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A Valuation Analysis of the Physical Oceanographic Real Time System (PORTS)

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The findings and conclusions of this study are those of the authors and do not necessarily represent the views of the National Oceanic and Atmospheric Administration.

Abstract
This analysis estimates several economic benefits derived from national implementation of the National Oceanic and Atmospheric Administration's Physical Oceanographic Real-Time System (PORTS®) at the 175 largest ports in the United States. Significant benefits were observed owing to: (1) lower commercial marine accident rates and resultant reductions in morbidity, mortality and property damage; (2) reduced pollution remediation costs; and, (3) increased productivity associated with operation of more fully loaded commercial vessels. Evidence also suggested additional benefits from heightened commercial and recreational fish catch and diminished recreational boating accidents. Annual gross benefits from 58 current PORTS® locations exceeded $217 million with an addition $83 million possible if installed at the largest remaining 117 ports in the United States. Over the ten-year economic life of PORTS® instruments, the present value for installation at all 175 ports could approach $2.5 billion.

1. INTRODUCTION

The National Ocean Service (NOS) is responsible for providing real-time oceanographic data and other navigation products to promote safe and efficient navigation within U.S. waters. The need for these products is great and rapidly increasing as maritime commerce has tripled in the last 50 years and continues to grow. Ships are getting larger, drawing more water and pushing channel depth limits to derive benefits from every last inch of draft. The Department of Commerce's US Trade Online recently reported that about 72 percent of U.S. international trade moves through the nation's ports and harbors, with a sizeable portion being hazardous materials. Although there are over 360 ports in the United States according to the United States Army Corps of Engineers' Channel Portfolio Tool (CPT), the largest 175 ports account for about 98 percent of all vessel trips.

A major challenge facing the nation is to improve the economic efficiency and competitiveness of U.S. maritime commerce, while reducing risks to life, property, and the coastal environment. With increased marine commerce comes increased risk to the coastal environment making marine navigation safety a serious national concern. From 1996 through 2010, for example, commercial vessels in the United States were involved in nearly 12,000 collisions, allisions, and groundings.

The NOAA Physical Oceanographic Real-Time System (PORTS®) is a collection of oceanographic and meteorological instruments integrated into a system to provide accurate, reliable, real-time, quality-controlled information about the environment in which commercial mariners and recreational personnel operate.[1]

This study was conducted for two purposes. First, while Kite-Powell (2005a, 2007, 2009, 2010) estimated gross benefits which might be obtained from four individual locations with PORTS®, no investigation had been conducted to develop an overall estimate for the 58 existing locations with ports or estimate benefits if PORTS® were to be installed at the175 dominate U.S. ports. Second, as the process for installing PORTS® originates by individual ports petitioning

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[1] PORTS® is managed by the Center for Operational Oceanographic Products and Services (CO-OPS) within NOAA's National Ocean Service (NOS)

the NOS, this study sought to provide port authorities without PORTS® estimates of the physical and monetary levels of benefits which might be enjoyed from such installations.

PORTS® is a decision support tool that seeks to improve the safety and efficiency of maritime commerce and coastal resource management through the integration of real-time environmental observations, forecasts and other geospatial information.

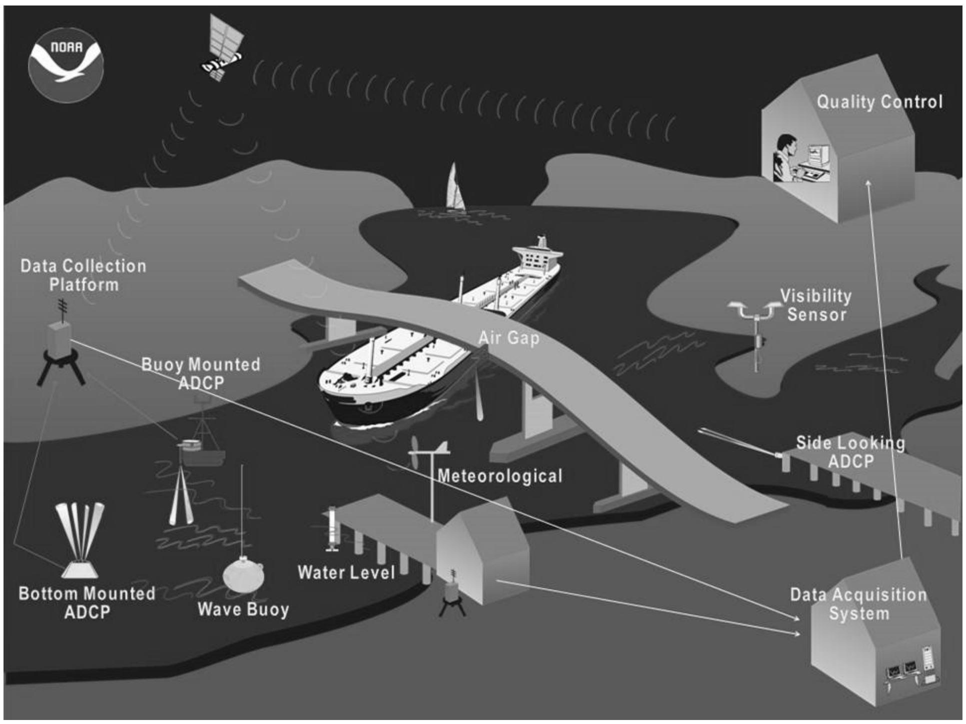

Figure 1. Data flows within PORTS®

Edwing (2013) related that PORTS® measures and disseminates observations and predictions of water levels, currents, salinity, and meteorological parameters (e.g., winds, atmospheric pressure, air and water temperatures) that mariners need to navigate safely. The system is designed to provide users with high quality information to support decision making (e.g., is there sufficient water for a ship to safely operate, can a ship safely transit under a bridge, are sea and weather conditions favorable to undertake a recreational boating trip, are conditions favorable for fishing near a port, etc.).

PORTS® provides information tailored to the specific needs of the local community and comes in a variety of sizes and configurations (Figure 1). As some ports are physically larger and more complex than others, they might require a greater of number of sensory instruments. The largest of NOS's existing PORTS® installations is comprised of over 50 separate instruments; the smallest consists of a single water-level gauge and associated meteorological instruments (e.g., measuring winds, barometric pressure, etc.). Regardless of port size, each PORTS® installation can provide information that allows mariners to maintain an adequate margin of safety for the increasingly large vessels visiting U.S. ports, while allowing port operators to maximize port throughput.

Gross benefits in this study were defined for the 58 ports that had access to PORTS® data in 2010 and expanded to include the next largest 117 ports that did not in order to identify the advantages PORTS® currently provide and could be generating.[2] The study was conducted in such a way as to be conservative in stating benefits, and well documented to enable readers to evaluate the gross benefits of PORTS® for themselves. A benefit-cost analysis was not undertaken owing to our inability to obtain costs from existing, let alone all future PORTS® participants as NOAA only sets standards for PORTS® sensors and related communication infrastructure. The local port partner determines how many sensors and where those sensors will be located and is responsible for purchase, installation and maintenance of its system.[3] Moreover, there is no way of knowing the number of sensors that the remaining 117 ports may desire at the time they install or potentially later modify a PORTS® system. Hence only gross benefits were estimated in this study.

[2] The 58 ports with PORTS® at the time of this analysis represented approximately 72 percent of all tonnage transported during 2010. The next largest 117 ports were selected owing to their traffic levels in 2010. In some cases, smaller ports in this second group did not report traffic in 2010 but were included as having had reported the largest levels of traffic during at least one year during the 2006 to 2010 period employed to identify port activity. Source: “Channel Portfolio Tool (CPT),” United States Army Corps of Engineers, https://www.cpt.usace.army.mil/cptweb/, accessed between March 2011 and July 2012.

[3] Sensory arrays at individual ports vary from a single sensor to over one hundred depending upon the size of the port. NOAA itself does not sell sensors. Individual ports acquire sensors from an approved list of vendors whose products meet or exceed NOAA specifications.

2. PREVIOUS RESEARCH

Beginning in 1995, a series of investigations were undertaken to assess the economic benefits derived from PORTS® (Kite-Powell 2005a, 2007, 2009, 2010). In his analysis of the ports of Tampa Bay, Houston/Galveston, New York/New Jersey and the Columbia River, Kite-Powell noted that economic benefit from PORTS® information arose from:

- Greater draft allowance/increased cargo capacity and decreased transit delays for commercial maritime transportation (water level information);
- Reduced risk of groundings/allisions for maritime traffic (currents and wind information);
- Enhanced recreational use of coastal waters boaters, windsurfers, etc. (winds, weather forecasts, and other information) and;
- Improved environmental/ecological planning and analysis, including hazardous material spill response (currents and wind information).

Kite-Powell (2005b) stated that most information-based products are valuable because they reduce the user's uncertainty about a factor that is important to the physical outcome (such as weather, waves, or water level). Another study performed by VOLPE (2009) estimated benefits from the same areas as the earlier Kite-Powell studies.

Based on an expansion of earlier work this study estimates collective benefits arising from near universal PORTS® installations and identifies a larger range of potential beneficiaries as well as provide estimations in both physical unit and monetary bases with a greater degree of granularity.

2.1 Value Estimation

Economic surplus, also referred to as social surplus, is the total value added by an activity or product enjoyed by those groups who are impacted by the activity or product. This includes both direct and indirect beneficiaries.[4]

[4] Traditionally, this refers to two related quantities: (1) consumer surplus – situations where consumers are able to purchase products as less than the price that they would be willing to pay; and, (2) producer surplus – situations where producers are willing to sell their products at levels higher than the least amount they would take.

Estimates of social surplus may be available through extensive surveying, but precise data to support an explicit model of how systems (e.g., PORTS® information) are used in economic decisions is currently lacking. In such cases, an order-of-magnitude estimate of potential value of PORTS® information may be obtained by applying a rule of thumb developed by Nordhaus (1986) and others. Kite-Powell (2007) states:

> "In other situations, estimates of social surplus may be available but data to support an explicit model of how PORTS® information is used in economic decisions are lacking. In such cases, an order-of-magnitude estimate of potential value of PORTS® data may be obtained by applying a rule of thumb developed by Nordhaus (1986) and others; the value of weather and climate forecasts to economic activities that are sensitive to weather/climate tends to be on the order of one percent of the economic activity in question."

Kite-Powell (2005a, 2005b, 2007, 2009, 2010) delineates several major groups of potential benefits which can result from the installation and use of PORTS® which include: (1) improvements in safe shipping and boating; (2) efficiency in marine operations; (3) improved environmental protection and planning; (4) enhanced recreational experiences; (5) improved weather forecasts; and, (6) additional support of academic, scientific and educational endeavors.

This report makes use of this Nordhaus tool making sure that there is at least anecdotal evidence, if not empirical evidence that the subject user group in fact uses PORTS® data and achieves some benefit. A *de minimis* value of one percent (1.0%) of total benefits is assigned to the use of PORTS® when there is an indication that the user achieves a significant benefit from the use of PORTS®.[5] A smaller value of one tenth of one percent (0.1%) is assigned to PORTS® when the benefit to the user is not considered as great but is still of some importance. In all cases it is believed that the *de minimis* value used (1.0 or 0.1 percent) represents a significantly lower value than what would be calculated if the supporting data were available. In the absence of directly supporting economic data it is

[5] For example, if the total benefit in one area (e.g. reduction of pollution remediation costs) was $10 million in areas served by PORTS® this study assumed that only one percent ($100,000) was due to PORTS® information.

preferable that some attempt, even if imperfect, be used to estimate the benefit to a user group rather than just ignoring the benefit for lack of conclusive data.

Kite-Powell concluded in studies from four ports total benefits ranged from $45 to $51 million when restated in 2010 dollars. Collectively, these four ports handled almost 27.5 percent of all vessel movements between 2005 and 2010. When expanded to the top 175 ports in the United States based on tonnage, total benefits are estimated to range from $215 to $240 million in 2010 dollars. The 2009 VOLPE study suggested annual PORTS® benefits from the same sources at $182 million (when restated in 2010 dollars.)

3. DATA EMPLOYED

Data from several government departments were employed including the: (1) United States Army Corps of Engineers (USACE); (2) United States Coast Guard (USCG); (3)United States Department of Transportation (DOT); (4) Environmental Protection Agency (EPA); (5) United States Department of Labor; (6) United States Nuclear Regulatory Commission (USNRC); the (7) United States Department of Commerce (DOC) along with its agencies the National Oceanic & Atmospheric Administration (NOAA) and United States Census Bureau (UCB) and; (8) the Office of Management and Budget (OMB)

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3.1 Channel Portfolio Tool

Critical to this investigation of PORTS® value is the proprietary Channel Portfolio Tool (CPT) developed by Dr. Ken Mitchell at the U.S. Army Corps of Engineers.[6] The CPT is a method to transform raw data involving water transportation into unique tabular and graphic representations of activity. With data on channel depth, commodity transported, vessel depth, cargo value, cargo weight, cargo type (container versus bulk), ship type and ship direction, it is possible to review actual movements and how those movements might be at risk

[6] Proprietary in the sense that access to the CPT requires prospective users to consult with USACE officials involving the type of research and planned usage of its data. Once approved, users are required to sign a confidentiality agreement with the USACE to ensure that sensitive data is not released to the public. This agreement must be updated on an annual basis.

owing to channel and other navigational constraints. Central to the value of the CPT is its ability to uniquely assess traffic by river or channel segment and provide summary origin or destination data without double counting vessel passings, tonnages or values of cargo.

3.2 Accident Data

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.[7] The data reflect information collected by the Coast Guard concerning vessel and waterfront facility accidents and marine pollution incidents throughout the United States and its territories. In December 2001, the USCG transitioned from the Marine Safety Information System (MSIS) to the Marine Information for Safety and Law Enforcement (MISLE) information system, which is employed in this study to assess both commercial and recreational boating accidents.

Using a geographic information system (ArcGIS), the operational area for each of the 58 locations with a PORTS® sensory array was identified using a "lasso" technique in which industry experts reviewed port maps and identified the effective coverage area for each port.[8] Accidents within that "lassoed" area were assigned to the respective port. A similar effort was undertaken for the largest 117 ports without PORTS®. Here again estimates of the sensory areas which might be covered if PORTS® were installed in the future were made by industry experts.

Accident data from the USCG's annual Recreational Boating Statistics (RBS) and estimates on recreational boating use from the National Marine Manufacturer's Association's annual reports were also employed to assess the benefits of PORTS® on recreational boaters.

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[7] Marine casualty reporting requirements are in 46 CFR 4.03, but the rule exempts recreational vessels covered under 33 CFR 1783.51. 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.

[8] The lasso technique describes the method of manually drawing polygons which encapsulate the geographic areas that were thought by NOAA experts to be influenced and benefited from PORTS® information.

3.3 Value of a Life

In assessing the potential benefits associated with reductions in mortality resulting from fewer groundings, allisions and collisions, the value of a life must be assigned. At a 2012 United States Nuclear Regulatory Commission (USNRC) workshop several Federal agencies delineated their methodologies to value lives. When adjusted to 2010 dollars, the value of a life across agencies ranged from $4.3 at the USNRC's Headquarters and National Nuclear Security Agency (NNSA) to $8.2 million at the Food and Drug Administration's (FDA) Food Safety Inspection Service (FSIS). Given the transportation-related nature of the deaths that could be reduced through timely accurate and complete use of real-time port data, the Department of Homeland Security's USCG's figure of $6.3 million and the U.S. Department of Transportation's (DOT) figure of $6.2 million were further considered.[9] In keeping with the overall conservative nature of this valuation study, the more moderate $6.1 million (2010) dollar DOT figure was employed.

3.4 Value of an Injury

The National Highway Transportation Safety Administration (NHTSA) has calculated the comprehensive accident costs through the "Maximum Abbreviated Injury Scale" (MAIS). (U.S. DOT 2008) Although the MAIS identifies several categories of injuries, neither the MAIS nor the USCG's Marine Information for Safety and Law Enforcement (MISLE) database identities the cost of injuries by level of severity.[10] Absent such data a normal distribution was assumed in this analysis. This assumption resulted in an average injury cost of cost of $0.6 million (based on a $6.1 million value of a life) (refer to Table 1).

3.5 National Navigation Operation and Maintenance Performance Evaluation and Assessment System (NNOMPEAS)

NNOMPEAS is the USACE tool for estimating marine transportation costs and performing economic analyses on waterway projects. (Mathis 2002, 2007) It is

[9] The Department of Transportation's figure was $6.2 million (2011 dollars). It was adjusted to 2010 dollars ($6.1 million)

[10] The MISLE database stores pollution releases as well as marine accidents.

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the standard source for all marine transportation cost data and is employed as the basis for considering the benefits of proposed USACE projects. The data is constructed from a large number of variables (e.g. vessel length, beam, draft, engine horsepower, crew size, distance traveled, cost of fuel, engine fuel efficiency, diameter of the propeller, etc.) all of which affects the costs of operating the vessel. It does not include profit margin, market pricing decisions, competitive pricing strategies, etc.

Table 1. MAIS Values for Societal Willingness to Pay to Avert Injuries (USDoT, 2008)

MAIS scale for level of severity	Injury severity	Fraction of the WTP value of an averted fatality	Estimated distribution of injuries (percent of total)	Estimated weighted average of injury costs
MAIS 1	Minor	0.0020	5 %	$ 610
MAIS 2	Moderate	0.0155	12 %	$ 11,346
MAIS 3	Serious	0.0575	66 %	$ 231,495
MAIS 4	Severe	0.1875	12%	$ 137,250
MAIS 5	Critical	0.7625	5 %	$ 232,563
				Total: $613,264
MAIS 6	Fatal	1.0000	Not Applicable	

Actual transportation costs are highly sensitive and not shared by marine transportation companies for competitive reasons. The best that can be done is the very detailed NNOMPEAS model. This gives the USACE a stable platform upon which to make cost comparisons across multiple years without having to consider the market competitive elements of rates.

3.6 Discount Rate

Since the inception of PORTS®, it has been observed that the economic life of a PORTS® system is ten years after which it is more economical to replace the equipment than repair it. In order to assess the present value of benefits provided over the ten-year life of PORTS® equipment, the discount rate (3.9 percent) established for ten year investments by the Office of Management and Budget (2009) was employed in this study.

4. BENEFIT VALUATION ESTIMATES

In keeping with the nature of PORTS® and the data it provides that could help prevent or lessen the impact of accidents only instances that specifically identified the accident as an: (1) allision; (2) collision and; (3) grounding were retained for observation where:

- Allisions are collisions between ships and fixed facilities (e.g., docks, bridge, etc.);
- Collisions are instances that result from a ship crashing into a floating object (e.g., ship to ship, ship to floating object) and;
- Groundings involve instances where the ship impacts the seabed or channel / waterway side.

While no empirical evidence is available to precisely estimate the gross benefits from reduction or elimination of PORTS® information, following an overall PORTS® logic model, it is highly probable that the following would result if PORTS® did not exist or were reduced in scope:

- An increase in the number of collisions, allisions and groundings could occur;
- Limitations on the distance between the vessel's keel and channel bottom (referred to as Depth Under Keel (DUK)) might result in an increased number of vessel trips necessary to handle current levels of marine traffic and in turn give rise to an increased number groundings, allisions and collisions;
- Increased vessel transits might result in enhanced mortality and morbidity as a result of additional opportunities for groundings, allisions and collisions;
- Increased instances of oil pollution could result as well as reduced capacity to remediate such occurrences on a timely, accurate and complete level;
- Commercial and recreational fish catch might either be less or schools costlier and difficult to locate without information regarding local environmental conditions and;
- Recreational boaters might experience more accidents and resultant higher rates of mortality and morbidity.

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5. DOMINANT BENEFICIARIES OF PORTS® DATA

The benefit of PORTS® to marine transportation occurs from both the aspects of efficiency and safety. Efficiency benefits come principally from the ability of a cargo vessel to more fully utilize the available water depth to carry the maximum amount of cargo without running aground. The more cargo carried per trip the less the transportation costs per ton. Safety benefits result from reductions in accidents (collisions, allisions and groundings) that can produce injuries and deaths among both members of the ship's crew and bystanders in proximity to the vessel.

5.1 Depth-Under-Keel (DUK) Minimization

Understanding the exact depth of water under the deepest part of the vessel is essential to planning cargo loading and executing a safe passage. New vessel design and construction has followed a trend for years of increasing length, width, depth and height. Larger vessels can generally be made and operated more efficiently with lower transportation costs. This is illustrated in the overall increase in average vessel size, which rose from 47,625 Dead Weight Tons (DWT) in 2002 to 53,593 DWT in 2010 – a 12.5 percent increase.[11]

With the opening of the expanded Panama Canal in 2016 container ships are forecast to get even larger.[12] Today post-Panamax ships alone make up only 16 percent of the world's container fleet but carry 45 percent of the cargo. The next generation of ships will require deeper drafts and costlier dredging to maintain coastal entrance channels to insure safe navigation. DUK is the required minimum distance between the ship's keel and the bottom of the channel. The DUK is a function of the ship size and hydrodynamic characteristics, the channel cross-section and shape, and the ship speed. Since every foot of dredging can cost millions of dollars, considerable savings can be realized if the vessel can be fully loaded while maintaining a safe DUK. Sollosi (2013) reports while the USCG does not regulate DUK because it is such a political issue in ports, some ports

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[11] Changes in containership size were even larger growing from 42,158 DWT to 51,263 – a 22 percent increase during the same time frame.

[12] At the current time the maximum size ship that can transverse the Canal range is less than 4,500 TEUs. The new Panamax ships accommodated by the expanded Canal are expected to handle up to 13,000 TEUs. http://micanaldepanama.com/ expansion, downloaded July 22, 2015.

define a recommended minimum DUK and state it in their Harbor Safety Plans. Due to budget constraints the Port of New York and New Jersey had considered cessation of their funding of the existing PORTS® system effective March 31, 2013. In response to this potential loss of real time navigational data the USCG (2013) stated:

> "The Harbor Safety, Navigation and Operations Committee currently recommends that mariners maintain at least two feet under keel at all times, except for transits within Ambrose Channel where three feet under keel clearance is recommended due to wave and sea action. In addition, mariners are advised to maintain an air gap clearance of two feet while traveling under the bridges within the port. When a PORTS water level or air gap sensor becomes unavailable, the existing guidance will immediately increase to four feet under keel clearance, with five feet under keel in the Ambrose Channel, and four feet air draft clearance in the vicinity of that sensor."

As a result of the USCG proposal, a DUK of four feet was selected for this analysis based on a combination of written guidelines by several port authorities. In addition, an informal survey of marine pilots also revealed a consensus opinion when compared with other DUK alternatives that four feet was a critical threshold in vessel operations.[13] While there is a great deal of economic data available for the analysis of the benefit of PORTS® to commercial shipping it is essential that there be some effort to ground truth the results with knowledgeable users of PORTS® information. Pilots represent that pinnacle of expert user thoroughly knowledgeable about conditions in a port area. They are responsible for moving large commercial vessels safely through the most treacherous waters of a ships journey - the port. Pilots typically convey large ships from 400 to well over 1,000 feet in length through narrow channels barely deeper than the ship's draft over

[13] Given resource restrictions a detailed statistical survey of port pilots was not undertaken at this time. Instead, five port pilots representing large pilotage areas on the east and gulf coasts were interviewed as to their valuation and use of PORTS® data and other navigational aids (e.g., radar, electronic navigational charts, communication with other vessels, AIS information, buoys, etc.) in a variety of operational conditions (e.g., weather, draft constrained, special issues, etc.) Port pilots reported that vessel operations became additionally difficult and the need for real time information more critical with DUKs under four feet.

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hung by bridges that are barely higher than the ships. This coupled with the challenges from heavy vessel traffic, periods of reduced visibility; low bridges, high winds and strong currents make the movement of these large ships the job for only the most highly skilled mariners. Kemmerly (2013) was representative of comments made by pilots when he stated, "I can't image doing my job without PORTS®"

According to CPT data, almost 18 percent of total waterborne tonnage and 14 percent of cargo value is transported in vessels with DUKs of four or fewer feet.[14] (Refer to Figure 2) If DUK was restricted to four feet, a larger number of vessel trips employing smaller or more lightly loaded ones would be needed to transport the same volume of cargo.

Employing NNOMPEAS data and surveys of a number of major ports for both Great Lakes and coastal ports, added costs to transport the same volume of materials were estimated. These costs included fees for the following: (1) arrival tug, pilotage and stevedore line handling; (2) dockage; (3) fresh water; and, (4) administrative overhead. Total added port fees per round trip were calculated to be over $27,000 for coastal ports and $7,300 for Great Lakes shipments.[15]

Uses of vessels with lower DWTs were calculated to result in the required use of more than 2,000 addition vessel trips to transport the same volume of cargo. Employing USACE's NNOPMEAS costing model, coupled with added port costs it was estimated that the current 58 PORTS® installations annually saved almost $120 million through reduction in vessel trips resulting from more fully loaded vessels with DUKs of less than 4 feet. Expansion to the next largest 117 port locations could add $41 million in additional savings through reduction in the number of vessel trips.

[14] All benefit calculations were based on the number of vessel passings within 4 feet DUK – some 18 percent of total passings. The overall conservative nature of this analysis is reflected in the statements of interviewed port pilots who believed that PORTS® data was necessary in 70 percent of their transits.

[15] These operational costs were obtained from conversations with several ports on the east, gulf and west coasts as well as several the Great Lakes ports.

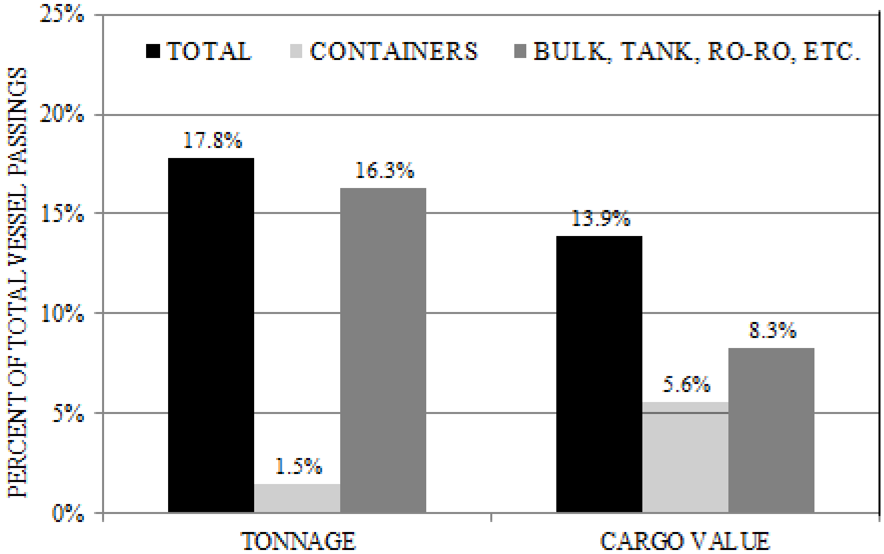

Figure 2. Vessel transits with depth under keel of four feet or less, determined using Channel Portfolio Tool (US Army Corps of Engineers, 2010).

The disproportionate amount of estimated benefits from the existing 58 port installations reflect their dominance as they already handled the majority of deep-sea traffic (e.g., approximately 73 percent of all vessel trips, 72 percent of total tonnage and 77 percent of cargo value transported through U.S. ports in 2010). Refer to Figure 3.

Over the ten-year study period, a total of $979 million was estimated to have been saved from the existing 58 ports with PORTS® while an additional savings of $333 million could be enjoyed through expansion of PORTS® to an additional 117 locations.

5.2 Commercial Traffic Delay

Information that can improve the overall speed of the vessel or reduce its delay can significantly add monetary benefits to marine transportation. While issues related to groundings, allisions, collisions and depth under keel requirements no doubt represent the major source of such cost-savings from avoidance of delays due to lack of data regarding wind, current and air gaps can make significant contributions toward increased marine transportation efficiency.

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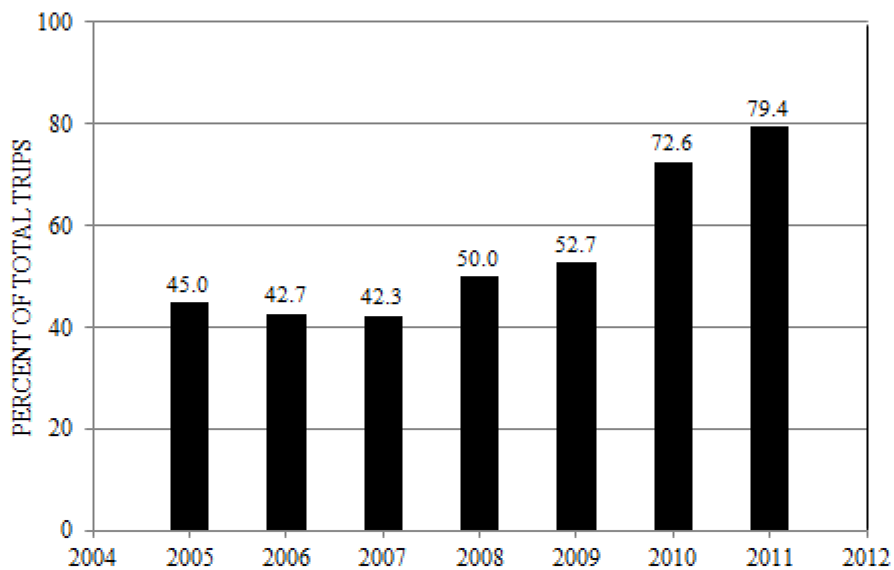

Figure 3. Locations with PORTS® handle most commercial vessel trips—excluding Great Lakes traffic (USACE Channel Portfolio Tool).

Kite-Powell (2009), calculated that if delays occurred in only three percent of ship passings by 90 minutes (given an average operating cost of $2,000/hour) about $1.4 million per year in cost savings could occur. Based on the empirical evidence provided by Kite-Powell across several of his studies which included an array of different kinds of ports with differing characteristics (e.g., channel depth, width, prevailing winds and currents, etc.) his analysis suggested that PORTS® had an impact on about 2.5 percent of all vessel transits.

The USACE's CPT data reported that in 2010 a total of 1.67 million vessel transits occurred where one of the 58 physical ports with PORTS® has been installed with an additional 0.62 million vessel transits located at one of 117 ports without PORTS®. Employing the overall weighted average of 2.5 percent, it is anticipated that more than 42,000 vessel transits are currently aided by PORTS® with the potential to aid an additional 16,000 vessel transits if PORTS® were installed at the 117 locations currently without them.

Recent estimations of costs per hour for container ships at sea underway by the USACE's NNOMPEAS model ranged from about $2,100 to over $3,300 for the sizes of ships which frequently call at ports in the United States. Kite-Powell

(2009) stated that containerships were among the most directly impacted by DUK restrictions.

Employing a conservative figure for operating costs at sea of $1,800 per hour from the USACE for a Panamax containership carrying 5,000 TEUs, benefits from PORTS® were calculated to approach $76 million if each ship's trip was accelerated by only one hour.[16] An additional $29 million could be saved if PORTS® were installed at the remaining 117 locations based on the same assumptions. Over the ten-year life of equipment, benefits from the existing 58 locations with PORTS® was almost $625 million while expansion to an additional 117 ports could add an additional $236 million.

5.3 Oil Pollution Remediation

The National Oil and Hazardous Substances Pollution Contingency Plan, more commonly called the National Contingency Plan or NCP, is the federal government's blueprint for responding to both oil spills and hazardous substance releases. The 1968 NCP provided the first comprehensive system of accident reporting, spill containment, and cleanup, and established a response headquarters, a national reaction team, and regional reaction teams (precursors to the current National Response Team[17] and Regional Response Teams).

[16] The twenty-foot equivalent unit (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 intermodal container, a standard-sized metal box which can be easily transferred between different modes of transportation, such as ships, trains and trucks. There is a lack of standardization in regard to height, ranging between 4 feet 3 inches and 9 feet 6 inches with the most common height being 8 feet 6 inches (2.59 m). Also, it is common to designate 45-foot containers as 2 TEU, rather than 2.25 TEU. Source: Intermodal Association of North America (IANA)

[17] Response planning and coordination is accomplished at the federal level through the U.S. National Response Team (NRT), an interagency group co-chaired by the Environmental Protection Agency and the USCG. Although the NRT does not respond directly to incidents, it is responsible for three major activities related to managing responses: (1) distributing information; (2) planning for emergencies; and (3) training for emergencies. The NRT also supports the Regional Response Teams. Members include: (1) The U.S. Coast Guard (USCG); (2) Federal Emergency Management Agency (FEMA); (3) Department of Defense (DOT); (4) U.S. Department of Agriculture (USDA); (5) Department of Commerce's (DOC) National Oceanic and Atmospheric Administration

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The Department of Commerce (DOC), through the National Oceanic and Atmospheric Administration (NOAA), provides scientific support for resources and contingency planning in coastal and marine areas including hazard assessment and spill trajectory (direction) monitoring to predict movement and dispersion of oil and other hazardous substances. NOAA contributes information about sensitive coastal environments, and furnishes data about actual and predicted meteorological, hydrological, ice, and oceanographic conditions. NOAA also serves as the natural resource trustee for the living marine resources it manages and protects. Additional regulation requires that even *de minimis* amounts of oil released into the environment must be reported. Under the legal authority of the Clean Water Act, the Discharge of Oil regulation, more commonly known as the "sheen rule", provides the framework for determining if an oil spill to inland and/or coastal waters and their adjoining shorelines should be reported to federal regulatory authorities. The regulation requires the person in charge of a facility or vessel responsible for discharging oil to report the spill to the federal government and establishes the criteria for determining whether an oil spill may be harmful to public health or welfare, thereby triggering the reporting requirements, as follows:

- Discharges that cause a sheen or discoloration on the surface of a body of water;
- Discharges that violate applicable water quality standards and;
- Discharges that cause a sludge or emulsion to be deposited beneath the surface of the water or on adjoining shorelines.[18]

NOAA's Office of Response and Restoration (OR&R) uses real-time information on winds, currents, visibility, water levels, waves, salinity when responding to spill events whenever they can get access to the data. Payton (2013) stated that it (PORTS®) helps OR&R in the containment and cleanup as well as planning for the restoration efforts based on information involving tides, currents

(NOAA); (6) Department of Health and Human Services (HHS); (7) Department of Interior (DOI); (8) Department of Justice (DOJ); (9) Department of Labor (DOL); (10) Department of Transportation (DOT); (11) Nuclear Regulatory Commission (NRC); (12) Department of State; (13) General Services Administration and; the (14) Treasury Department.

[18] Because the Oil Pollution Act of 1990, which amended the Clean Water Act, broadly defines the term "oil," the sheen rule applies to both petroleum and non-petroleum oils (e.g., vegetable oil).

and temperature it can provide. In instances where PORTS® installations do not exist in the event of a spill, temporary sensing instruments can be installed. NOAA responds to about 100 of the largest events annually while the USCG responds to about 10,000 events of all sizes annually.

Given the potential environmental impact which can result from the release of petroleum, the prospective value of PORTS® can be much larger than for shipments of non-hazardous or non-environmentally sensitive materials. An example of the value of such an accident avoidance related to grounding was delineated by the United States Coast Guard (USCG) in 1993:

> ".... in 1993, a 634 foot tanker, *Potomac Trader*, while maneuvering in the New York harbor using "predicted Tides Tables" ran aground in Hells Gate. Had the tanker had access to a real-time NOAA PORTS®, this near-disaster could have been averted. The vessel master would have obtained information about an abnormally large tidal range that caused the actual tide to be 3 feet lower than the predicted tide. Fortunately, the vessel was a double-hull tanker and none of its cargo of over 7 million gallons of crude oil spilled."

Accidents tend to be rare and random events. Consequently, analysis of any one year or short period of time could lead to erroneous conclusions based on such random occurrences. Use of a longer time period can help eliminate year-to-year variations and reveal more accurate long-term trends.

Pollution data was obtained from three files within the MISLE system. This included pollution from vessels, fixed facilities and other sources.[19] Analysis was based on data from 2002 to 2011. While the largest number of total pollution releases (about 54 percent) involved amounts of one or less gallons, in keeping with the conservative nature of this investigation and considering that relatively little remedial action may be taken in these instances, they were removed from future calculations.[20] Overall, these small releases of less than one gallon

[19] Other sources included instances of land origination (e.g., vehicles driven into the water, runoff from oil storage facilities, leaking dockside containers, etc.) as well as sources of unknown origin (e.g., floating oil drums.)

[20] Before estimating the potential benefit from the provision of data involving currents and tides from PORTS® the size of the spill was considered a factor. As even *de minimis* oil spills of less than one gallon can initially appear innocuous, it takes only one gallon of oil

accounted for only 13 percent of the total gallonage spilled. The vast majority of incidents (almost 96 percent) involved release of petroleum products. However, given several large chemical releases in recent years, the proportion of total gallonage released was 52.3 percent petroleum-based with chemicals representing 47.3 percent of the total. Garbage and unknown sources represent the remaining 0.4 percent. Solubility of most chemicals in water makes this type of remediation task, especially in relatively open water, extremely difficult. As a result, prior to the estimation of benefits from PORTS®, all chemical releases were excluded from final analysis. Finally, only those spills that had been recorded as lost into water (as compared with land or air) were included in benefits estimation.[21]

White (1993) reported that a number of factors determine the costs of remediating oil spills: (1) type of oil, (2) physical, biological and economics of the spill location; (3) weather and sea conditions; (4) amount spilled and rate of spillage; (5) time of the year and; (6) effectiveness of cleanup.

In their Notice of Proposed Rulemaking (NPR), the USCG (2011) calculated $10,700 as the total cost per barrel to recover spilled oil. In this analysis, this value was employed to assess the cost of every petroleum spill reported to exceed one gallon in volume and comparisons were made between those 58 ports with and 117 ports without PORTS® installed.

If data from the existing 58 PORTS® (e.g., current and wind speed and direction, salinity, tides, water levels, etc.) were used to enhance only the capture of one percent of the total petroleum losses of $348 million, an annual average benefit approaching $3.5 million was estimated. An additional savings of about $0.6 million occurred owing to obviating the need to deploy temporary sensing buoys to assist in clean-up operations.[22]

Expansion of PORTS® to the remaining 117 locations could help reduce future remediation costs by about $1.1 million in addition to the $0.6 million that

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to contaminate 50 gallons of fresh water. Even a one gallon spill can result in an oil sheen with a thickness of between 0.01 to 0.001 millimeters across up to four acres of water surface.

[21] During the study period almost 91 percent of all petroleum releases into the environment ended up in the water.

[22] Given the conservative nature of these estimates, the $0.6 million was not added to the estimated annual $3.5 million benefits from existing PORTS® installations.

could be saved through not having the necessity to deploy temporary sensor equipment for an annual savings of about $1.7 million.[23] During the ten-year period of benefit estimation, the current 58 ports returned $29 million in benefits. Expansion of ports to an additional 117 locations could add an addition $14 million in benefits over the ten year forecast period.

5.4 Commercial Marine Accidents

The incidence of property losses and the loss of life and injuries among passengers, crews and others associated with commercial marine activities that occurred within the area of a port was investigated employing the USCG's MISLE information system.[24]

In keeping with the conservative nature of this review, commercial shipping accidents retained for use in this analysis were limited to those which were reported to have occurred within the vicinity of the existing PORTS® or what area PORTS® would cover if it has been installed at the port.[25] In addition identification of ship type was made to ensure that only commercial vessels (e.g., cargo, ferry, excursion, cruise ships, etc.) were included in the study. In instances where the ship type was unknown or recreational craft had been mistakenly included, those observations were removed from further analysis as were other craft such as U.S. Navy warships. In keeping with the transition to the MISLE system in 2001, data from the 2002 to 2011 period was selected for analysis. Given the random and relative rare instance of commercial waterborne accidents, such a ten-year period was employed to more accurately provide a long-term assessment of losses owing to morbidity and mortality as well as to match the economic life of instruments employed at PORTS®.

[23] Historically, an average of 970 instances of petroleum release occur each year. Five percent of these are considered serious in nature (48 per year). Of these annual 48 losses, ten percent (about five) have OR&R buoys assigned to the spill at a cost of about $119,000 each. Consequently, the total annual cost for OR&R technology could approach $0.6 million.

[24] The area assigned to a port can significantly differ owing to the local geographic conditions. For example, while area governed by the port of Savannah, GA can be arrayed as an arc swath from the central point of the port seaward, the port of Baltimore, MD includes not only the inner and outer harbor but the entire Chesapeake Bay area.

[25] This was accomplished by using the "lassoing" technique explained earlier.

While the USCG's MISLE database contains a count of accidents and associated deaths and injuries, it does not contain the population count of the number of vessels over which the accidents occurred. As the USACE's CPT database provides a count of the entire population of marine cargo transits, it was employed as the base is for calculating the relative accident rates for collisions, allisions and groundings. During the 2002 to 2011 study period, a total of 9.6 million vessel passings or trips occurred at the 58 locations with PORTS® while 8.3 million occurred through the 117 ports without PORTS®.

Results showed that the overall rate of grounding, allision and collision-based accidents at locations with PORTS® occurred at only 67 percent of the rate which was calculated for locations without PORTS® (0.030 versus 0.067 percent of vessel trips).[26] The incidence of groundings in areas where PORTS® were in use was more than 59 percent less than in areas without PORTS® (0.027 versus 0.011 percent).[27] Collisions were also lower (0.005 percent to 0.004 percent) -- a 25 percent difference. Only in the case of allisions was the opposite seen where locations with PORTS® posted a slightly higher accident rate than locations without PORTS® (0.013 versus 0.015 percent). This is assumed to be due to natural variability in the rate of accidents rather than a causal effect.

[26] Care was exercised to ensure that the installation year of each of the 58 port locations was included in the calculations of collision, allision and grounding instances per vessel trip. In this way, a location that only had PORTS® sensors for limited period was not given credit for the entire span of this analysis but only for the actual years sensors were in place and operational.

[27] This figure replicates the 60 percent reduction in grounding risk identified by Kite-Powell (2007) in the ports of Houston and Galveston

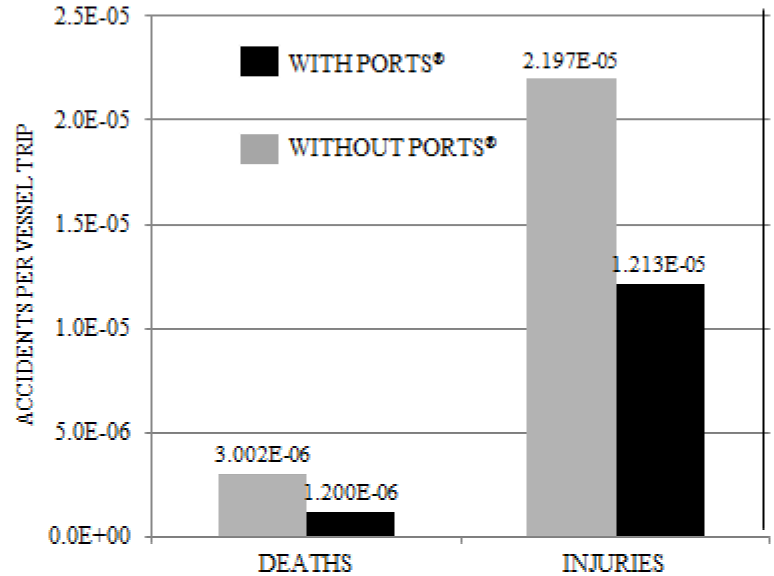

Figure 4. Deaths and injuries per vessel passing resulting from commercial ship allisions, collisions and groundings, excluding Great Lakes traffic (US Coast Guard MISLE Accident Database, USACE CPT).

Property losses per trip were seen to be *de minimis* (about $10 dollars in places where PORTS® had been installed and $16 dollars where no PORTS® support had been provided). Expanded by the number of trips, annual savings in property damages of $5.2 million was calculated for the existing 58 PORTS® locations and $2.5 million for the remaining 117 locations. Over the ten-year study period, benefits from the existing 58 port locations were $44 million while PORTS® installation at the additional 117 ports could return an additional $21 million.

Mortality and morbidity rates were also lower where PORTS® had been installed. Normalized by the number of vessel trips overall mortality was about three times as great and morbidity almost twice as great when PORTS® instruments were not present. (Refer to Figure 4) Assuming $6.1 million as the value of a life and $0.6 million for each injury, $11.8 million has been saved annually due to PORTS® at the 58 current locations. Additional installation at 117 locations could add an additional $7.3 million in savings. Over ten years, benefits from the existing 58 locations with PORTS® were $97 million. If expanded to the next largest 117 ports an additional $60 million in benefits from morbidity and mortality reductions could be enjoyed.

6. FISH CATCH

Jones (2013) reports that tides and currents are important to understand, as fish are easier to catch when they are feeding and it's the tide and currents that dictate this. This means the tide and current will concentrate the bait and the movement of water will initiate and stimulate feeding activity. As the water begins to move, smaller baitfish are at the mercy of the current and get confused in the turbulent water. Larger game fish have an advantage because they are equipped to feed in turbulent water. As such, moving water is often best for fishing. Becker (2013) states that fish can be caught on a rising or falling tide, but not a time of high or low water when there is little water movement. When the tide is at its high or low point, there is very little water movement, and when there is little or no water movement, fish do very little feeding. There can be days when there is considerable water movement, and there are days when there is an absence of currents. On some days the currents are strong, while on others they are reasonably mild.

Nix (2010) reports that many marine organisms can only survive within a particular salinity range, which makes salinity a notable factor in determining the types of potentially commercial organisms found in the Gulf of California. The reported mean annual ranges of salinity of the Sea of Cortez are between 3.5 to 3.58% at the surface. Earlier Brusca (1973) noted that, the salinity of the water of the Northern Gulf of California is generally higher than the central and Southern faunal regions due to the increased amount of evaporation that occurs in that region.

In more wide-ranging analysis, Love (1997) observed that fish were extremely sensitive to their environment. He stated that major environmental factors in a fish's life include: (1) water temperature; (2) water clarity; (3) water motion; (4) water salinity; and, (5) light levels (both daily and seasonally). He attributed these five parameters to six phenomena: (1) currents; (2) waves and swells; (3) time of day; (4) time of year; (5) tides; and, (6) rainfall. Obviously, some of these phenomena produce more than one effect. For instance, when an El Niño occurs, water temperature and water clarity rise. During storms, waves cause more water motion near shore, which causes sand and mud to be kicked up, resulting in a decline in water clarity. Time of year influences rainfall, light levels, water motion, water clarity, water temperature etc. A full moon also produces more light at night, but it at the same time produces larger tides.

6.1 Commercial Fishing

NOAA's Fisheries records the market value of commercial fish catch. Furthermore, catch is broken down between finfish and non-finfish catch (e.g., crab, lobsters, clams, oysters, etc.) by distance from shore. Total commercial catch has ranged between 3.8 and 4.7 million metric tons with an associated value of between $4.0 and $5.6 billion dollars during the 2005 to 2011 period. Overall, an average of over 34 percent of the tonnage and 41 percent of the value of commercial fishing comes from distances of between zero and three miles from shore during the 2005 to 2011 period. Although commercial fishermen may utilize PORTS® data either directly or indirectly from another source, no empirical data exists as to the extent of that usage. Based on the logic model for the situation, if even a *de minimis* subjective evaluation of 0.1 percent of all close to shore activity (3 or fewer miles) was due to PORTS®, an average annual benefit in excess of $1.8 million could have been enjoyed based on the average market value for landed fish between 2005 and 2011. Over the ten-year economic life of PORTS® the PV could exceed $15 million.

As we do not have information of the specific port location of commercial catch, some form of further apportionment must be made to account for 58 locations that have PORTS® versus those 117 ports which currently do not have them. A simple allocation based on the proportionality of ports with PORTS® -- 33.1 percent (58 with PORTS® out of 175 total ports). Hence, the portion of benefits assigned in this analysis to PORTS® was $1.8 million times 0.331 or $0.6 million annually. The remaining annual $1.2 million is the potential added benefit should the remaining 117 ports receive PORTS®. Over the ten-year period of this study, the 58 current port locations provided $5 million in benefits while the additional 117 locations could add an additional $10 million.

6.2 Recreational Fishing

It had been estimated that in 2011, ten million anglers made more than 69 million marine recreational fishing trips. Over 201 thousand pounds of fish were landed.

During the period 2006 to 2011, total recreational landings reported by the National Marine Fisheries Service (2007, 2012) declined in terms of metric tonnage and numbers of fish. At the same time, the average weight of those fish retained and not released increased from 1.22 to 1.46 pounds each. From 2006 to 2011, more than one-quarter of all fish in terms of weight and numbers were caught three and fewer miles from shore.

Although numerous academic writings and practitioner anecdotes describe and support logic models which document the optimum environments in which to catch fish, no current data set is collected which specifically relates fish catch by species by specific ecological situations. Clearly, as PORTS® provides data on issues related to currents, tides, salinity, etc., prudent use of its data could logically enhance recreational catch experiences. Value from PORTS® need not directly come from PORTS® but may also be distributed from other entities which make use of PORTS® data. Moreover, as recreational landings are not often resold in formal markets, their value has historically been calculated on a non-market basis which has included a number of factors involving the value of recreation, vacation, value of "living simply or getting back to nature", etc. (Pendleton 2006) Consequently, several assumptions have to be made in order to estimate the value of benefits provided by PORTS® to recreational fishing.

In commercial fishing, the National Marine Fisheries Service (2011) determined the value of landed finfish catch approached $2.4 billion dollars in 2010. During 2010, over $800 million was landed within 3 miles of U.S. shorts while almost $1.3 billion in finfish was landed by U.S. fishing craft between 3 and 200 miles from U.S. shores. Another $330 million was taken on the high seas for off foreign shores.

In this investigation it was assumed that the "value" of landed recreational catch was $0.50 cents per pound or slightly above the overall ($0.37) average value of landed commercial finfish taken within three miles of shore. The value to the recreational fisherman is probably well in excess of $0.50 per pound as evidenced by their willingness to charter private or group party vessels or operate their own craft for fishing trips. Employing this assumption and this benefit transfer approach would range between $25 and $38 million dollars per year in benefits. If data from PORTS® is either directly or indirectly employed by recreational fishermen during the 2205 to 2011 period as a group in only one percent of the time in locations within three miles of shore, the annual benefit from PORTS® could range between $250 and $380 thousand per year and the annual average benefit could exceed $307,000.

As we do not have information of the specific port location of recreational catch, some form of further apportionment must be made to account for 58 locations that have PORTS® versus those 117 ports which currently do not have them. Lacking more specific information a simple allocation of the total potential annual and potential 10-year benefit streams based on the proportionality of ports with PORTS® -- 33.1 percent (58 with PORTS® out of 175 total ports). Hence, the portion of potential benefits which are assigned in this analysis to PORTS® was $101,649 annually (or 0.331 times $307,000). The remaining annual $205,449 are assigned to the additional potential should the remaining 117 ports receive PORTS®. Over ten years, the 58 existing PORTS® returned benefits worth $0.9 million while the remaining 117 could add an additional $1.6 million.

7. RECREATIONAL BOATING ACCIDENTS

Recreational boating is a popular pastime with the U.S. population. According to the National Marine Manufacturer's Association (NMMA 2012) and the USCG's 2011 Recreational Boating Statistics (2012), there are almost 12.2 million recreational boats in the United States. Of these it has been estimated that about 54 percent of all recreational boats are located in coastal states with over 45 percent operating out of an area identified as a one of the 175 major ports in America reviewed in this study.[28] The remaining 55 percent of recreational craft are located in inland areas not covered by one of the existing or planned PORTS®. At the current time it is believed that over 2.2 million recreational boats are operated out locations with PORTS® installed. This represents about 41 percent of all such craft, which total about 5.5 million. Like any other mariners recreational boaters can benefit from the use of real-time environmental information that PORTS® provides.

[28] The NMMA compiles recreational boating statistics by U.S. Congressional District. These maps were overlaid with the 58 current and 117 planned locations scheduled to have PORTS® installed. A port was assigned the number of recreational boats located in the Congressional District in which the port was located. In the situation when two ports were located in the same Congressional District the number of recreational boats were apportioned based on 2010 U.S. Census population figures for the port cities.

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Recreational boaters operate in waters throughout all 50 states and territories of the United States. But, PORTS®, even when fully implemented to cover the 175 most major ports will only cover a portion of the waters used by recreational boaters. PORTS® only covers the coastal counties of the coastal states. But for those boaters in areas covered, PORTS® offers a real advantage in obtaining real-time information about parameters especially important to boaters namely weather and tides.

Employing USCG MISLE data covering recreational boating accidents, data from 2005 to 2012 morbidity and mortality data was collected. Weather was found to be the 5th most common primary contributing factor of recreational boating deaths in 2010, the 10th and 11th most common primary contributing factor in boating accidents and boating injuries respectively. Of all the types of accidents and primary contributing factors there are only two, groundings and weather related accidents, that PORTS® data could possibly be used to reduce the number of recreational boating accidents, injuries and deaths. Overall, while some recreational boating accidents included both deaths and injuries, there were over three times as many grounding accidents versus weather-related ones during the study period. The use of real-time environmental data from PORTS® is logically presumed to have a beneficial effect on accident chain of events when applied under the following conditions.

- Only those boating in areas with PORTS® can benefit from this real-time information. Only accident records that occurred in counties that would be covered by a PORTS® as part of the 175 port implementation were considered. All other data was deleted;

- Only mariners with unimpaired judgment were considered. All accidents involving drugs or alcohol as one of the major causes were eliminated from the data set as were accidents involving reckless behavior or excessive speed as a primary cause;

- Accidents that had weather or weather related issues like low visibility, fog, or high seas identified as one of the causes were kept as a “Weather” related data set; and,

- Of the remaining accident data those related to groundings that might benefit from having access to real-time water level information were kept in a "Grounding" related data set.

While no doubt of assistance in reducing recreational boating accidents, the number of accidents due either solely or mainly to weather and/or groundings were very small. During the study period the MISLE database reported that weather related events ranked fifth among deaths (41) and tenth among injuries (102) among contributory factors resulting in recreational boating accidents. Overall, weather (ranked eleventh) was the primary causal agent in 209 recreational boating incidents.[29] Consequently it was not unexpected that the role of the existing 58 PORTS® in property losses due to groundings and weather was *de minimis* – on the order of well less than $0.1million year. Due to the low value added, the addition of an addition 117 installations would not exceed $0.1 million per year in benefits. Over the ten-year life of PORTS®, the PV remained less than $0.1 million for the 58 current locations and less than $0.1 million for the additional 117 locations.

Similarly, the annual benefit from the existing 58 PORTS® installations was estimated to be less than $0.2 million per year. If expanded to the additional 117 largest ports, an additional $0.2 million might be enjoyed.

8. OTHER BENEFITS

NOAA's Coastal Services Center maintains the (ENOW) data base which combines data from the DOC' Bureau of Economic Analysis, and DOL's Bureau of Labor Statistics. Colgan (2007) explains how this data combined in the NOAA's Economics: National Ocean Watch (ENOW) provides time series data on the ocean and Great Lakes economies based on six economic sectors which are dependent on the oceans and the Great Lakes**.**

Although not quantified in this analysis, near shore vessel movements involving aquaculture, deep water mining and energy exploration all can obtain

[29] Operator Inattention, alcohol use and "unknown/other" were the three dominant reasons for the occurrence of recreational accidents and resultant deaths and injuries.

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the same navigational support which cargo and other support vessels have been shown to receive from the existing 58 locations with PORTS® and could obtain from its implementation at 117 areas where no PORTS® currently exist.

9. CONCLUSIONS

Several authors have concluded PORTS® implementation has resulted in improvements in waterborne traffic safety and efficiency as well as environmental protection in several previous studies as illustrated by the decline in the incidence of collisions, allisions and groundings in the wake of PORTS® installations. This study expands previous research by estimating gross benefits from current and potential installation of PORTS® at the dominant 175 ports in the United States. In addition, this analysis provides both additional physical and monetary granularity of the benefits derived from PORTS®. From these results, ports without PORTS® could make more informed decisions regarding the value of such installations as well as ports with PORTS® understand the continuing value of such investments.

Table 2. Summary of Benefits from PORTS® (in millions of 2010 dollars)

Benefit type		Annual benefits			Present value of benefits over 10 years		
	Portion of total benefits assumed to result from presence of PORTS®	**From 58 ports with PORTS®**	**Potential benefits from 117 ports w/o PORTS®**	**Total current and potential benefits from 175 ports w/ PORTS®**	**From 58 ports with PORTS®**	**Potential benefits from 117 ports w/o PORTS®**	**Total current and potential benefits from 175 ports w/ PORTS®**
Commercial traffic – fewer trips	1.0 %	$119.6	$40.7	$160.3	$978.6	$333.2	$1,311.8
Commercial traffic – reduced delays in transit	1-hour reduction in transit time	$76.4	$28.8	$105.2	$624.8	$235.7	$860.5

Benefit type	Portion of total benefits assumed to result from presence of PORTS®	Annual benefits			Present value of benefits over 10 years		
		From 58 ports with PORTS®	Potential benefits from 117 ports w/o PORTS®	Total current and potential benefits from 175 ports w/ PORTS®	From 58 ports with PORTS®	Potential benefits from 117 ports w/o PORTS®	Total current and potential benefits from 175 ports w/ PORTS®
Oil pollution remediation	1.0 %	$3.5	$1.7	$5.2	$28.5	$13.8	$42.3
Commercial marine accidents – property damages	1.0 %	$5.2	$2.5	$7.7	$43.8	$20.6	$64.4
Commercial marine accidents - morbidity and mortality	1.0 %	$11.8	$7.3	$19.1	$96.5	$59.8	$156.3
Fish catch – commercial	0.1 %	$0.6	$1.2	$1.8	$5.0	$10.1	$15.1
Fish catch - recreational	0.1 %	$0.1	$0.2	$0.3	$0.9	$1.6	$2.5
Recreational boating accidents – property damages	1.0 %	< $0.1	< $0.1	< $0.1	< $0.1	< $0.1	< $0.1
Recreational boating accidents – morbidity and mortality	1.0 %	$0.2	$0.2	$0.4	$1.2	$1.9	$3.1
TOTAL		**$217.4**	**$82.6**	**$300.0**	**$1,779.3**	**$676.7**	**$2,456.0**

In estimating benefits in this study a conservative approach was followed where no more than one percent of any total benefit group or type was attributed to PORTS®. In several cases only 0.1 percent of potential benefits were ascribed to PORTS®. While additional factors undoubtedly have aided in improvements in accident reduction, reduced transit delays and enhanced vessel productivity through the ability to carry larger loads, PORTS® clearly played a significant role in providing major benefits in four areas associated of waterborne commerce:

- Diminish overall transportation costs due to fewer commercial trips owing to the ability to navigate with more highly loaded vessels with resultant deeper drafts;
- Reduction in transportation costs owing to faster vessel trip times resulting from reduced delays in transits;
- Lessening of the time to identify and predict locations of oil spills and;
- Reduce commercial marine accident which cutback on levels of morbidity and mortality among vessel crew members and others working near or on the waterways.

While additional benefits were also seen to be provided to several groups (e.g., increases in commercial fish catch, enhancements in recreational fish catch and reduction in deaths and injuries among recreational boaters) the cumulative benefit from these lesser groups was very small – representing less than 0.5 percent of total benefits.

Overall, the 58 ports with PORTS® instruments produced over $217 million (2010 dollars) in annual benefits. (Refer to Table 2) If PORTS® were also installed on the largest remaining 117 port locations an additional annual benefits of $83 million are expected for a potential total of $300 million per year. These results represent expansion of those projected from Kite-Powell's earlier work ($215 to $240 million) and the VOLPE study ($182 million).

Over the ten-year life of a PORTS® installation, the PV of total benefits from the existing 58 locations with PORTS® was estimated to approach $1.8 billion with an addition $0.7 billion possible if installed at the remaining 117 locations without PORTS® for a potential total of almost $2.5 billion. Finally, although not quantitatively explored in this analysis, the existence of additional benefits resulting from PORTS® in support of support of aquaculture, deep water mining and energy exploration are also indicated.

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