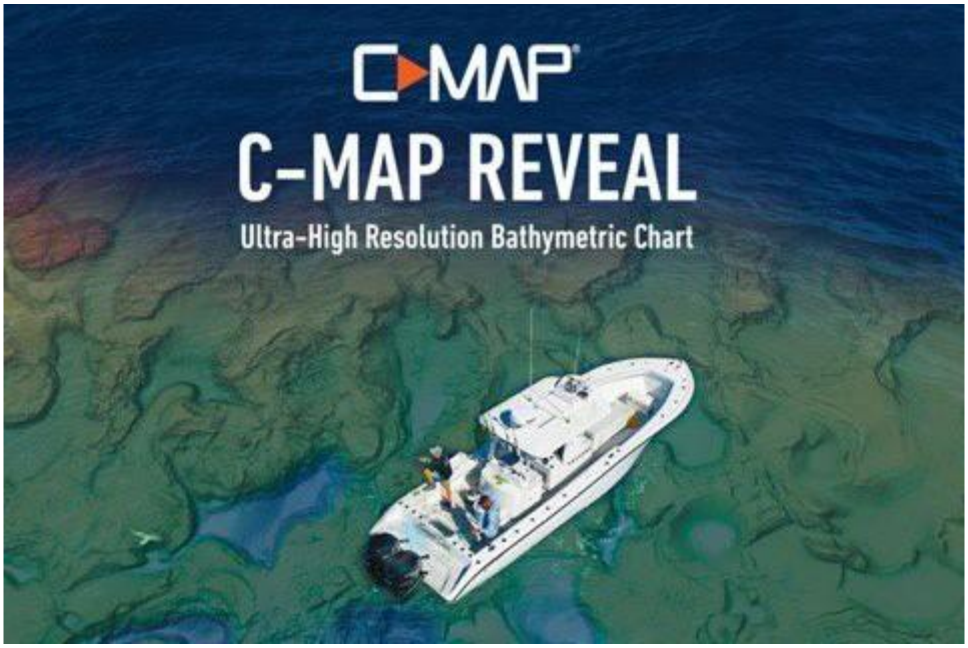
**Louisiana Nearshore fishing map 3D with high resolution images of the seafloor.**

****Preview map is LOW RESOLUTION. See gallery below for HD sample images****

- Description: **Louisiana Nearshore fishing map features high definition 3D images of the seafloor.**
- Location:**Louisiana Nearshore fishing chart 3D coverage includes 0-30 miles offshore the Louisiana coast, from New Iberia to the Chandeleur Islands.**
- Fishing Map Size:**4,500 square miles of potential fishing spots.**
- Depths: **Max Depth of 480 ft.**
- Works on: **Lowrance, Simrad, Raymarine, B&G, VesselView, iPhone, iPad, and Android tablet. Got a Garmin? Click here. (See: StrikeLines GPS Unit Compatibility Chart)**
- Resolution: **Varies depending on the quality of data available.**
- Notes: **With StrikeLines' HD view of the ocean floor you'll see exactly where those potential fishing spots are on the map. See where all the oil rigs, shipwrecks, massive natural cliffs, rock piles and other structures are in realtime on your GPS unit, mobile device, or computer.**

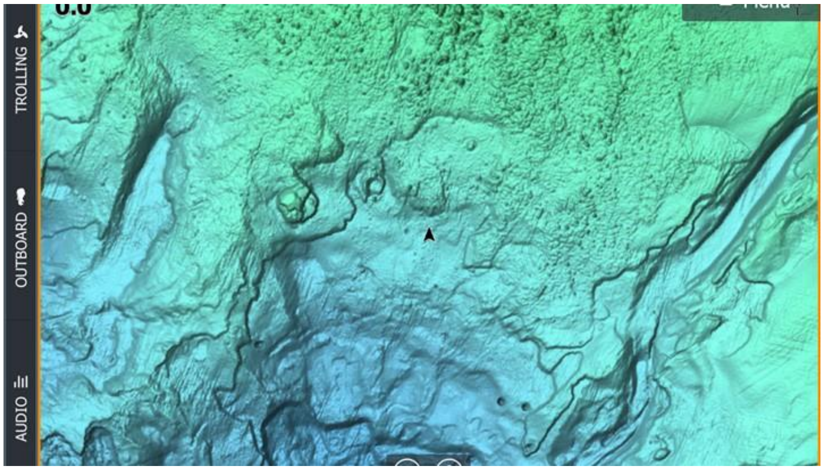
# C-Map Reveal

https://www.lowrance.com/lowrance/type/mapping/c-map/c-map-reveal/



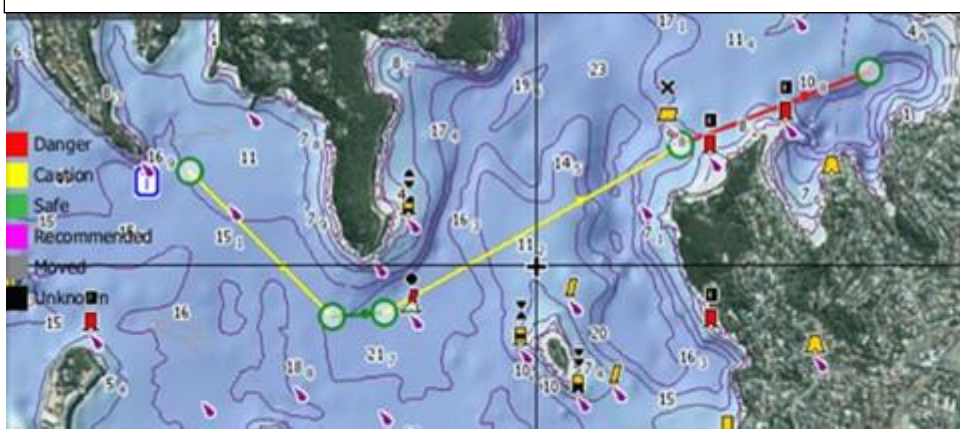

## Ultra-high resolution bathymetric imagery

Enter a new world of mapping with C-MAP Reveal. View the sea floor in a new light and clearly identify sea floor structure, along with reefs and ledges to find the best fishing and diving spots. C-MAP Reveal will take your charts to the next level.




**Shaded relief**

Attractive three-dimensional views of land elevation and bottom contours bring to life the world around your boat. Visualize underwater pinnacles and topographical

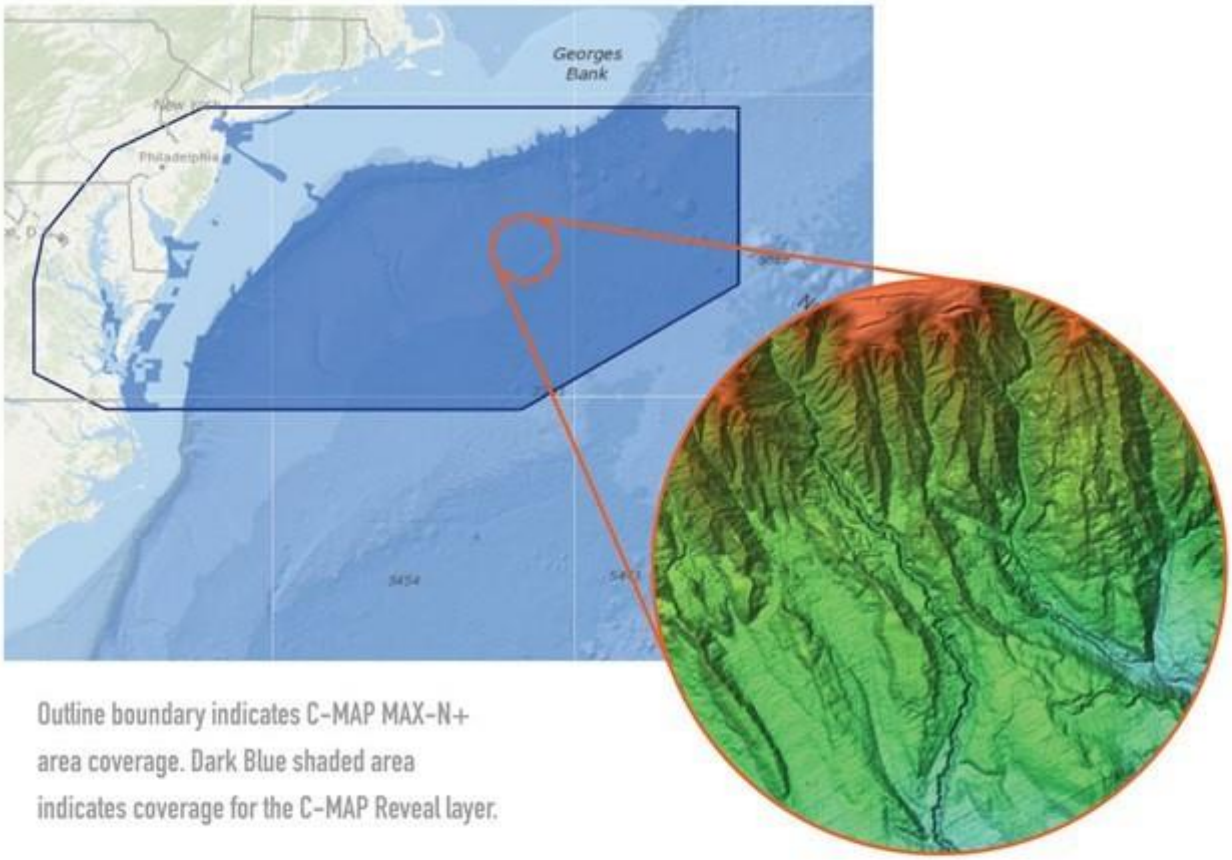



**Easy routing**

Make navigation easy, with C-MAP Easy routing. Automatically calculate a detailed suggested route between two points, taking into

**Harbor and port plans**

Every journey on the water starts and ends at a marina. C-MAP charts feature more detail on marinas than any other charting provider on the market, with more than 12,000 marinas in the database. Whether you are looking to identify an area to berth or




Outline boundary indicates C-MAP MAX-N+ area coverage. Dark Blue shaded area indicates coverage for the C-MAP Reveal layer.

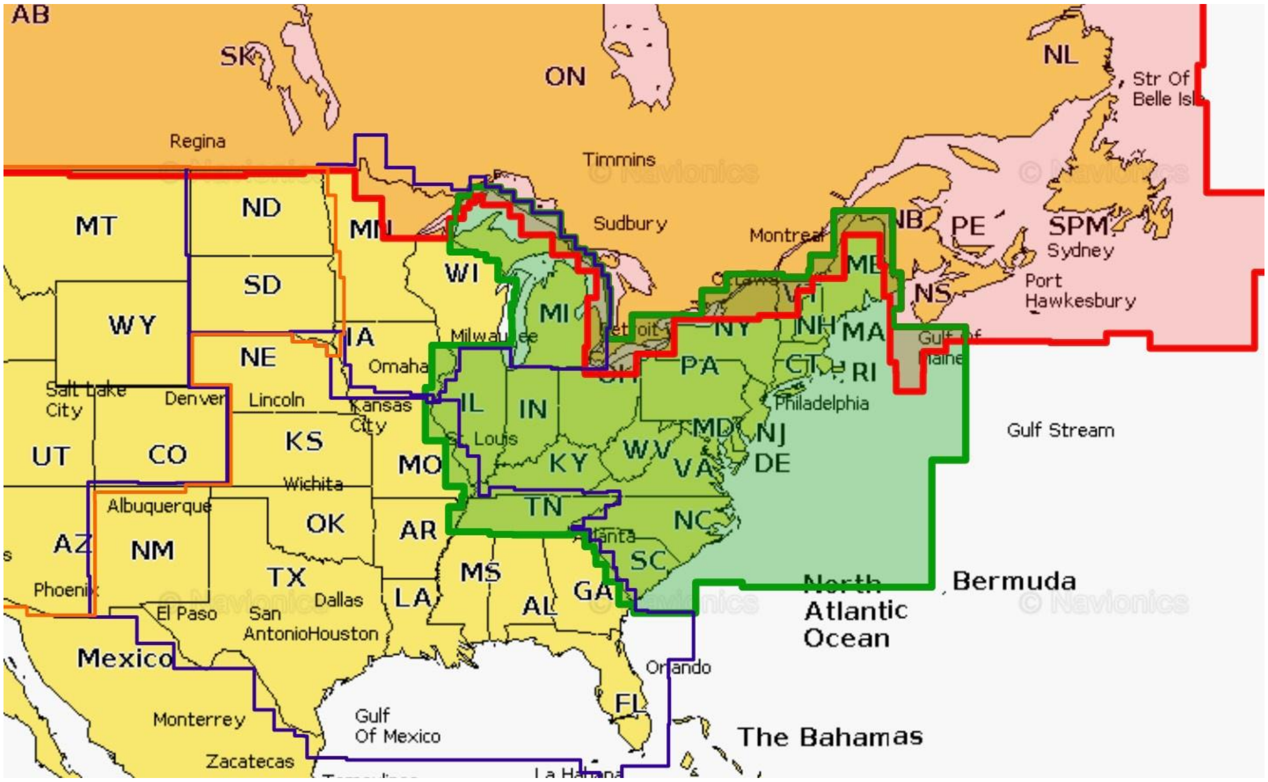
**C-MAP REVEAL: LONG ISLAND - NORFOLK AND CANYONS**

C-MAP® Reveal charts help anglers and divers save time on the water, finding key areas faster with the high-definition views of structure, wrecks and contour changes on the sea floor. The high-detail C-MAP® Reveal imagery replaces shaded relief data in selected areas with more accurate depth variations, revealing the best fishing and diving spots. C-MAP Reveal charts include C-MAP HRB Coastal Data, Genesis social map data and satellite imagery that can be overlaid on top of the standard vector charts used for navigation. The C-MAP Reveal layer is activated by turning on the Shaded Relief setting and is available for use on Lowrance®, Simrad® and B&G® chartplotters.

View Key Features

## Navionics

https://www.navionics.com/usa/charts/




| | Navionics+ | Platinum+ | HotMaps Platinum |
|---|---|---|---|
| Marine | • | • | |
| Lakes | • | | • |
| Nautical Chart | • | • | • |
| SonarChart™ | • | • | • |
| Community Edits | • | • | • |
| Daily Updates | • | • | • |
| Dock-to-dock Autorouting[1] | • | • | • |
| SonarChart™ Live | • | • | • |
| Advanced Map Options | • | • | • |

| | Navionics+ | Platinum+ | HotMaps Platinum |
|---|---|---|---|
| Plotter Sync | • | • | • |
| Satellite Overlay with SonarChart Shading | | • | • |
| Relief shading | | • | • |
| 3D View[2] | | • | • |
| Panoramic Photos | | • | • |

**Price $149.00**