Socio-Economic Study: Scoping the Value of NOAA's Coastal Mapping Program

Final Report

Irv Leveson

Leveson Consulting

Prepared for the Remote Sensing Division of the National Geodetic Survey, National Ocean Service, National Oceanic and Atmospheric Administration, U.S. Department of Commerce
under contract DG133C11SE1521

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Preface

The Coastal Mapping Program contributes solutions to issues ranging from marine safety to geographic information to resource management to emergency response. It supports a surprisingly wide range of activities in the economy and society. This scoping study provides information on the program's customers and applications, preliminary order of magnitude estimates of the value of CMP products and services, and an estimate of the number of jobs supported. Benefit estimates are rough orders of magnitude. They are a minimum since only some applications are included in the estimation.

The value of benefit analysis is in:

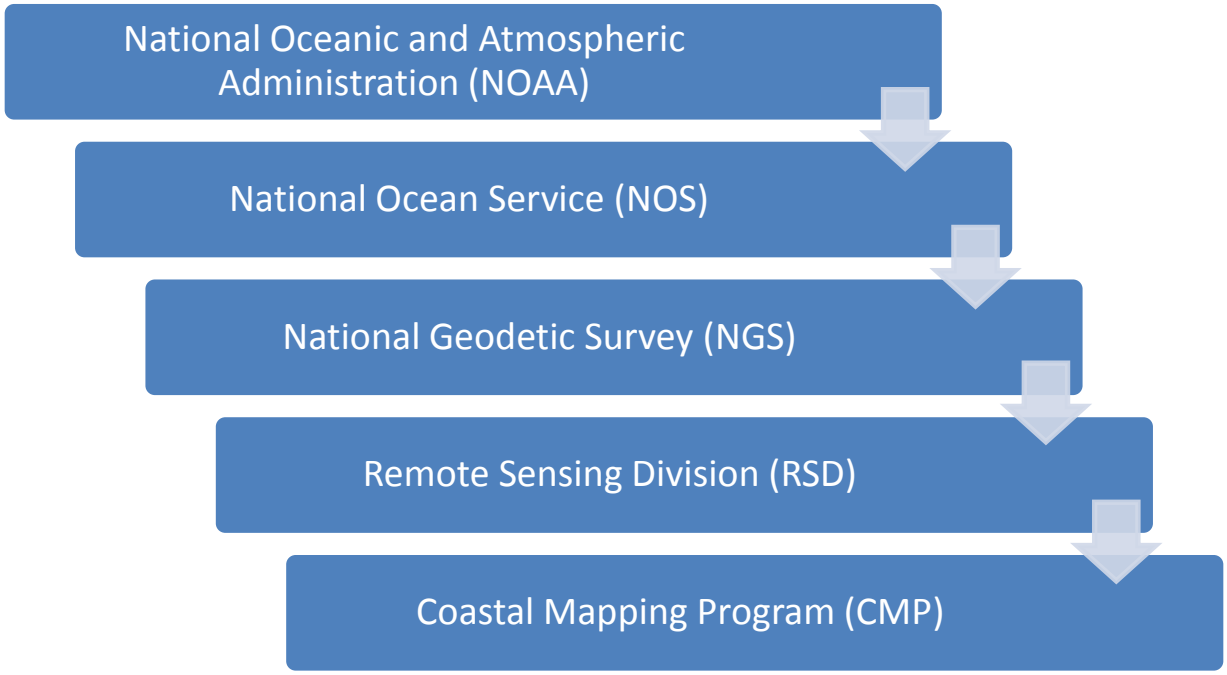
- Improving understanding of customers and their applications and requirements
- Informing decisions about the allocation of resources among programs
- Advancing recognition of the contributions of the program

In addition to providing data on customers and applications and order of magnitude benefit estimates, the value of a scoping study is in framing issues and methods and examining research opportunities, setting the stage for more comprehensive and definitive analysis.

This analysis is one of a series of benefit studies sponsored by NOAA's National Ocean Service to facilitate planning and decision-making. The work was carried out by Dr. Irving Leveson, an economist and strategic analyst who has worked extensively with NOAA.

The study has benefitted from discussions with and/or information provided by many people, including Mike Aslaksen, Susan Bass, Colin Becker, CAPT Eric Berkowitz, LCDRNicole Cabana, Dave Enabit, Mike Epsey, CDR Al Girimonte, Doug Graham, Mark Howard, Tiffany House, Brett Howe, Dave Macfarland, Steve Matula, LCDR John Neuhaus, Chris Parrish, Meridith Westington, Pete Wiley, and Monica Youngman. Their assistance and insights are greatly appreciated. Unnamed staff of NGS developed valuable data and their contributions are appreciated as well.

The Coastal Mapping Program in the NOAA Organization



Executive Summary

Background

NOAA's National Geodetic Survey's Remote Sensing Division (RSD) is responsible for the Coastal Mapping Program (CMP). The program facilitates coastal economic activity by providing remote sensing data used to derive shoreline data. The Coastal Mapping Program has been defining the shoreline of the United States since the creation of the Survey of the Coast by Thomas Jefferson in 1807 and since then has provided a consistent, accurate, up to date National Shoreline.

The National Shoreline provides critical baseline data for updating nautical charts; defining our nation's territorial limits, including the Exclusive Economic Zone; and managing our coastal resources. The National Shoreline contributes to our nation's economy by supporting activities including maritime trade and transportation, coastal and marine spatial planning, coastal engineering and construction, scientific research, and insurance, to provide a means for enhancing our global competitiveness and more efficiently managing our resources.

An accurate, consistent, and up-to-date national shoreline can provide and improve:

- Official nautical charts for maritime navigation,
- Data to model sea level change, storm surge, coastal flooding, and pollution trajectories,
- Contemporary ocean management plans,
- Wave and wind energy site selection,
- Land and marine geographic information system base layers, and
- Environmental analysis and monitoring.

This scoping study of NOAA's Coastal Mapping Program (CMP) provides a qualitative and quantitative analysis of users and applications of CMP's charting and mapping products and services and the nature of the benefits of those services. It makes preliminary order of magnitude estimates of the value of the economic and societal contribution of CMP's services and the number of jobs they support. In addition, it seeks to provide the basis for a full analysis of the beneficiaries and socio-economic benefits of CMP.

Better understanding of customers and applications is essential to meeting service needs and designing programs. Benefit information helps to inform decisions about allocation of resources among programs.

CMP products and services included in this study are:

- Shoreline Mapping
    - Nautical Chart Production – high resolution, tide-coordinated shoreline data for nautical charts.
    - Change Analysis – consistent, accurate data for evaluation of port and other areas for changes to shoreline and critical infrastructure.
    - Boundary Determination and Legal Aspects – local, state, and federal boundaries related to National Shoreline and marine and on-shore spatial planning.

- Shoreline Imagery – geo-referenced imagery and Light Detection and Ranging (Lidar) data of the National Shoreline providing critical baseline data for demarcating U.S. marine territorial limits, including the Great Lakes and the nation's Exclusive Economic Zone, and for the geographic references needed to manage coastal resources and other uses. These data are considered authoritative when determining the official shoreline of the United States.

- Digitally Reproduced Historic Imagery – historical imagery of the National Shoreline.

- Emergency Response Imagery – post event imagery used for impact assessment and planning for hurricane and flood damage, earthquakes and other natural disasters, and oil spill response.

To meet the requirements of the Coastal Mapping program, RSD employs an all-source approach utilizing a broad spectrum of sensors on both aircraft and satellites. The predominant source is digital imagery collected from aircraft followed by imagery from high resolution satellite systems and lastly Lidar from aircraft.

Evolving Technology

The technologies used to meet CMP's mandate have changed dramatically over the last 200 years. Beginning with field survey methods, they then transitioned to analog photogrammetry and then analytical photogrammetry, to where we are today with digital photogrammetry, active laser topographic/bathymetric airborne systems, and high resolution satellite systems. The advancement in technologies has also lent itself to the sharing and multiuse of this digital data. The CMP provides the data through the Integrated Ocean and Coastal Mapping initiative which simply states "Map once – Use many times". Making the source easily distributed and used maximizes the taxpayers' investment in the CMP and the effectiveness of the information.

Customers and Applications

CMP products and services contribute to many public and private activities, including:

- Navigation safety
- Shoreline modification
- Environmental protection (including precise coordinates of sensitive and protected areas)
- GIS applications in coastal zone management
- On-shore development
- Recreation
- Fish habitat mapping
- Energy exploration, development and production
- Underwater exploration and construction
- Offshore aquaculture
- Planning and response to natural disasters and environmental emergencies
- Coastal and ocean jurisdiction mapping and dispute prevention and resolution
- Marine spatial planning
- Legal and insurance applications
- Homeland and port security
- Monitoring sea level change
- Scientific research
- National and international standards
- Archaeology and cultural heritage
- Military activities

CMP services are used by many of the 18 federal agencies with responsibilities for marine activities that participate in the Cabinet-level interagency Committee for the Marine Transportation System. At least 15 federal agencies are themselves involved in mapping in one way or another. Some are CMP customers or partners. Many state agencies and academic institutions are also involved in mapping and use NOAA's National Shoreline and/or its other products. Many international organizations and foreign governments make use of CMP information as well.

A variety of government organizations distribute CMP information. Some add to it and/or use it to provide services. Data is distributed more widely as nautical charts since CMP data is a supporting product for the charts. Private companies are increasingly important to the distribution of NOAA and non-NOAA charts and maps. Methods of distribution have been shifting over time for some products as alternatives have increased. The lack of data on external Web sites that distribute CMP data and products utilizing it (including both NOAA distribution partners and value added resellers) poses a challenge in understanding changing overall demands. At the same time, the increasing number of channels provides opportunities to reach wider audiences and better serve constituents.

More than 25 million page requests were made on CMP and related NOAA Web sites during 2011 (Table ES1). The total is dominated by page requests from the aerial image storm site for which downloads surged to over 25 million from 402,781 in 2010.

Table ES1. Page Requests from CMP and Related NOAA Web Sites, 2011

Web Site	Page Requests
Aerial Photo Orders	5,694
Coastal Mapping Program	20,730
NOAA Shoreline Data Explorer	26,089
Aerial Image Storm	25,664,507
Total	**25,717,020**

Downloads of paper charts from NOAA have been declining as electronic charts have come into more widespread use. Only 210,843 paper nautical charts were downloaded from NOAA in 2009. In addition, public sales of Coast Pilot chart books totaled 18,695 in 2010.

Downloads of Electronic Navigation Charts totaled 141,615,580 in 2011. Downloads of Raster Navigation Charts (full-color images) totaled 97,550,043. These were typically downloads of zip files which include many charts in one file, and often consisted of downloads of zips of all of the charts. Many of these downloads represent updates.

Industry Users

CMP serves many large and important industries and activities. The statistics of those industries are instructive about the beneficiaries of CMP services.

- The private surveying and mapping except geophysical services industry had sales of $6.8 billion in 2007 and 69,000 employees. Sales increased 33% above inflation from 2002 to 2007, reflecting the construction boom as well as the underlying trend of growth in the industry that has been stimulated by technological advances.

- More than 8,000 United States flag passenger and cargo vessels were operating or available for operation in the Atlantic, Gulf, and Pacific coasts and the Great Lakes on December 31, 2009.

- The U.S. deep sea, coastal and Great Lakes water transportation industry had revenues of $28.8 billion in 2007. The largest category was deep sea passenger transportation, of which cruise ships accounted for $11.0 billion.

- Sea, coastal and Great Lakes water transportation directly employed 40,000 people in 2007. It accounted for three-fifths of the 66,000 people employed by water transportation nationwide. Support activities for all water transportation employed 100,000 people in 2007 and 93,000 in 2009. Ship and boat building (including military) employed 160,000 in 2007 and 132,000 in 2009.

- The top 23 U.S. foreign trade water freight gateways had a value of exports of $676 billion and a value of imports of $984 billion in 2009.

- The value of Gulf oil production is estimated at about $70 billion and natural gas production at about $10 billion in 2011. Alaskan production of oil is valued at about $19 billion and gas at about $1.4 billion. These numbers do not include the value added in downstream production and transportation.

- There were 59,442 commercial fishing and processing vessels in the coastal and Great Lakes states in 2008.

- Seventy five million people or 32% of the U.S. adult population participated in recreational boating (including fishing) at least once during 2010. Recreational boating and fishing involved an estimated 16.7 million boats in 2010. There were 11.3 million recreational anglers in 2009, of which 9.4 million lived in coastal areas. National retail spending on recreational boating (including spending for recreational fishing) was $30.4 billion in 2010.

- More than 56 million people surveyed in 2009 went to the beach during the previous 12 months. Seventeen million went at least once a month and 5.5 million went at least once a week.

Marine safety continues to be a serious problem. There were 4,458 accidents on commercial vessels in 2009. Property damage related to vessel casualties was $60.5 million in 2009 and $106.7 million in 2010. Recreational boating had 4,730 accidents and 736 fatalities in 2009, involving 6,190 vessels. Property damage from recreational boating accidents was $35.9 million in 2009.

Benefits of CMP

Approach to Benefit Measurement

The concept of benefits for this study is gross economic and societal value. Gross economic and societal value includes economic benefits and also non-economic benefits to society such as those to health, safety and the environment. It does not subtract the costs incurred by CMP or its customers in achieving those benefits.

Benefit estimates represent rough orders of magnitude. The estimates demonstrate that economic benefits of CMP are large in comparison with program costs. Non-economic benefits are especially conjectural and are labeled as illustrative.

Direct economic benefits, which are those to users of the products, are built up from estimates of component application areas. The resulting direct economic benefit estimate for CMP and the total economic benefit estimate that depends on it are minimum estimates because many application areas are not included. Therefore, the true ratio of benefits to costs is greater than shown here.

Emphasis should be placed on the benefit estimates for CMP as a whole rather than on individual products since benefits of some products are captured in the estimates for other products, a result of the interdependence of the activities and the nature of the data available.

Total economic benefits include direct, indirect and induced benefits. Direct economic benefits are estimated based largely on "willingness to pay" for products or outcomes, and in some cases on estimates of market values. Benefits measured by "willingness to pay" implicitly exclude costs that users incur to take advantage of the products.

Direct economic benefits include productivity effects and product and process innovation in sectors using the services. Indirect and induced economic benefits include demand effects on industries supplying using sectors, demands created by spending of using industries and their employees, and effects on innovation beyond using industries. Total economic benefits are derived from direct economic benefits by applying a multiplier based on findings of econometric studies.

Economic benefits include consumer surplus, the value to businesses, governments or households above what they pay. Consumer surplus is implicitly included in measures of willingness to pay.

Where other agencies are involved in producing a product or service along with the Remote Sensing Division, a portion of the benefits of the overall effort is allocated to CMP.

Where applicable, estimates are made specifically for the coastal areas and Great Lakes.

Illustrative estimates are made for non-economic benefits to suggest possible orders of magnitude.

Benefits are incremental in that they measure the differences in economic and societal values from those that would be expected if CMP products and services were not available. Alternatives may involve activities in other organizational settings and/or use of alternative technologies, or some users going without service. Alternatives reflect consideration of business models. They do not include replication of CMP services in another government agency since it would have to do the same things about in the same way as CMP. Based on consideration of market considerations, in most cases benefits are reduced by half to roughly exclude benefits that would be obtainable with alternatives. No reduction is made for Digitally Reproduced Historic Imagery or for the Boundary Determination and Legal Aspects energy components, for which alternative sources are assumed to not be available or are not authoritative.

In addition to the reduction in benefit estimates for alternatives that would be expected in the absence of CMP. About 20%-25% of the data that CMP uses is satellite data from other sources. However, CMP provides processing, interpretation and dissemination in addition to collection of data. Consequently, a reduction of 8% is applied to allow for CMP's use of satellite data. This adjustment is applied to the total of benefits of all of the products since there is no basis for allocation among the individual products.

Ranges are shown for benefit estimates to illustrate the difference alternative values would make.

The estimates are based on the current program. They do not indicate what the benefits would be if remote sensing were done more frequently, if improved technologies were deployed, or if demand for the products increased.

Order of Magnitude Benefit Estimates

The component applications for which direct economic benefits of the CMP products are estimated are shown in Table ES2 along with indications of the methods used.

Table ES2. Basis of Component Estimates of Direct Economic Benefits of CMP

Nautical Chart Production
Commercial vessels – willingness to pay
Recreational boating– willingness to pay
Recreational fishing– willingness to pay
Change Analysis
Benefits to ports based on construction
Boundary Determination and Legal Aspects
Avoidance of delays in offshore oil and gas production
Avoidance of delays in offshore wind power
Reduction in the cost of title insurance
Shoreline Imagery
Value of page requests
Digitally Reproduced Historic Imagery
Value of page requests
Emergency Response Imagery
Contribution to willingness to pay for weather forecasts

The order of magnitude of gross direct economic benefit of Coastal Mapping Program products and services is estimated as $100.4 million in calendar year 2011. Under the assumptions in this study and reasonable assumptions about the distribution around the midpoints, CMP benefit totals are likely to be within 10% of their midpoints. This equates to between $90.4 million and $110.4 million for direct economic benefits.

Emphasis should be placed on totals of benefits across products benefits of some products are included in estimates for other products. For example, the benefits of the Change Analysis to mariners are included in the benefits of the Nautical Charts product. Some benefits of Shoreline Imagery are included under Boundary Determination and Legal Aspects. The largest benefit estimates are for Nautical Charts, Boundary Determination and Legal Aspects and Emergency Response Imagery. As noted, estimates for CMP as a whole and for some products are a minimum since only some applications are included.

The budget of the Coastal Mapping Program, which falls under NOAA Navigation Services, was $6.49 million in FY 2011. Allowing $300,000 for aircraft costs, the cost of the program is $6.8 million. Direct economic benefits alone are about 15 times program costs.

Indirect and induced economic benefits of CMP are taken into account by applying a multiplier of 2.0 to direct benefits. The order of magnitude of total economic benefits of CMP is $200.8 million, 30 times the cost of the program.

An illustrative value of non-economic benefits of CMP is calculated based on averted fatalities and injuries associated with coastal mapping and the Emergency Response Imagery Program, along with a factor for environmental benefits. The illustrative value of non-economic benefits of CMP is $40.2 million. Actual non-economic benefits may be higher.

The order of magnitude of total economic and illustrative non-economic benefits of CMP is $241.4 million. Benefits and their ranges are summarized in Table ES3.

Table ES3. Summary of CMP Benefits, 2011 (millions of dollars)		
	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, with 8% adjustment and 10% range)	$40.6	$36.5-$44.7
Total Benefits	**$241.4**	**$217.4-$265.**

CMP is estimated to support about 1,500 full time equivalent jobs, including approximately 40 full-time equivalent jobs in CMP and its contractors.

Next Steps

One objective of this scoping study is to provide a foundation for a more comprehensive and definitive analysis of benefits and jobs created. Several components would be useful for inclusion in a full study to better measure and understand the nature and magnitudes of CMP customers and benefits.

Before and After Comparisons of Map and Chart Updates to Measure Benefits to Mariners

Benefits to mariners from the National Shoreline, Change Analysis and Nautical Charts products can be examined by comparing groundings, accidents and other measures before and after remote sensing information in each location was updated. Much of the data needed for this part of the analysis is available from the Coast Guard. Separate analyses can be conducted for changes in commercial shipping and recreational boating activity.

Measures of the impact of CMP products on both the economy and resource management can be considered. Economic impacts can be assessed by examining the numbers and types of construction, new business formation and other activities that took place before and after map and chart updates in an area. Possible acceleration in resource management efforts can be examined in reviewing projects and in discussions with resource managers.

Before and after comparisons have the advantage of providing evidence on causal links. The case studies they include express stories that help understand the nature of the benefits and the ways they come about.

Before and After Comparisons of Chart Updates to Measure Benefits to Ports

A quantitative assessment can be made of the impact of updated maps and charts in the National Shoreline, Change Analysis, and Nautical Charts programs in facilitating port operations and construction projects. This would be based on before and after comparisons where remote sensing surveys were done. Interviews with port managers can supplement data collection.

- The impact of reduced delays in construction can be measured in ports that are willing to provide data on construction spending.

- Any extent of more efficient operations and reduced accidents as a result of operational or construction changes that were enabled can also be assessed.

- Impacts on the volume, value and type of shipping (e.g. domestic vs. international) can be examined.

- Results can potentially be extrapolated from case studies to other ports covered by CMP products.

Examining Many Uses of CMP Products

Additional work could shed light on many more types of users of CMP products and services, their applications and the nature and magnitude of the benefits to users and society. Among the uses that could be included are on-shore economic development, use of imagery and Lidar for offshore energy exploration and production and on-shore support, planning and operations of companies and governments, coastal resource management and disaster and emergency response.

One approach to accomplishing this is through interviews and quantitative analysis, using data obtained from users and industry organizations. Cooperation of industry and professional organizations would be helpful in obtaining access and information. Alternatively, unstructured information can be elicited through a Web site.

Use of CMP Data Learned from Web Site Visitors

Those who download imagery from the NOAA Shoreline Data Explorer and other data distribution Web sites could be offered a link to a Web page in which they are asked to discuss how they use the imagery and what other imagery they use. Examples of productivity improvements users have achieved with CMP products and innovations they made possible could be elicited. Visitors also can be asked to provide comments on what they would like to see in CMP products, distribution, and training.

Expansion of CMP Services

In addition to refining the estimates of benefits of the present level of services, a follow-on study can examine the benefits of expansion of CMP products and services. The Hydrographic Services Review Panel 2010 update report recommended expansion in many areas. The study can provide rough order of magnitude estimates of the benefits if many or all of HSRP proposals for CMP products and services were implemented. It could include examining the potential benefits of new technologies, benefits of delivering updates more quickly, and benefits of increasing information to navigation and non-navigation communities. Benefits could be calculated for meeting alternative percentages of CMP or HSRP goals. A variety of valuation techniques could be used, depending on the product and availability of information.

A full study can improve understanding of customers and their applications and requirements and inform decisions about the allocation of resources among programs.

Socio-Economic Study: Scoping the Value of NOAA's Coastal Mapping Program

The Study

The Coastal Mapping Program

The U.S. has approximately 95,000 miles of coastline. Population and economic activity are concentrated along the coasts and Great Lakes. Shoreline adjacent counties were the home to 87 million people and accounted for 47 million jobs and $2.4 trillion in wages in 2008.[1]

NOAA's National Geodetic Survey's Remote Sensing Division (RSD) is responsible for the Coastal Mapping Program (CMP). The program facilitates coastal economic activity by providing shoreline data. The data is used in creating nautical charts and in support of GIS analysis and special purpose maps. The images developed are used to define the United States' territorial limits, for storm surge and coastal flooding modeling, for analyzing coastal change, for planning and operations of maritime and other industries, for on-shore development and environmental monitoring, and for a host of other public and private sector applications. The data include the Great Lakes, the U.S. territorial waters which extend 12 nautical miles from the coast, and the nation's Exclusive Economic Zone (EEZ) which extends 200 nautical miles from the shoreline.

The Coastal Mapping Program supports the Integrated Ocean and Coastal Mapping (IOCM) Initiative which fosters interagency coordination and cooperation. CMP plays a leading role in the development of federal geographic data standards through the Federal Geographic Data Committee.

CMP products and services included in this study are:

- Shoreline Mapping
    - Nautical Chart Production
    - Change Analysis
    - Boundary Determination and Legal Aspects
- Shoreline Imagery
- Digitally Reproduced Historic Imagery
- Emergency Response Imagery

[1] U.S. Census Bureau, *Coastline Population Trends In the United States: 1960*-2008, Current Population Reports P25-1139, May 2010 and NOAA National Ocean Economics Program Web site market data http://www.oceaneconomics.org/

Goals

While the benefits of the nation's coasts have been widely described and many of the ways charting and mapping contributes have been enumerated,[2] there is little in the way of *quantitative* information about the users of mapping products and the economic and societal benefits derived. The purpose of a scoping study is to generate baseline information and order of magnitude estimates that can be validated and extended in a fuller analysis. This scoping study of NOAA's Coastal Mapping Program (CMP) provides a qualitative and quantitative analysis of users and applications of CMP's charting and mapping products and services and the nature of the benefits of those services, and order of magnitude estimates of the value of the economic and societal contribution of CMP's services. In addition, methodologies that can be used for fuller analysis are identified and suggestions for analysis are offered.

The goals of the study are to answer the following questions:

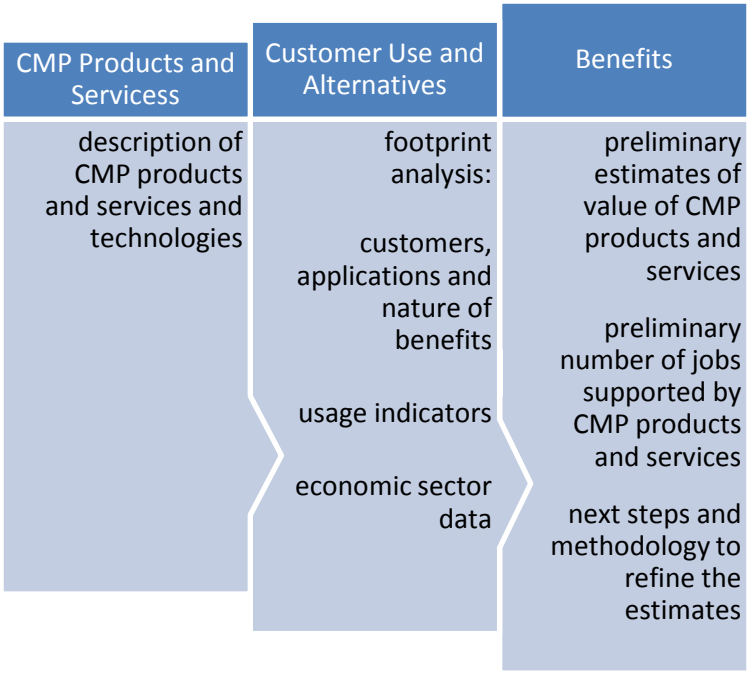
1. Who benefits from NOAA's CMP?
2. What is the nature of these benefits (how are these benefits accrued)?
3. What methodology is appropriate to best estimate the value of CMP products and services to these users?
4. What are the preliminary estimates of the value of CMP products and services?
5. How many jobs do CMP products and services support?

Study Components

Figure 1 depicts the study process and products as it flows from description of CMP products and services and technologies, to examination of customers and applications, to benefits and jobs supported, and to opportunities to refine the estimates in the future. Benefits are defined to include direct, indirect and induced economic benefits and non-economic benefits. Direct economic benefits include productivity effects and product and process innovation in sectors using the services. Indirect and induced economic benefits include demand effects on industries supplying using sectors, demands created by spending of using industries and their employees, and effects on innovation beyond using industries. Non-economic benefits include improvements in health and safety and the environment.

[2] National Research Council, *A Geospatial Framework for the Coastal Zone: National Needs for Coastal Mapping and Charting*, Washington, D.C.: The National Academies Press, 2004, Admiral Richard West, "Electronic Navigation Charts: Global Tools for Safety at Sea and Economic Benefits, slides, n.d., and Hydrographic Services Review Panel, *HSRP Most Wanted Hydrographic Services Improvements*, Federal Advisory Committee Special Report, 2007 http://nauticalcharts.noaa.gov/ocs/hsrp/hsrp.htm

Figure 1.Study Flow



A wide range of sources of information are utilized, including trade and academic studies, government statistical reports and NOAA Web sites. CMP provided information on data downloads, Web site activity and other program information.

CMP Products and Services and Technologies

CMP Products and services contribute to current social, economic and environmental activities and to meeting NOAA's long term goal of resilient coastal communities and economies, as articulated in NOAA's Next Generation Strategic Plan.[3] The objectives of that goal are:

- Resilient coastal communities that can adapt to the impacts of hazards and climate change
- Comprehensive ocean and coastal planning and management
- Safe, efficient and environmentally sound marine transportation
- Improved coastal water quality supporting human health and coastal ecosystem services
- Safe, environmentally sound Arctic access and resource management

The CMP products and services addressed were selected by CMP for inclusion in this study. They are shown in the order presented in the study contract. The descriptions here draw heavily from NOAA Web sites.[4]

The primary objective of the Coastal Mapping Program is to serve nautical charting requirements and adjunct scientific and engineering purposes. The data and information serve a great many additional purposes and stakeholders as well.

To meet the requirements of the Coastal Mapping program, RSD employs an all-source approach utilizing a broad spectrum of sensors on both aircraft and satellites. The predominant source is imagery collected from aircraft followed by imagery from high resolution satellite systems and Lidar from aircraft.

The Shoreline Mapping product group includes Nautical Chart Products, Change Analysis and Boundary and Legal Aspects.

Nautical Chart Production – high resolution, tide-coordinated shoreline data for nautical charts. The Remote Sensing Division of the National Geodetic Survey acquires digital imagery and remote sensing data and compiles shoreline data, primarily for application to the nautical charts produced by NOAA's Office of Coast Survey. Data for recent years have been produced in digital form. Many older, hardcopy shoreline manuscripts have been converted to digital form. The program also provides paper nautical charts and raster navigational charts (full-color images) that are geo-referenced digital images of all of NOAA's paper charts.

Nautical charts and maps are used primarily in in commercial shipping, commercial fishing, and recreational boating and fishing. CMP services help improve the efficiency of shipping lanes, peers and

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[3] National Oceanic and Atmospheric Administration, *Chart the Future: NOAA's Next Generation Strategic Plan*, December 2010 http://www.ppi.noaa.gov/ngsp/

[4] Links to some of these sources are:
http://www.ngs.noaa/gov/RSD/coastal/index.shtml
http://www.ngs.noaa.gov/RSD/shoredata/NGS_Shoreline_Products.htm
http://geodesy.noaa.gov/RSD/coastal/cscap.shtml
http://www.ngs.noaa.gov/RSD/cscap.shtml
http://oceanservice.noaa.gov/topics/navops/mapping/
http://www.ngs.noaa.gov/RSD?erp.shtml
Sources also include Captain Richard P. Floyd, "National Ocean Service Shoreline Mapping Program," downloaded January 17, 2010 http://cors.ngs.noaa.gov/PUBS_LIB/shore_map.html and Doug Graham, "Overview of NOAA's National Shoreline Mapping in the National Geodetic Survey," slides, National Oceanic and Atmospheric Administration, Coastal Geo Tools 2011, March 24, 2011.

ports. They are intended to help prevent shipping and environmental accidents in the first place as well as help in dealing with their aftermath. They also facilitate on-shore activities.

Change Analysis – consistent, accurate data for evaluation of port and other areas for changes to shoreline and critical infrastructure, and for analyzing the impact of sea level rise. The Coastal and Shoreline Change Analysis Program (CSCAP) analyzes shoreline changes by comparing recent high resolution satellite imagery or high altitude reconnaissance aerial photography with existing NOAA raster and vector nautical charts. High resolution satellite images are at a 61cm spatial resolution. All data (imagery and nautical charts) are brought to a common projection, spheroid and datum, and displayed as layers in a geographic information system (GIS). Changes are analyzed and recorded with descriptions in a point file.

By digitally overlaying satellite imagery with the charts, changes in shoreline features such as peers, bulkheads, shoreline configuration, jetties, groins, etc. can be easily detected. Shoreline changes are used to aid in updating nautical charts. The focus is on areas that have ports or otherwise are important to maritime commerce or are sensitive to change. The charts also are used internally by RSD to help determine which shoreline areas require revision using aerial photography and standard photogrammetric techniques.

Boundary Determination and Legal Aspects – local, state, and federal boundaries related to National Shoreline and marine and on-shore spatial planning. The shoreline data is used as a source to define the boundaries between private, state, and federal ownership and jurisdictions, including U.S international jurisdictions (see Shoreline Imagery). Tidal datum lines derived from NOAA nautical charts are used in determining marine and maritime limits.

Shoreline Imagery – georeferenced imagery and remote sensing data of the National Shoreline providing critical baseline data for demarcating U.S. marine territorial limits, including the Great Lakes and the nation's Exclusive Economic Zone, and for the geographic references needed to manage coastal resources and other uses. These data are considered authoritative when determining the official shoreline of the United States.

The shoreline is primarily delineated by means of stereo photogrammetry using tide-coordinated digital imagery and remote sensing data controlled by kinematic Global Positioning System (GPS) techniques. Photogrammetry is a branch of remote-sensing in which precise spatial relationships between objects are extracted from photographs. Additional technologies used include Light Detection and Ranging (Lidar), Interferometric Synthetic Aperture Radar ((IfSAR or InSAR), and hyperspectral imagery. RSD uses both internal resources and contractors to collect the data.

The result is a seamless, digital database of the national shoreline and a database of aerial photography. A critical difference between these maps and many other mapping efforts is that they are tide-coordinated or tide-controlled, which allows for the shoreline elevation data to be referenced to a tidal reference as required by nautical charting standards and federal and state law.

The primary aerial photographic product is has been a 9x9-inch color photograph. Historically this usually has been at scales from 1:10,000 to 1:50,000, but for the last ten years it has been digital imagery at scales from 1:5,000 to 1:10,000. Aerial photography surveys are conducted on varying time cycles, depending on the amount of change caused by human or natural forces. Once the data are processed, the accuracy of discrete points is generally 1.4 m horizontal and 2.8 m vertical. Other types of photographs acquired include panchromatic, false-color infrared, and black-and-white infrared.

The shoreline depicted in NOAA's nautical charts approximates the line where the average high tide,

known as Mean High Water (MHW), intersects the coast. Shoreline mapping also provides the line where Mean Lower Low Water (MLLW) intersects the coast.

The aerial photography, both analog and digital, is primarily accessed by the public through the National Ocean Service Data Explorer Web site (http://oceanservice.noaa.gov/dataexplorer/) which provides coastal maps (nautical charts without navigation aids), shoreline surveys (for mapping the official U.S. shoreline), coastal aerial photography, environmental sensitivity index maps, geodetic control points, maritime boundaries, estuarine and bathymetry data, and data from water-level stations. Other sites include metadata at geodata.gov (http://geo.data.gov/geoportal/catalog/main/home.page), the Digital Coast Web site (http://www.csc.noaa.gov/digitalcoast/) and the Aerial Photo Ordering System Web site (http://egisws02.nos.noaa.gov/ngsPhotos/).

CMP also conducts research on development of a multiple sensor approach to shoreline mapping.

While the program concentrates efforts on the most navigationally important areas, one-third of the U.S. shoreline has not been mapped since 1960 and the rest is maintained on a 30-year cycle. As a result, lack of a current shoreline remains a significant problem for marine safety and legal boundary determination.[5]

Digitally Reproduced Historic Imagery –historical imagery of the National Shoreline. More than 500,000 photo negatives from 1945 to the present are maintained in RSD archives. RSD is building a database of its digital shoreline holdings, accessible through Shoreline Data Explorer. Many older hardcopy shoreline manuscripts have been converted to digital form, mostly by projects managed by the NOAA Coastal Services Center. Historical data are available for download both in the Photo Ordering System and on the Notable Photographs Web page. The Notable Photographs file was populated in 2005.

Emergency Response Imagery – post event imagery used for impact assessment and planning for hurricane and flood damage, earthquakes and other natural disasters, and oil spill response. A variety of spatially-reference data sets can be acquired and rapidly disseminated to federal, state, and local government agencies, as well as businesses, media and the general public.

Other activities – In addition to the products and services described, CMP conducts research to develop tools and techniques, educates constituents through extensive material on its Web site, and contributes to scientific development through presentations at conferences and publications in professional literature. Activities to develop remote sensing for other activities include developing methodologies and acquiring remote sensing data to support NOAA's Coral Reef Program, Marine Debris Program, and oil spill response and damage assessment. Activities that engage the scientific community include, for example, workshops held and papers presented and at American Society for Photogrammetry & Remote Sensing meetings in 2008, 2009, and 2010. The article "National Ocean Service Shoreline: Past, Present, and Future," by Graham, Sault, and Bailey[6] is linked to from 24 other professional papers.

[5] Doug Graham, "Overview of NOAA's National Shoreline Mapping in the National Geodetic Survey," slides, National Oceanic and Atmospheric Administration, Coastal Geo Tools 2011, March 24, 2011, page 11.
[6] D. M. Graham, Sault, and J. Bailey, "National Ocean Service Shoreline: Past, Present, and Future," in Byrnes, M., M. Crowell, and C. Fowler (eds.), *Shoreline Mapping and Change Analysis: Technical Considerations and Management Implications*, Journal of Coastal Research, Special Issue No. 38 (2003), pp.14-32.

Footprint Analysis of Customers

The "footprint" or "trade space" analysis includes discussion of CMP customers, applications, and the nature of the benefits of CMP products and services. Quantitative indicators are provided on the extent to which CMP information is used and data on key using sectors is examined.

Applications, Customers, and the Nature of Benefits

Applications

Information has the most value when action can in fact be taken in response to it, when the consequences of making the wrong decision are large, and when the constraints on using the information and the costs of the information are small.[7] The conditions for high value are well met in uses of CMP information.

Charts and maps of maritime zones are used to ensure safe navigation and efficient commerce, protect the marine environment, and for many other functions throughout society.

NOAA maps and charts delineate the nation's coasts, the Great Lakes, the nation's territorial waters, and offshore boundaries through the 200 mile Exclusive Economic Zone (EEZ).[8] An illustration of the various limits is shown in Appendix A. The EEZ is the official shoreline defined on NOAA's charts.[9]

The shoreline boundaries established by CMP are used to define federal and state jurisdictions and authorities and private riparian rights.[10] Businesses and government activities benefit from greater accuracy and removal of uncertainty. Marine boundaries can change rapidly, creating a need for frequent updating for use in government and business operations and legal challenges, as well as for navigation.

The nation's coasts are managed by the individual states. The coastal zone beyond 3 miles is the responsibility of the federal government.

Financial assistance to the states is administered through NOAA's Coastal Zone Management Program. NOAA provides technical guidance and information on coastal management to states, local governments and port authorities. CMP charts and maps are an important part of that process. State environmental agencies alone spent more than $12 billion in 2008.

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[7] Molly Macauley and Ramanan Laxminarayan, "The Value of Information: Methodological Frontiers and New Applications for Realizing Social Benefit," Conference Summary, June 28-29, 2010, Resources for the Future, August 2010, pp.4-5.

[8] M.W. Reed, *Shore and Sea Boundaries: Volume 3, The Development of International Maritime Boundary Principles through United States Practice.*U.S. Department of Commerce and U.S. Department of the Interior, Washington, D.C.: U.S. Government Printing Office, 2000 and Congressional Research Service, *Federal-State Maritime Boundary Issues*, The Library of Congress, May 5, 2005.

[9] See Reed, M.W., *Shore and Sea Boundaries: Volume 3, The Development of International Maritime Boundary Principles through United States Practice.* U.S. Department of Commerce and U.S. Department of the Interior, Washington, D.C.: U.S. Government Printing Office, 2000, and NOAA Office of the General Council, "Maritime Zones and Boundaries," http://www.gc.noaa.gov/gcil_maritime.html

[10]Coastal States Organization, *Putting the Public Trust Doctrine to Work: The Application of the Public Trust Doctrine to the Management of Lands, Waters and Living Resources of the Coastal States*. Washington, D.C.: Coastal States Organization, 1997.

Official NOAA boundaries have factored into administrative and legal cases, including the proposed wind turbines off Nantucket, Alaskan energy development, and a 2011 administrative decision involving Alaska fisheries management. Clear boundaries can prevent or resolve disputes or provide a basis for legal action. Their primary value may be in preventing disputes from escalating.

One important area of application is in determining federal and state jurisdictions in oil and gas leasing in the Gulf of Mexico, off the coasts, and in Alaska.

Alaska shoreline is of particular importance for boundary determination today because, while it has a limited geospatial infrastructure, melting sea ice is causing receding shorelines that impact populations and businesses. Substantial energy and mineral resources may be exposed. Moreover, the opening of a Northwest Passage in summer would be important to maritime commerce. "The U.S. EEZ in the Arctic encompasses 568,000 square nautical miles, about a third of which is considered navigationally significant."[11]

Fishing issues also are a concern, including encroachment of other nations around the U.S. Pacific territories and the migration of species north around Alaska with warming.

Under the United Nations Convention on the Law of the Sea (UNCLOS), a nation can extend its EEZ jurisdiction beyond 200 nautical miles if it can demonstrate submerged extensions of its continental margin based on a complex set of rules that requires an analysis of the depth and shape of the seafloor and an understanding of the thickness of the underlying sentiment.[12] Some hydrographic studies have been carried out in preparation for a possible extension of the U.S. jurisdiction. Extension would be possible if the U.S. acceded to UNCLOS, which it has not yet agreed to join. However, the U.S. might follow UNCLOS rules without joining, as it has in setting its EEZ.

EEZ extension is primarily an issue around Alaska and the U.S. Pacific territories. One reason for interest in extending the EEZ in the Pacific is the increasing importance of manganese nodules and rare earths, especially lithium.

CMP is part of NOAA's Arctic initiative and will be playing a role in assessing the physical environment in Alaska. However, as yet there are no charts or geologic framework. Extension could potentially have large economic benefits and CMP could make an important contribution to achieving those benefits in the future.

CMP products and services contribute to many public and private activities, including:

- Navigation safety
- Shoreline modification
- Environmental protection (including precise coordinates of sensitive and protected areas)
- GIS applications in coastal zone management
- On-shore development
- Recreation
- Fish habitat mapping
- Energy exploration, development and production

[11] Jane Lubchenco, "Defending U.S. Economic Interests in the Changing Arctic: Is There a Strategy?" written statement before the Committee on Commerce, Science and Transportation, Subcommittee on Oceans, Atmosphere, Fisheries , ad Coast Guard, United States Senate, July 27, 2011, p.7.

[12] National Research Council, *A Geospatial Framework for the Coastal Zone: National Needs for Coastal Mapping and Charting*, Washington, D.C.: The National Academies Press, 2004, pp.59-60.

- Underwater exploration and construction
- Offshore aquaculture
- Planning and response to natural disasters and environmental emergencies
- Coastal and ocean jurisdiction mapping and dispute prevention and resolution
- Marine spatial planning
- Legal and insurance applications
- Homeland and port security
- Monitoring sea level change
- Scientific research
- National and international standards
- Archaeology and cultural heritage
- Military activities

The 2004 National Academies study: *A Geospatial Framework for the Coastal Zone: National Needs for Coastal Mapping and Charting* developed a framework of seven themes that capture the needs and activities of the government agencies involved in coastal zone mapping and charting:[13]

- Navigation
- Homeland Security
- Coastal Zone Boundaries
- Environmental and Living Resource Management
- Coastal Hazards
- Minerals and Energy Management
- Cultural Resource Management

Environmental and living resource management includes coastal wetland monitoring for flood maps and habitat monitoring.

Cultural resources along coasts and offshore areas include coastal and maritime parks, maritime preservation sites, underwater and coastal archaeological sites, maritime national historic landmarks, and national monuments.

Some insights into applications of CMP customers come from surveys conducted for broader purposes. The 2010 Coastal Services Center Coastal Resource Management Customer Survey reported results from 218 responding Center partners, contacts, and members of mailing lists. The study found that:[14]

- The priority topics were climate change impacts, land use planning and growth development, and wetlands loss. Data use was highest for land use planning and growth management, public access, and wetland loss. Coastal conservation data were used by more than half of respondents. The most cited data needs were economic data and climate change.

- Collaboration with other groups was highest with audiences in coastal management, the scientific community and the public.

[13] Committee on National Needs for Coastal Mapping and Charting, National Reserach Council, *A Geospatial Framework for the Coastal Zone, National Needs for Coastal Mapping and Charting*, National Academies Press, 2004. P.25 http://www.nap.edu/openbook.php?isbn=0309091764

[14] MRAG Americas, Inc., *2010 Coastal Resource Management Customer Survey*, Final Report to the National Oceanic and Atmospheric Administration Coastal Service Center, July, 2010.

- Spatial data was primarily used in the areas of flooding, inundation, and storm surge, sea level rise and erosion. Remote sensing data and derivatives (imagery, elevation, land cover, bathymetry, and mapping) was used by more than 4 out of 5 respondents. It was most often used on a monthly rather than on a daily or weekly basis, and was rated of high importance for decision-making.

- Technical assistance was rated most useful for data access, for using GIS for coastal management and for applying data for decision-making.

Indications of interest in RSD activities and the subjects it addresses also come from the frequency of mentions of various terms in Google searches. These magnitudes are shown in Appendix D.

Customers

CMP products and services serve many types of customers and applications (Table 1).

Table 1. Customers and Applications by Product or Service		
Product or Service	**Customers and/or Stakeholders**	**Applications**
Nautical Chart Production	• Office of Coast Survey • Shipping industries • Energy producing industries • Commercial fishing • Recreational boating and fishing • Cruise ships • Military • Commercial mapping information vendors and publishers and their public and private customers	• Guiding ships and boats for safety and efficiency • Managing ports and their construction • On-shore economic development • Offshore energy exploration and production and on-shore support • Planning and operations of companies and governments • Coastal resource management – habitat, inundation monitoring, sustainable development, and other aspects of assessing and managing environmental change • Disaster and emergency response • Adjunct scientific and engineering purposes
Change Analysis	• Nautical Chart Production program • Remote Sensing Division • Office of Coast Survey • Federal, state, and local agencies • Port authorities • Companies • Emergency response managers • Coastal resource managers • Environmentalists and conservationists	• Detection of changes in shoreline features (peers, bulkheads, shoreline configuration, jetties, groins, etc.). • Updating nautical charts • Port development • Coastal engineering and development, including ports • Planning and operations of companies and governments • Coastal resource management – habitat, inundation monitoring, sustainable development, and other aspects of assessing and managing environmental change • Disaster and emergency response • Shoreline changes are used internally by RSD to help determine which shoreline areas require revision using aerial photography and standard photogrammetric techniques

Boundary Determination and Legal Aspects	• Federal, state, and local agencies • Private businesses and developers • The general public • Lawyers, courts and plaintiffs • Property and casualty insurance companies • Title insurance companies • Military • International organizations	• Defining the boundaries between private, state, and federal ownership and jurisdictions, including the Great lakes, the territorial sea, and the Exclusive Economic Zone • Preventing and resolving boundary disputes • Testifying as experts in court cases • On-shore economic development • Planning and operations of companies and governments • Coastal resource management • Assessing damage • Disaster and emergency response • Setting boundaries in the Arctic, including preparing for opening of the Northwest Passage • Preparing for possible extension of the EEZ
Shoreline Imagery	• Nautical Chart Production program and British and Canadian programs • Office of Coast Survey • Remote Sensing Division • Federal, state, and local agencies and the general public • Cooperative project partners, including federal government and state agencies, private organizations, universities and international organizations • Coastal resource managers • Emergency response managers • Developers • Environmentalists and conservationists • Commercial mapping information vendors and publishers and their public and private customers • Companies	• U.S., British Admiralty and Canadian Hydrographic Service nautical charts and maps • Defining the boundaries between private, state, and federal ownership and jurisdictions, including the Great Lakes, the territorial sea, and the Exclusive Economic Zone • Coastal elevation mapping to determine water level change • Topographic mapping • Seabed mapping • Locating features or obstructions to ensure the safety of marine and air navigation • Offshore energy exploration and production and on-shore support • On-shore economic development • Planning and operations of companies and governments • Natural resource identification • Coastal resource management – habitat, erosion and inundation monitoring, sustainable development, etc. • Natural hazard modeling (storm

		surge, coastal flooding, inundation) and pollution modeling • Disaster and emergency response • Homeland security • Measuring sea level rise • Testing equipment and developing techniques for data collection and mapping • Developing and promoting mapping standards in cooperation with other agencies
Digitally Reproduced Historic Imagery	• Users conducting GIS analysis • Users producing special purpose maps • Environmentalists and conservationists • Historians • Archeologists	• Geographic Information System analysis • Historical nautical charts • Special purpose maps of the coastal zone • Archaeology and cultural heritage • Assessing environmental change • Measuring long term sea level changes
Emergency Response Imagery	• Federal, state, and local agencies and the general public, including the Department of Homeland Security • Military • Emergency managers • Airlines and other transportation companies • Retailers and other businesses • Commercial mapping information vendors and publishers and their public and private customers • Broadcast, Internet and print media, including weather and news reporters • Environmentalists and conservationists	• A variety of spatially-referenced datasets, many of which can be acquired and disseminated rapidly are used in responding to disasters • Developing disaster recovery strategies, including evacuation routes • Determining flight and other transportation routes • Damage assessment through observation and comparison of before and after imagery • Natural hazard modeling (storm surge, coastal flooding, inundation) and pollution modeling • Opening ports quickly after emergency closings • Determining when to open and close businesses • Determining when to send insurance adjusters • Rebuilding damaged properties • Allowing those displaced to see images of their homes and neighborhoods • Weather and news reporting • Assessing environmental impacts of events

CMP services are used by many of the 18 federal agencies with responsibility for marine activities that participate in the Cabinet-level interagency Committee for the Marine Transportation System. The Committee has representation from the following agencies:

Department of Transportation
Department of Agriculture
Department of Commerce
Department of Justice
Department of Defense
Department of Labor
Department of Homeland Security
Department of Energy
Treasury Department
Joint Chiefs of Staff
State Department
Environmental Protection Agency
Department of the Interior
Federal Maritime Commission
Council on Environmental Quality
Assistant to the President for Homeland Security
Assistant to the President for Domestic Policy
Assistant to the President for Economic Policy

Customers of the national shoreline and/or its products include the U.S. Geological Survey (USGS), the Interior Department's Bureau of Ocean Energy Management, Regulation and Enforcement (BOEMRE, formerly the Minerals Management Service), the Federal Emergency Management Agency (FEMA), the U.S. Army Corps of Engineers (USACE), the Bureau of Land Management (BLM), the Fish and Wildlife Service (FWS), the National Park Service (NPS), the U.S. Department of Agriculture Forest Service, the Environmental Protection Agency (EPA), the Department of Homeland Security (DHS), the U.S. Coast Guard (USCG), and the U.S. Navy.

Users of Katrina imagery included FEMA, USACE, NGA, USGS, DOJ, ASAF, USATCOM, USMC, Centers for Disease Control, Canada Department of Defense, URS Corporation, Google, Digital Globe, Allstate, Southeast Louisiana Flood Protection Authority, NVision Solutions, Mississippi State University Geosystems Research Institute, University of Florida Department of Civil and Coastal Engineering, Dewberry, High Noon Entertainment, Crowsey, Inc., BAE Systems, Rookery Bay National Estuarine Reserve, C.H Fenstermaker & Associates, National Geographic Magazine, SAIC, Haag Engineering Co., Nacona News, Earth Data International, and LSU Department of Geography and Anthropology.

At least 15 federal agencies are themselves involved in mapping in one way or another.

- The U.S. Army Corps of Engineers is responsible for maintaining, dredging and surveying inside the channel. It does bathymetry, primarily to support dredging. A shoreline assessment study is in progress which is tied to sediment transport rather than shoreline mapping. CMP partners with USACE on activities throughout the U.S. and its territories in which USACE applies CMP methods to CMP data to derive the shoreline. In this process USACE is a user of CMP data.

- The coastal mapping done by the U.S. Geological Survey (USGS) is oriented toward research. USGS is proposing a Lidar for the Nation initiative for determining elevation which is not yet funded.

- FEMA is a customer for floodplain maps.

Interagency coordination takes place in setting standards. However, agencies with different missions often use inconsistent standards (e.g. whether the data are tide-coordinated) and different vertical datums. The USGS and the USACE are among users of different standards than NGS.

Many state agencies are also involved in mapping and use NOAA's national shoreline and/or its other products. These include the California Department of Transportation, New Hampshire state government, South Carolina Department of Health and Environmental Control, and the Connecticut Department of Information Technology. Some, including Florida, California and Massachusetts, do so as partners with NOAA.[15]

Academic institutions using CMP products include the United States Naval Academy, Coast Guard Academy, United States Merchant Marine Academy, Southeastern Missouri State University, University of California-Berkeley, Harvard University, Florida Atlantic University, Florida Institute of Technology, North Carolina State University, University of Arizona, Georgia Tech Savannah Campus, Rochester Institute of Technology, The University of Texas Austin-Institute for Geophysics, Columbia University-Lamont-Doherty Earth Observatory, Ohio State University-Civil and Engineering and Geodetic Science, University of Wisconsin-Information & Media Technologies, Milwaukee, Clemson University, Oregon State University, and various state maritime academies.[16]

Many international organizations and foreign governments make use of CMP information. Among these are the Pacific Region of Fisheries and Oceans Canada and the Renaissance Computing Institute at Europa. NGS' contributes to the Integrated Ocean and Coastal Mapping Initiative, which supports the U.S. Ocean Action Plan call for Coordination of Ocean and Coastal Mapping Activities, with 295 Lidar and 184 orthomosaic image downloads in 2011 and 1281 Lidar and 454 orthomosaic images since 2006.[17]

A variety of government organizations distribute CMP information. Some add to it and/ or use it to provide services. The Office of Coast Survey distributes nautical charts to end-users and intermediaries, along with aerial imagery, Lidar and emergency response imagery and other CMP information on its Digital Coast Web site.[18] The U.S. Geological Survey distributes emergency response imagery on its Hazards Data Distribution System Web site. USGS also includes maps of hurricanes and other natural hazards as well as boundaries of Federal, state, county and Native American lands on its Web site for The National Map.

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[15] For details see Floyd, Captain Richard P., "National Ocean Service Shoreline Mapping Program," downloaded January 17, 2010 http://cors.ngs.noaa.gov/PUBS_LIB/shore_map.html

[16] The Shoreline Imagery Program has received email requests for information in recent years from organizations including:

U.S National Park Service; USDA Forest Service; NASA SocioEconomic Data and Applications Center Florida Department of Environmental Protection; California Department of Transportation; The University of Arizona; Michigan State University; Bucknell Universit, University of Georgia; Britannia Royal Naval College; University of Virginia; Naval Postgraduate School; Scripps Institution of Oceanography; Smithsonian Environmental Research Center; CEERD-HC-SE Coastal and Hydraulics Laboratory; New Dungeness Lightstation Association; Coral Bay Community Council; SEDAC Eastern Panhandle Regional Planning & Development Council; Henderson District Public Libraries; Geomatrix Consultants, Inc.; Sneed Shipbuilding Inc.; various engineering and architectural firms and individuals; professional surveyors; and private individuals

[17] For a description of the program see http://ngs.noaa.gov/RSD/IOCM.shtml

[18] CMP currently notifies OCS of new products, but OCS doesn't disseminate the information. Some form of dissemination to potential users could be considered.

Private companies are important to the distribution of NOAA and non-NOAA charts and maps. For example, HAS Images distributes digital imagery under contract with RSD. OceanGrafix is NOAA's official distributor of print-on-demand paper nautical charts. Navionics distributes electronic charts through dealers for recreational boating and fishing. Navionics Mobile is a downloadable electronic nautical chart app for the iPhone, iPad and Android devices that automatically covers the area of the mariner's location at the time of download. Nautical maps are included on Garmin's installed GPS system on recreational boats.

The lack of data on external Web sites that distribute CMP data (including both NOAA distribution partners and value added resellers) poses a challenge in understanding changing overall demands. At the same time, the increasing number of channels provides opportunities to reach wider audiences and better serve constituents.

In a 2005-2006 survey, 49% of respondents representing commercial vessels reported using private sector electronic navigation charts in their electronic nautical chart systems.[19]

After hurricane Katrina, "Several commercial vendors incorporated the [RSD] remote sensing data into web-based map servers, allowing for searches on street addresses, city names, and points of interest."[20]

Methods of distribution have been shifting over time for some products as alternatives have increased. Data is distributed more widely as nautical charts for which CMP data is a key supporting product. The lack of data on external Web sites that distribute CMP data and products based on it (including both NOAA distribution partners and value added resellers) poses a challenge in understanding changing overall demands. At the same time, the increasing number of channels provides opportunities to reach wider audiences and better serve constituents.

One way of identifying numbers of potential customers is by examining data on employment. Table 2 shows employment in 2008 for selected occupations in the order which they appear in the occupational classification. The largest employment numbers are in water transportation, surveying and mapping, engineering and environmental sciences.

[19] Hauke Kite Powell, *Use and Value of Nautical Charts and Nautical Chart Data in the United States*, report to the NOAA Office of the Coast Survey, Woods Hole Oceanographic Institute, August 2007, p.21.
[20] Hydrographic Services Review Panel, *Most Wanted Hydrographic Services Improvements*, Federal Advisory Committee Update Report, 2010, p.29 http://www.nauticalcharts.noaa.gov/ocs/hsrp/docs/2010_Most_Wanted_%20Hydrographic_Services_Improvements.pdf

Table 2. Employment in Selected Occupations, 2008
(thousands)

Occupation	Employment
Natural science managers	44.6
Emergency management specialists	12.8
Cartographers and photogrammetrists	12.3
Surveyors	57.6
Environmental engineers	54.3
Marine engineers and naval architects	8.5
Petroleum engineers	21.9
Environmental engineering technicians	21.2
Surveying and mapping technicians	77.0
Conservation scientists	18.3
Environmental scientists and specialists, incl. health	85.9
Geoscientists, except hydrologists and geographers	33.6
Hydrologists	8.1
Economists	14.6
Urban and regional planners	38.4
Geographers	1.3
Historians	4.7
Geological and petroleum technicians	15.2
Environmental science and protection technicians, including. Health	35.0
Fishers and related fishing workers	35.6
Air transportation occupations	50.4
Water transportation occupations	81.1

Note: Includes military.
Source: Alan T. Lacey, and Benjamin Wright, "Occupational Employment Projections to 2018," *Monthly Labor Review* (November 2009), pp.82-123.

Some data are available indicating the type of employer which persons were employed by, using a similar but less detailed occupational classification (Table 3). The large share of workers in the private sector, including for profit firms and the self-employed, stands out for a number of occupations. Of course, some are under contract from governments.

Table 3. Distribution of Selected Occupations by Type of Employer, 2005-2009							
Occupation	**Federal Gov't**	**State Gov't**	**Local Gov't**	**Private, For Profit**	**Self-Employed**	**Academic and Other Not-for-Profit**	**Total**
Natural sciences managers	8.0%	14.2%	3.7%	58.4%	2.3%	13.5%	100.0%
Surveyors, cartographers, and photogrammetrists	8.9%	8.7%	14.4%	52.5%	13.0%	2.5%	100.0%
Environmental engineers	10.5%	14.5%	13.3%	56.5%	3.2%	2.0%	100.0%
Marine engineers and naval architects	26.0%	1.2%	0.5%	66.0%	5.0%	1.3%	100.0%
Surveying and mapping technicians	2.1%	5.0%	7.9%	75.1%	8.8%	1.2%	100.0%
Conservation scientists and foresters	31.6%	22.5%	9.3%	22.2%	9.9%	4.5%	100.0%
Environmental scientists and geoscientists	11.9%	15.9%	5.9%	54.8%	8.7%	2.8%	100.0%
Economists	35.8%	11.2%	7.4%	28.3%	4.2%	13.1%	100.0%
Urban and regional planners	2.9%	6.4%	71.5%	14.4%	1.8%	3.0%	100.0%
Note: Employed and at work in the civilian labor force. Source: Author's tabulations of U.S. Census Bureau, American Community Survey, Public Use Microdata Sample, 2005-2009.							

CMP Usage Indicators

Page request and download information from RSD provide indications of use of CMP products. As indicated, various other sites, including those under contract with NOAA, distribute CMP information. Page requests and image and chart downloads do not include distribution from those other sites.

Page Requests

More than 25 million page requests were made on CMP and related NOAA Web sites during 2011 (Table 4). The total is dominated by page requests from the aerial image storm site for which downloads surged to over 25 million from 402,781 in 2010. Of course all page requests and downloads are not of equal economic and societal significance and some downloads are widely distributed to others by those who download the information.

Table 4. Page Requests from CMP and Related NOAA Web Sites, 2011	
Web Site	**Page Requests**
Aerial Photo Orders	5,694
Coastal Mapping Program	20,730
NOAA Shoreline Data Explorer	26,089
Aerial Image Storm	25,664,507
Total	**25,717,020**

Nautical Chart Downloads

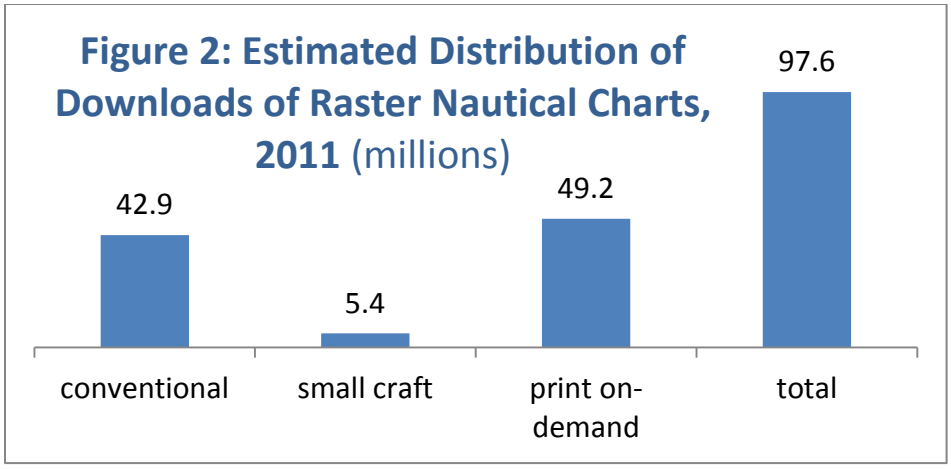
Downloads of paper charts from NOAA have been declining as electronic charts have come into more widespread use. Only 210,843 paper nautical charts were downloaded from NOAA in 2009. In addition, public sales of Coast Pilot chart books totaled 18,695 in 2010.[21]

NOAA makes two versions of electronic charts, Electronic Navigational Charts (ENCs) and Raster Navigational Charts (RNCs). Both are available for free download over the Internet. Electronic (Vector) Navigation Charts are a rendering of a lithographic chart in a point-by-point format. Used with a chartplotter, they allow zooming in without distortions. Raster Navigation Charts are digital scans of printed lithographic charts.

Downloads of Electronic Navigation Charts totaled 141,615,580 in 2011. Downloads of Raster Navigation Charts totaled 97,550,043.

Downloads of ENCs in 2011 totaled 141,615,580, an average of 12 million per month. Downloads of RNCs in 2011 totaled 97,550,043, an average of 8 million per month. ENC downloads were typically downloads of "zip files" which include many charts in one file and often consisted of downloads of the entire suite of charts. Many of these downloads represent updates to already downloaded charts. Keeping charts updated with critical changes is extremely important for safety and has now become much more widespread.

The estimated distribution of raster navigation charts in 2011 is shown in Figure 2.



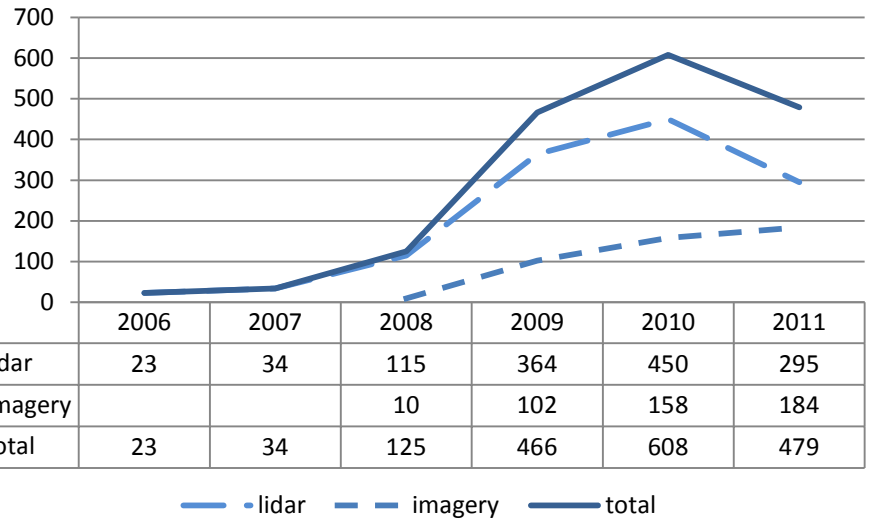
[21] The United States Coast Pilot is a series of nine nautical books by geographic area that contain supplemental information that is difficult to portray on electronic nautical charts.

The above data do not include distribution by NOAA vendors or British Admiralty and Canadian Hydrographic Service versions of NOAA charts. Many large vessels carry British and Canadian versions as well as NOAA charts.

Digital Coast Downloads of Lidar and Imagery

The National Ocean Service Digital Coast Web site has been an increasingly important source of coastal mapping information as it has become known. Figure 3 shows the numbers of downloads of Lidar and imagery from the site in 2011. Domain names from requesting sites have been predominantly com (34%), edu (28%), and gov (23%), with much less demand from org (4%), mil (3%) and net (2%). Three percent of top level domain names' requests for images were from UK domain names. Other domain names, largely those of other countries, accounted for 2%. This data does not include downloads of navigation charts or the shoreline and emergency response images for which the Digital Coast site routes users to CMP sites.

Figure 3: Number of Digital Coast Downloads of LIDAR and Imagery, 2006-2011



	2006	2007	2008	2009	2010	2011
lidar	23	34	115	364	450	295
imagery			10	102	158	184
total	23	34	125	466	608	479

There are 180,000 photos on the Photo Ordering System. The data include both historic and current imagery. Downloads from the system began during part of 2009. In 2011 there were 5,694 page requests.

Vector Shoreline Downloads

Because of limitations in the way data is currently collected, some information on downloads by product is last available only for the first half of 2008. Total vector shoreline product downloads from the Shoreline Data Explorer were 827 during that period. The annualized number of downloads, assuming the same number in the second half of the year, is 1,652. The number of users, including users in multiple months, averaged about 40 per month.[22]

[22] Similar data for imagery downloads from the NGS Imagery Viewer cannot be taken as representative because they are heavily influenced by the timing of hurricanes and tornadoes.

Emergency Response Imagery

Insured catastrophic losses alone totaled more than $350 billion in the U.S. in today's dollars between 1990 and 2009.[23] Nearly half were due to hurricanes and tropical storms and nearly one third to tornadoes. Table 5 shows the values for 2000-2011 in dollars of the year the event occurred and in dollars of year 2010 purchasing power. Losses vary greatly from year to year. Losses were $35.9 billion in 2011, a level only exceeded in the last decade in 2005.

Interest in emergency response imagery has been influenced by the increased damage associated with growth of population and economic activity along the coasts and other vulnerable areas. Other factors may include weather extremes associated with climate change[24] and the expansion of emergency response services after 9/11. The growth of alternative media may be a source of increased interest as well. Bouwer states that: "…direct economic losses from large weather disasters [not adjusted for inflation] have increased at a rate of about 125% per decade since the 1970s,…"[25]

Table 5. Value of U.S. Insured Catastrophic Losses, 2000-2011
($billions)

Year	Current Dollars	Dollars of 2010 Purchasing Power
2000	4.7	5.9
2001	26.5	32.4
2002	5.9	7.0
2003	12.9	15.2
2004	27.5	31.4
2005	62.3	68.9
2006	9.2	9.9
2007	6.7	7.0
2008	27.0	27.6
2009	10.6	10.6
2010	14.1	14.1
2011	35.9	34.8

Note: Includes terrorism.
Source: Insurance Information Institute from ISO.

The Emergency Response Imagery program has provided remote sensing information for many emergencies, typically serving among early responders. RSD coordinates with and is often tasked by government agencies such as the Department of Homeland Security. A majority of responses have been in coastal regions affected by hurricane landfalls. Aircraft utilize high resolution collection systems. Accurate geospatial products provided include geo-referenced imagery, Lidar, Geographic Information Systems (GIS), and digital files and maps. The goal is to make the data available as soon as possible, generally within 24 hours. Final digital products are posted on NOAA, USGS and other Web sites (http://storms.ngs.noaa.gov/eri_page/index.html; http://hdds.usgs.gov/hdds2/).

The most frequent involvements have been for hurricanes, but there also have been engagements for tornadoes, the Deepwater Horizon (BP) oil spill, earthquakes, flooding, and Nor'Easters. Events the Emergency Response Imagery program has responded to include:

- Hurricane Irene (2011)
- Joplin, MO Tornado (2011)
- North Dakota Flooding (2011)
- Alabama Tornadoes (2011)
- Hurricane Earl (2010)

[23] Insurance Information Institute based on ISO's Property Claim Service Unit (PCS) http://www.iii.org/media/facts/statsbyissue/catastrophes/ Direct insured losses of more than $25 million. Excluding terrorism. Author's calculations based on ISO for 2010.
[24] Laurens M. Bouwer, "Reply to Neville Nichols Comments on 'Have Disaster Losses Increased Due to Anthropogenic Climate Change?,'" *Bulletin of the American Meteorological Society* (June 2011), notes that anthropogenic changes have been established for smaller-scale weather extremes such as heat waves, droughts and heavy precipitation events but states that there has not been a demonstrated trend for larger events.
[25] *Ibid* , p.792.

- Deepwater Horizon (2010)
- Mexico/Baja California Earthquake (2010)
- Haitian Earthquake (2010)
- Nor'Easter Nov09 (2009)
- Hurricane Ike (2008)
- Hurricane Gustav (2008)
- Hurricane Humberto (2007)
- Tropical Storm Ernesto (2006)
- Hurricane Wilma (2005)
- Hurricane Rita (2005)
- Hurricane Ophelia (2005)
- Hurricane Katrina (2005)
- Hurricane Dennis (2005)
- Hurricane Ivan (2004)
- Hurricane Jeanne (2004)
- Hurricane Isabel (2003

FEMA uses remote sensing data to coordinate search and rescue efforts and to determine eligibility for federal disaster aid. Insurance companies use current and historic imagery to assess damage and to decide when to send adjusters. After the 2011 Alabama tornadoes, lumber companies used remote sensing images to examine impacts to forests to determine how many trees could be removed.

Boundary Determination and Legal Aspects

The boundaries established from CMP maps are the legal boundaries for determining the coverage of the U.S., including the Great Lakes, and the U.S. Exclusive Economic Zone (EEZ) which extends 200 nautical miles beyond the shore. The boundaries of the U.S. territorial sea, contiguous zone and continental shelf are also determined.[26] The survey establishes the boundaries between the federal government and the states and between governments and private ownership and jurisdictions.

The official boundaries are used in public and private negotiations and administrative processes, in planning and in legal proceedings for purposes ranging from dispute resolution to resource exploration to economic development and environmental management.

The EEZs boundaries are essential in designating mineral and fishing rights and responsibilities for shipping lanes. EEZs are established under the United Nations Convention on the Law of the Sea, and while the United States has not yet signed the treaty, it adheres to it for boundary purposes. If the U.S. joined the treaty it could claim rights to an extended continental shelf beyond the 200 mile EEZ, if it could show that the continental shelf extended based on seabed conditions.

Among the legal applications that can be supported by remote sensing data and maps are environmental litigation, government and private boundary resolution, and litigation and land management cases. Lawyers use historical imagery for before and after comparisons to show damage that was caused by a storm or the presence of an obstruction before an incident. The data is used in support services from legal certification to research to exhibits for trials and administrative hearings.[27]A number of firms such as

[26] For an explanation, see NOAA Office of the General Council, "Maritime Zones and Boundaries," http://www.gc.noaa.gov/gcil_maritime.html

[27] Aerial Archives, "Aerial Photograph, Satellite Imagery and Remote Sensing Data for Litigation and Other Legal Applications," aerialarchives.com http://www.aerialarchives.com/legal.htm

International Mapping and Aerial Archives provide aerial photography, remote sensing data and satellite imagery for boundary and other legal applications.

Economic Sector Data

The private surveying and mapping industry is both a user and (often value added) reseller of CMP products. Resellers may add value by enhancing the information on the maps, integrating products, or in the manner in which data is distributed. Information is provided in this section on attributes of several other industries that are customers for CMP products and services. Data on marine safety also is included.

The Private Surveying and Mapping Industry

The 2007 Economic Census provides information on establishments, revenue, payroll and employment of the surveying and mapping (except geophysical services) industry (NAICS code 541370). The industry is defined to include "establishments primarily engaged in performing surveying and mapping services of the surfaces of the earth, including the sea floor. These services may include surveying and mapping of areas above or below the surface of the earth, such as the creation of new easements or segregating rights in parcels of land by creating underground utility easements."

Detail is provided on the size distribution of establishments and on revenue by product. "Establishments" refers to individual locations. The same firm may have multiple establishments.

The private surveying and mapping except geophysical services industry had sales of $6.76 billion and 69,201 employees in 2007.

Sales increased 50% from 2002 to 2007, reflecting the construction boom as well as the underlying trend of growth in the industry that has been stimulated by technological advances. After inflation, the increase was 33%.

Many establishments had the majority of their revenue in other product lines, including geophysical surveying and mapping, information systems, and engineering.

Activities took place in establishments with widely varying sizes (Table 6).

Table 6. Sales Size Distribution of Establishments Operated the Entire Year in the U.S. Private Surveying and Mapping (Except Geophysical Services) Industry, 2007							
Sales	**Establish-ments**	**Sales ($ millions)**	**Receipts per Establish-ment**	**Annual Payroll ($ millions)**	**Paid Employees**	**Payroll Per Employee (dollars)**	**Sales per Employee**
Establishments operated for the entire year							
Under $25,000	283	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
$10,000-$24,999	343	12.7	37,026	4.5	408	11,029	31,127
$50,000-99,999	906	67.6	74,614	25.4	1,493	17,013	45,278
$100,000-$249,999	2,349	394.0	167,731	167.0	6,427	25,984	61,304
$250,000-499,999	1,896	684.0	360,759	325.3	10,167	31,996	67,276
$500,000-$999,999	1,542	1,089.9	706,809	540.9	13,904	38,902	78,388
$1,000,000-$2,499,999	1,006	1,502.3	1,493,340	746.6	16,277	45,868	92,296
$2,500,000-$4,999,999	260	891.8	3,430,000	430.9	8,124	53,040	109,774
$5,000,000-$9,999,999	97	663.7	6,842,268	306.3	5,286	57,946	125,558
$10,000,000 or more	41	1,274.4	31,082,927	309.8	4,706	65,831	270,803
Establishments not operated for the entire year	1,137	175.7	154,529	68.7	2,135	32,178	82,295
All Establishments	**9,860**	**$6,760.3**	**685,629**	**$2,927.1**	**69,201**	**$42,299**	**$97,691**
Source: U.S. Census Bureau, 2007 Economic Census.							

The importance of construction demand is evident in the mix of products shown in Table 7.

Table 7. Product Sales of Establishments in the U.S. Private Surveying and Mapping (Except Geophysical Services) Industry, 2007
(thousands of dollars)

Product Code	Description	Sales
37210	Geospatial image and photo acquisition	242,794
37220	Geospatial Image and Photo processing	206,381
37230	Geospatial data interpretation (exc. Geophysical)	83,235
37241	Topographic & plan metric surveying & mapping services	1,077,747
37242	Hydrographic and bathymetric surveying and mapping services	105,799
37243	Boundary, property line, and cadastral surveying and mapping	1,869,878
37244	Subdivision layout and design services	533,040
37245	Construction surveying services	1,462,524
37246	Geodetic surveying and ground control services	159,313
37250	Thematic mapping and orthophoto mapping and charting services	53,323
37260	Information system development and customization services	107,707
37270	Geospatial consulting services	16,904
37280	Geospatial data conversion services	14,076
37290	Geospatial product sales	89,781
37310	Geospatial data collection	14,076
37340	Integrated geophysical services	16.239
37346	Geophysical borehole logging surveys	8,906
39280	Engineering services	373,833
39400	Licensing of rights to use intellectual property	209,511
39401	Licensing of rights to use intellectual property – protected by copyright	208,382
39624	Resale of merchandise	10,669
39724	All other operating receipts	96,049
	All Establishments	**6,760,251**

Source: U.S. Census Bureau, 2007 Economic Census.

The Water Transportation Industry

More than 8,000 United States flag passenger and cargo vessels were operating or available for operation in the Atlantic, Gulf, and Pacific coasts and the Great Lakes on December 31, 2009, according to the U.S. Army Corps of Engineers. The numbers of vessels by type are displayed in Table 8.

Table 8. Number of U.S. Flag Passenger and Cargo Vessels Operating or Available for Operation on December 31, 2009 by Region			
Type of Vessel	**Atlantic, Gulf and Pacific Coasts**	**Great Lakes**	**Total**
Self-Propelled			
Dry cargo and/or passenger, offshore support	1,479	175	1,654
Vehicular ferries and railroad cars	428	71	499
Tankers	65	5	70
Towboats	1,831	134	1,965
Total Self-Propelled	***3,803***	***382***	***4,185***
Non-Self-Propelled			
Barges, dry cargo	3,831	171	4,002
Barges, tanker	629	10	639
Railroad car floats	24	1	25
Total Non-Self-Propelled	***4,034***	***182***	***4,216***
Grand Total	**7,837**	**564**	**8,401**
Note: Excludes fishing vessels, derricks, and dredges, etc., used in construction work. Source: U.S. Army Corps of Engineers, *Waterborne Transportation Lines of the United States, Calendar Year 2009, Volume 1 – National Summaries*, February 9, 2010, Table 1.			

Kite-Powell cites a U.S. Coast Guard estimate of about 7,600 foreign-flag ships and 400 U.S.-flag ships operating in U.S. waters in mid-decade.[28] This is consistent with the Institute of Shipping Economic and Logistics report that in 2010, 85.7% of total controlled tonnage attributable to North American shipping companies was operated by foreign flag carriers.[29] The later does not include companies based outside of North America, the inclusion of which would raise the percentage.

The U.S. deep sea, coastal and Great Lakes water transportation industry had revenues of $28.8 billion in 2007 (Table 9). The largest category was deep sea passenger transportation, of which cruise ships accounted for $11.0 billion. Revenue of all private water transportation in the U.S. was $34.3 billion in 2007.

Gross Domestic Product (GDP) of the for hire water transportation industry was $13.5 billion in that year (and $14.3 billion in 2009). [30] The difference between revenue and GDP primarily reflects the inclusion in GDP of purchases of fuel, equipment and services from other industries.

[28] Hauke Kite Powell, *Use and Value of Nautical Charts and Nautical Chart Data in the United States*, report to the NOAA Office of the Coast Survey, Woods Hole Oceanographic Institute, August 2007

[29] Institute of Shipping Economics and Logistics, *Shipping Statistics and Market Review*, Volume 54, No-7, 2010, p.6 http://www.infoline.isl.org/index.php?newlang=eng

[30] U.S. Department of Transportation, Bureau of Transportation Statistics, *National Transportation Statistics, 2009*, Washington: 2009, Table 3-1.

Table 9. Revenue of the U.S. Private Water Transportation Industry, 2007 (billions of dollars)		
Industry Code	**Description**	**Revenue**
483	All water transportation	34.3
4831	**Deep sea, coastal and Great Lakes water transportation, total**	**28.8**
483111	Deep sea freight transportation	8.2
483112	Deep sea passenger transportation	12.6
483113	Coastal and Great Lakes freight transportation	7.3
483114	Coastal and Great Lakes passenger transportation	0.6
Source: U.S. Census Bureau, 2007 Economic Census.		

Sea, coastal and Great Lakes water transportation directly employed 40,000 people in 2007. The sector accounted for three-fifths of the 66,000 people employed by water transportation nationwide in 2007 and the 64,000 employed in 2009. Support activities for all water transportation employed 100,000 people in 2007 and 93,000 in 2009. Ship and boat building (including military) employed 160,000 in 2007 and 132,000 in 2009.[31]

Table 10 shows the value of export and import shipments for the top 23 U.S. foreign trade water freight gateways in 2009. Their combined value of exports was $676 billion and their value of imports was $984 billion.

Table 10. Value of Shipments of Top U.S. Water Freight Gateways, 2009 (billions of dollars)			
Value of Shipments	**Exports**	**Imports**	**Total**
Los Angeles, CA	28.0	167.7	195.6
New York, NY	38.3	104.5	142.8
Houston, TX	48.4	57.7	106.1
Long Beach, CA	24.2	44.4	68.5
Savannah, GA	18.9	27.7	46.6
Charleston, SC	16.3	28.6	44.9
Norfolk, VA	18.9	24.0	43.0
Oakland, CA	12.7	21.1	33.8
Seattle, WA	18.5	14.4	32.9
New Orleans, LA	18.5	14.4	32.9
Baltimore, MD	10.7	19.4	30.1
Tacoma, WA	6.0	19.2	25.2
Philadelphia, PA	2.8	20.5	23.3
Annapolis, MD	0.0	19.4	19.4
Corpus Christie, TX	4.0	14.7	18.7
Miami, FL	9.1	9.5	18.5
Morgan City, LA	0.2	16.8	17.1
Port Everglades, FL	9.5	6.8	16.3
Gramercy, LA	9.7	6.4	16.1
Jacksonville, FL	6.0	7.5	13.5
Texas City, TX	2.7	10.6	13.3
Port Arthur, TX	2.3	10.8	13.1
Beaumont, TX	2.5	9.7	12.2
Source: U.S. Department of Transportation, Bureau of Transportation Statistics, *National Transportation Statistics, 2009*, Washington: 2009, Table 1-51.			

[31] *Ibid*., Table 3-23.

Commercial Fishing

In 2008, 20,231 commercial fishing and processing vessels in service had valid U.S. Coast Guard Certificates of Documentation. However, the National Transportation Safety Board determined based on examining state reports that the national total, including those without certificates, was 78,903.[32] Allocating federally documented vessels to states proportionally to state numbers, the vessel count for the coastal and Great Lakes states is 59,442.

Commercial fishing landings in 2009 totaled 7.9 billion pounds. Revenue of commercial fishing was $3.9 billion. [33]

Sales of commercial harvesters were $10.3 billion, seafood processors and dealers $25.2 billion and seafood wholesalers and distributors $6.5 billion, a total of $42 billion. About half of those sales, $19.5 billion, represented value added by the three sectors.[34]

Commercial harvesters employed 135,000 in 2009, seafood processors and dealers 184,000, and seafood wholesalers and distributors 47,000.[35] The total of 367,000 does not include the 484,000 retail jobs supported by domestic production and imports.

The landings, sales, value added and employment data cover the entire country.

Recreational Fishing and Boating and Other Recreation

Seventy five million people or 32% of the U.S. adult population participated in recreational boating (including fishing) at least once during 2010.

Recreational boating and fishing involved an estimated 16.7 million boats in 2010, of which 12.8 million were registered and 3.9 million unregistered. The total includes personal watercraft, jet boats, canoes, and kayaks. Of the 10.8 million recreational boats with motors, 8.2 million were outboard boats, 1.1 million inboard, and 1.5 million sterndrive boats.[36]

There were 11.3 million recreational anglers in 2009, of which 9.4 million lived in coastal areas. Nationally, recreational anglers took 74 million saltwater fishing trips. Thirty nine million of those were by private boat and 6 million by for hire boat, while 34 million were shore trips.[37]

The U.S. Fish and Wildlife Service found that there were 7.7 million saltwater and 1.4 million Great Lakes anglers in 2006. Each type made an average of nine trips lasting an average of 1.3 days.[38]

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

[33] National Marine Fisheries Service, *Fisheries Economics of the United States, 2009*, NOAA Technical Memorandum NMFS-F/SPO-118, May 2011, p.5 http://www.st/nmfs.noaa.gov/st5/publication/fisheries_economics_2009.html

[34] *Ibid.*, p.12 http://www.st/nmfs.noaa.gov/st5/publication/fisheries_economics_2009.html

[35] *Ibid.*

[36] National Marine Manufacturers Association, *2010 Recreational Boating Statistical Abstract*, NMMA, 2011, Table 1.3 http://www.nmma.org/statistics/publications/statisticalabstract.aspx Sterndrive boats have power in the front that is transmitted to the back.

[37] *Ibid.*

[38] U.S. Census Bureau, *Statistical Abstract of the United States*, 2011, Table 1255 http://www.census.gov/compendia/statab/

National retail spending on recreational boating (including spending for recreational fishing) was $30.4 billion in 2010. This includes spending on new and used boats, motors and engines, accessories, safety equipment, fuel, insurance, docking, maintenance, launching, storage, repairs and other expenses.[39]

National durable equipment expenditures for recreational fishing were $14.7 billion in 2009. Trip expenditures of U.S. residents were $4.5 billion, for a total of $19.1 billion. The impact of recreational fishing on value added in the economy was $23.2 billion, and the number of resulting jobs 327,000.[40]

More than 56 million people surveyed in 2009 went to the beach during the previous 12 months. Seventeen million went at least once a month and 5.5 million went at least once a week.[41]

Marine Safety

Marine safety continues to be a serious problem.[42]

- There were 4,458 accidents on commercial vessels in 2009. These came from developments such as groundings, collisions, fires, and explosions, and resulted in 57 vessel-related fatalities. In addition there were 93 fatalities not related to vessels (e.g. slips, falls, and electrocutions).

- Property damage related to vessel casualties was $106.7 million in 2010.

- Recreational boating had 4,730 accidents and 736 fatalities involving 6,190 vessels in 2009.

- Property damage from recreational boating accidents was $35.9 million I n 2009.

- The U.S. Coast Guard reported that its search and rescue operations handled 23,530 cases in 2009, saving 4,861 lives and otherwise assisting 34,425 persons. However, 816 lives were lost. While property loss prevented was $94.9 million, property lost or unaccounted for was $124.6 million. These data undoubtedly overlap with those preceding.

Oil and Natural Gas

The U.S. Energy Information Agency projected the 2011 value of Gulf oil production at about $70 billion and natural gas production at about $10 billion (Table 11). Alaskan production of oil was valued at about $19 billion and gas at about $1.4 billion. These values are based on wellhead prices and do not include the value added in downstream production and transportation or the secondary effects on the economy.

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[39] National Marine Manufacturers Association, *2010 Recreational Boating Statistical Abstract*, NMMA, 2011, Table 5.1 http://www.nmma.org/statistics/publications/statisticalabstract.aspx

[40] National Marine Fisheries Service, *Fisheries Economics of the United States, 2009*, NOAA Technical Memorandum NMFS-F/SPO-118, May 2011, p.13.

[41] U.S. Census Bureau, *Statistical Abstract of the United States*, 2011, Table 1239 http://www.census.gov/compendia/statab/

[42] U.S. Department of Transportation, Bureau of Transportation Statistics, *National Transportation Statistics, 2009*, Washington: 2009, Tables 2-1, 2-3, 2-45, 2-47 and 2-49.

Table 11. Size and Value of U.S. Oil and Natural Gas Production, 2011				
Location	**Oil**		**Natural Gas**	
	Production (millions of barrels per day)	**Value** (billions of dollars)	**Production** (trillion cubic feet)	**Value** (billions of dollars)
Lower 48 states offshore and Alaska	2.14	69.5	2.55	10.4
Alaska	0.59	19.2	0.35	1.4
Lower 48 states offshore	1.55	50.4	2.20	9.0
Gulf	1.48	48.1	n.a.	n.a.
Shallow	0.25	8.1	n.a.	n.a.
Deep	1.23	40.0	n.a.	n.a.
Pacific	0.08	2.6	n.a.	n.a.
Atlantic	0.00	0.0	n.a.	n.a.
Note: Reference case. Oil is valued at $89 per barrel, which is the price of $84 given in dollars of 2009 purchasing power, updated to the general 2011 price level. Natural gas is valued at $4.09 per thousand cubic feet. Source: U.S. Energy Information Administration, *Annual Energy Outlook, 2011*, April 26, 2011 http://www.eia.gov/forecasts/aeo/source_oil.cfm Data are from online table downloads.				

A study for the National Ocean Industries Association and the American Petroleum Institute found that in 2010, offshore oil and gas production in the Gulf of Mexico alone involved $17.7 billion in operating expenditures, $6.5 billion in capital expenditures and ultimate GDP impacts of $26.1 billion. Employment in the offshore Gulf industry was 60,000. Another 180,000 jobs were either involved in providing services to the industry or induced by its broader economic effects.[43]

[43] National Ocean Industries Association, "From the Gulf of Mexico → to the Entire Nation: The Impacts of GOM Offshore Oil and Gas Development on the U.S. Economy," Press Release, July 2011. The full report is Quest Offshore Resources, Inc., *United States Gulf of Mexico Oil and Natural Gas Industry Economic Impact Analysis*, prepared for the American Petroleum Institute and the National Ocean Industries Association, June, 2011.

Methods of Benefit Evaluation and Measurement

Concept and Nature of Benefits

The concept of benefits for this study is gross economic and societal value. Gross economic and societal value includes economic benefits and also non-economic benefits to society such as those to health, safety and the environment. It does not subtract the costs incurred by CMP or its customers in achieving those benefits.

The concept of benefits for this study is gross economic and societal value.

Benefits are incremental. Incremental value estimation considers the differences in the economic and societal value from technological and market alternatives that would be manifest if CMP products and services were not available and differences in the extent of use between the program and what would be expected with the alternatives.

CMP products and services can create new demands for products of using industries. Productivity gains can come about when the charting and mapping products and services lead to improvements within existing operating or production processes or when they lead to system changes and new processes. There also can be benefits from facilitating creation of new products and industries.

Productivity and cost savings are two sides of the same coin, since improvements in efficiency can be used either to produce more with the same resources or to produce the same with fewer resources.

Geographic information can provide network benefits that grow exponentially as larger numbers of users interact, learning from each other about information and its uses and sharing or building on each other's information. Network effects can be an important source of productivity gains and cost savings as well as a source of market growth.

Some uses of maps and other location information may be subject to diminishing returns as greater use leads to congestion, such as with crowding in beaches and pleasure craft waters. Chart and map information may reduce some congestion by identifying alternative locations for users and facilitating managing crowds, but it also can increase demand and lead larger numbers to congregate in the same places. Whether there is a net gain or loss in benefits depends on the size of the benefit from added choices and the effects of the information on managing crowds vs. the reduced benefit from crowding to initial users. If the number of new users is large relative to initial users, the change can increase total benefits even as average benefit per user falls.

Some activities, such as observing natural areas and maintaining coastal wetlands, are or create public goods for which one person's benefit does not detract from the benefits of others.

The benefits of charts and maps depend on how current they are since the shoreline and dangers of man-made obstructions are constantly changing. Currency of information is especially important in areas of major economic activity or environmental sensitivity and where major changes in the shoreline are taking place. NOAA's goal is to map port areas every five years. However, efforts are held back by budget constraints. NOAA's Hydrographic Services Review Panel notes that:

> "The rate of change of shoreline is faster than the rate of shoreline surveying….Currently NOAA and its contractors can remap only 12 percent of priority port area shoreline annually, falling short of NOAA's program target of 20 percent each year. The bulk of the 95,000 miles of U.S. coast is

> open shoreline, which NOAA can currently map at a rate of only three percent a year. Some U.S. shoreline, primarily in Alaska, has never been mapped to modern standards. There are also many charted areas with significant changes since they were last mapped."[44]

An approach for measuring the effects of update status on benefits is recommended in the discussion of steps for further analysis at the end of this report.

Measuring Benefits

Determining benefits involves assessing what people are willing to pay for services, as reflected in purchasing behavior, surveys of preferences or comparisons of costs (avoided costs) and productivity. Benefit differences may depend on the alternatives that would be expected to prevail if there were no CMP. Those alternatives may involve activities in other organizational settings and/or use of alternative technologies, or some users going without service.

In determining the benefits attributable to a particular product, account needs to be taken of the fact that money also has to be spent on complementary goods and services that are required to take advantage of the product, and that substitutes for the product may be available. For example, use of maps requires equipment and software to display them and obtaining less accurate or appropriate maps may be possible based on other technologies. When benefits are measured by what people, businesses or governments actually spend or by surveys of what people are willing to pay, both the need for complementary purchases and the availability of substitutes are already reflected in the measures. This is the case with the measures used in the present study.

To the extent possible, consumer surplus, the value *above* what businesses, governments or households pay, should be included along with direct revenues in measuring direct economic benefits. It may be calculated based on an assumed shape of the demand curve or be included because it is taken into account in a measure of "willingness to pay." When benefits are measured by productivity gains or cost savings to businesses, governments or consumers, much of consumer surplus already is implicitly included. That is because many users access the information to obtain productivity gains or cost savings, including gains worth more than what they pay.

In the present study, benefits include *both* what is actually paid and consumer surplus because benefits are defined as *gross* economic and societal value. In contrast, some studies have measured net benefits, gauging them by consumer surplus only (subtracting what users pay for the services from the value users place on them).

Producer surplus is the amount businesses receive for their products in excess of the costs of production. Measuring producer surplus depends on assumptions about the shape of the supply curve that shows the production that would take place at each price. The supply curves of government users are not known and those of private firms are not readily measured. Because of the difficulties of measurement, few studies have included producer surplus. Some have used rough assumptions about profits or margins for private entities. Producer surplus is not measured in the present study.

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[44] Hydrographic Services Review Panel, *Most Wanted Hydrographic Services Improvements*, Federal Advisory Committee Update Report, 2010, p.10 http://www.nauticalcharts.noaa.gov/ocs/hsrp/docs/2010_Most_Wanted_%20Hydrographic_Services_Improvements.pdf

A wide variety of methods have been employed in studies relied on here in determining benefits. Since the analysis makes estimates of benefits for several CMP products and draws on many existing studies, some of the underlying techniques will depend on the methods employed in the studies relied on.

Some outcomes depend on activities of multiple programs or agencies. Where applicable, a portion of the benefits associated both with CMP products and with other programs is allocated to CMP. Where a product that CMP contributes to involves efforts of other entities, such as with nautical charts, a portion of the benefits is allocated to CMP.

Where appropriate, a portion of benefits is allocated to coastal and Great Lakes areas.

Where data and resources are available, benefits can be measured by before and after comparisons of economic and societal benefit measures where important changes in technologies, services (e.g. updating remote sensing surveys of an area) or external conditions have occurred. This approach is proposed for subsequent efforts.

Economic benefits include direct, indirect and induced benefits. Direct economic benefits include productivity effects and product and process innovation in sectors using the services. Indirect and induced economic benefits include demand effects on industries supplying using sectors, demands created by spending of using industries and their employees, and effects on innovation beyond using industries. The combined effects are taken into account by means of a multiplier which is adapted from other studies to take advantage of extensive econometric work that has been performed.

Where benefits are to health and safety, outcomes may take the form of mortality, disability, and medical costs.[45]

The values of environmental amenities and preferences for an improved environment have been measured in contingent valuation studies that survey respondents about their willingness to pay for different sets of conditions. Some literature in this area is noted. When benefits are determined by using analogies to benefits found in other areas, the approach has been referred to as the transfer method. An illustrative estimate is made of environmental benefits based on the value of wetlands.

In the present study, some health and environmental benefits are included in economic benefits because they are not separated in estimates of "willingness to pay" in studies that are drawn upon. This leads to an overstatement of economic benefits but an equal understatement of non-economic benefits. This is allowed for in estimating the number of jobs supported.

Ranges are shown for benefit estimates to illustrate the difference alternative values would make.

The order of magnitude of benefits is illustrated for 2011 and also illustrated as a discounted sum over 15 years.

[45] Data on economic values of health and safety improvements are discussed in Appendix B Irving Leveson, *Socio-Economic Benefits Study: Scoping the Value of CORS and GRAV-D*, Report to the National Geodetic Survey, revised January 2009 http://www.ngs.noaa.gov/PUBS_LIB/Socio-EconomicBenefitsofCORSandGRAV-D.pdf

Alternatives to CMP Products and Services

In order to understand the contribution of the Coastal Mapping Program, it is necessary to consider what would happen if the program did not exist. Both economic and non-economic benefit estimates are reduced by 50% to allow for the benefits that would exist if there were no CMP.

The question is what other agencies using CMP services, private organizations and firms using CMP services, and vendors would do if there were no CMP. There are a number of possible alternatives for using non-NOAA maps and images. In some cases surveying or observation can be used. However, even taken together, alternatives do not fully compensate for the loss of CMP services. That is because they are likely to involve higher costs from lack of scale and/or fragmentation, loss of benefits from less complete coverage and availability of fewer or less featured products, and some users doing less or using lesser technologies or standards. Private firms would not offer official legal boundaries. Moreover, CMP is legally liable for accidents or other developments that result from errors in its data, a feature which private vendors would be expected to avoid with disclaimers.

CMP also plays a major role in setting standards. Without them there could be wider use of less appropriate standards, greater costs resulting from differing standards among users, and less scientific advance. Cooperative efforts among governmental units would be more difficult without a CMPs contribution to standards. Several shoreline definitions are in use by federal, state, and local authorities. The use of inconsistent shoreline definitions between maps, charts, Geographic Information Systems (GIS), and other products can lead to confusion on the part of users and contribute to ill-informed decision-making. Decentralization of imagery production among users or private vendors without an arbiter or central authority could lead to less standardization, resulting in higher costs, less use and errors.

Some have made comparisons with alternatives of making ground inspections of storm damage or other developments, using cost savings to gauge benefits. [46] Such examples are important to illustrate the potential for productivity gains among customers. They do not allow for the potential for other sources of imagery to fill some of the gaps. More importantly, however, they do not count the value of the information, which may be used for several purposes and by many people, providing benefits that greatly exceed its cost.

One or more government agencies that are doing related kinds of mapping might provide some or all of the services that CMP provides, but they could only do so if they had a budget comparable to CMP's. That means they aren't an alternative to having CMP products, just a shift in where the government provides them.

Some public or private users might try to provide services themselves. However, fragmentation of efforts among multiple users would likely lead to much higher costs and less usage. While it is unlikely that many government or private users would revert to very old technologies in an environment in which technology has been improving very rapidly, many might use less advanced technology than currently available, either because of cost or limited skills and/or because mapping is less central to their mission. There also could be underinvestment in developing new techniques when much of the gains from the investments accrue to other suppliers or their customers.

[46] In a recent example, FEMA reported that NOAA imagery eliminated the need to send contractors to make ground inspections of 10,000 homes after the 2011 tornado in Birmingham, Alabama. A rough estimate is that this saved FEMA at least $200,000 and as much as $333,333 in salaries, benefits and travel. It also enabled individual assistance payments to be made 32 days earlier. Similar results apply to the 2011 tornadoes in Tuscaloosa, Alabama and Joplin, Missouri, bringing the total savings to FEMA $0.6- $1 million.

It would be very difficult for either private contractors or other government agencies to integrate externally collected data with information collected and processed in other parts of NOAA, as is necessary for the production of nautical charts. Other parties will not want to duplicate the hydrographic data collection that NOAA undertakes. Also, private vendors might not have access to the classified satellite data that CMP uses for updates in its Change Analysis program and other activities.

Private sector alternatives could develop in information technology and services companies and surveying and mapping companies. CMP contractors that collect and process remote sensing data for CMP might offer services on their own. The National Academies noted that: "…topographic Lidar is relatively mature technology that is now dominated by the private sector, with numerous companies offering commercial Lidar services."[47] Numerous firms are available that could distribute the data, charts and maps.

The costs of private vendors would be higher because they would have to duplicate some of each other's fixed costs and they would have to spend much more on marketing in competition with each other than NOAA spends on distribution. Higher costs of fragmentation and distribution would make the market smaller which would spread fixed costs over a narrower base, leading to further cost increases and an even smaller market. Some users such as some in recreational boating and fishing and some not-for-profit organizations would not be able to afford the cost of private vendor services. Also, private vendors are unlikely to assume legal liability for consequences of inaccurate data. The net result is that the market would be smaller and incomplete, and important social as well as economic objectives would not be met.

Some users might rely on data from Google Earth, Microsoft maps or another service, but the licenses of those organizations say the data are not for navigation. Some would use the data for navigation and boundary negotiations anyway. That would create legal issues for the companies and safety issues for the public. It might be worthwhile for them to overcome the navigation issues by improving the data if the market was large enough, but it is not clear that it would be. They also would not provide official legal boundaries. If a company like Microsoft or Google provided shoreline data and nautical maps comparable to what CMP provides, they would have to duplicate CMP operations to do so. Costs of comparable coverage and services would likely be higher because of smaller scale, costs of marketing and profits. They might try to hold down costs by cherry picking the market, leaving areas in which activity is less dense or that are important for environmental and other purposes underserved.

Number of Jobs CMP Products and Services Support

The number of jobs supported is calculated based on the total direct, indirect and induced economic benefits for the CMP components, excluding consumer surplus. Economic benefits are first adjusted to remove non-economic benefits that have been included with them by the use of "willingness to pay" data that include some non-economic value. Adjusted economic benefits are divided by a measure of annual revenue per worker to obtain the number of jobs supported. The results are compared with the number of CMP jobs.

[47] Committee on National Needs for Coastal Mapping and Charting, National Reserach Council, *A Geospatial Framework for the Coastal Zone, National Needs for Coastal Mapping and Charting*, National Academies Press, 2004, p.40 http://www.nap.edu/openbook.php?isbn=0309091764

Review of Benefit Literature

Benefits of Mapping and Spatial Information

Benefits of the National Spatial Reference System, CORS and GRAV-D

The 2009 scoping study by Leveson Consulting for the National Geodetic Survey (NGS) made provisional estimates of the benefits of the National Spatial Reference System (NSRS). [48] The NSRS consists of more than 1,500,000 survey marks established through public and private cooperation to provide accurate horizontal and/or vertical position information, along with the then 1,300+ Continuously Operating Reference Stations (CORS) which NGS coordinates and monitors. The study found illustrative order of magnitude benefits of NSRS of $2.4 billion per year. This was derived by building on revenue from private surveying and mapping, adding assumptions for the government and not-for-profit sectors and adding a factor for societal benefits. The $2.4 billion per year, extended over 15 years and discounted at 7%, would lead to a present value for NSRS of $22 billion. If benefits grew at 7% per year, the discounted value would be $36 billion. The value is gross; it does not deduct the costs of providing the capabilities.

The study made tentative estimates of the gross value of CORS of $758 million per year, building on an estimate of the costs of field measurement if CORS were not available. The present value of these benefits over 15 years, discounted at 7% was $6.9 billion. If benefits grew at 15%, their present value would be $18.5 billion.

A conjectural estimate also was made of the benefits of a new program, Gravity for the Re-definition of the Vertical Datum (GRAV-D) which is being rolled out to provide greatly improved height measurement. A benefit of $522 million per year was estimated based on avoided costs of flood damage in floodplain areas and avoided costs of long line leveling. It is a minimum since it did not include other benefits such as the value of improved heights for evacuation routes and levees and the avoided costs of having to pay for height surveys before obtaining flood insurance. The present value of the calculated benefits over 15 years, discounted at 7%, is $4.8 billion.

Cost Saving of State Mapping Over Users Preparing Geological Maps for Themselves

Cobb reported on the results of a study of Kentucky's geologic mapping program in 2000 by S.B. Bhagwat and V.C Ipe.[49] Questionnaires sent to professional geologists led to 440 responses, a 20% reply. The responses are claimed to be representative. The average cost of preparing a single 1:24,000-scale geologic quadrangle map, if the geologists had to prepare it themselves rather than obtain it from the state program, was a minimum of $27,776 and a maximum of $43,527. Based on 81,000 maps that were provided by the state, this resulted in a saving of $2.25-$3.53 billion, vs. a cost of the program of $90 million.

Berg noted that:

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[48] Leveson Consulting , *Socio-Economic Benefits Study: Scoping the Value of CORS and GRAV-D*, January 2009. http://www.ngs.noaa.gov/PUBS_LIB/Socio-EconomicBenefitsofCORSandGRAV-D.pdf

[49] James C. Cobb, "The Value of Geologic Maps and the Need for Digitally Vectorized Data," Digital Mapping Techniques '02 ─ Workshop Proceedings, U.S. Geological Survey Open-File Report 02-370 http://pubs.usgs.gov/of/2002/of02-370/cobb.html

> "The comprehensive 20-year geologic mapping program that produced 707 1:24,000-scale quadrangles for the State of Kentucky yielded between $25 and $39 in returns for every State and Federal dollar spent."[50]

Berg reported that cost-benefit studies found similar results to Bhagwat and Ipe's Kentucky findings for Illinois. He points out that:

> "…for every State government dollar spent on geologically mapping 21 1:24,000-scale quadrangles in Winnebago and Boone Counties, Illinois returned as much as $55 in potential reduced costs for environmental cleanup."[51]

The studies did not allow for alternatives that might develop in the absence of the state program, such as one or more private firms preparing and selling the maps, enabling multiple users to obtain the maps at lower cost than preparing the maps themselves. This would allow some of the economies of scale that the state achieved. Excluding private alternatives could result in a large overestimate of the benefits in reduced cost. With either users or private firms preparing the maps, the cost to users would be higher than the cost of the state program, and some users would forego obtaining the maps. The studies also did not measure indirect and induced economic effects or broader societal benefits. A fuller study would be needed to determine the sizes of the cost savings over alternatives, the indirect and induced economic benefits, and the non-economic benefits of the state programs.

The Value of Spatial Information in Australia

The value of spatial information in Australia was examined by ACIL Tasman in a March 2008 report.[52] This study is important because of its comprehensive scope and methodology. The value of spatial information is defined to include the difference in economic performance of industries and the economy with vs. without spatial information. All types of spatial information are included: GPS, maps, GIS, etc. The study used estimates and assumptions drawing on available case studies and literature to develop productivity effects and levels of adoption for each spatial information application for the 2006-2007 year. Productivity is construed to include cost savings, revenue gains and/or facilitation of new applications.

The productivity values were entered into an input-output model of the economy to take account of secondary effects on other sectors, including productivity changes in other sectors and expansion of resources.[53] The findings are presented both for a more conservative lower bound scenario and a "realistic" scenario that tries to include more of benefits that are not well measured. The combined impact on GDP ranged from $6.43 billion to $12.57 billion Australian dollars, or .61% to 1.20% of GDP. Cumulative impacts on GDP in the single year examined are 10-18 times the $682 million (Australian dollars) gross value added of the spatial industry.[54]

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[50] Richard C. Berg, Richard C., "Societal and Economic Benefits of Three-Dimensional Geological Mapping for Environmental Protection at Multiple Scales: An Overview Perspective from Illinois, USA," in Stanislaw Ostaficzuk, *The Current Role of Geological Mapping in Geosciences*, Proceedings of the NATO Advanced Research Workshop on Innovative Applications of GIS in Geological Cartography, Kazimierz Dolny, Poland, November 24-26, 2003, p.23.

[51] *Ibid*.

[52] ACIL Tasman, *The Value of Spatial Information*, prepared for the Cooperative Research Centre for Spatial Information and ANZLIC – The Spatial Information Council, March 2008.

[53] The Tasman-Global model is a computable general equilibrium model developed from the Global Trade Analysis Project database (GTAP) constructed at the Center for Global Trade Analysis at Purdue University. The input-output model was developed to study international trade.

[54] *Ibid*., p.135 and pages 5-6.

The estimates should be understood as describing what the benefits of spatial information would be, *given* that investments already had been made in equipment to collect or make use of the information (such as automated tractors, software, communications and other systems). The contribution of those investments was not separated from the contribution of the information. This means that the estimates, if taken to reflect the contribution of spatial information alone, greatly overstate its value. However, non-economic benefits, while discussed, were not included in the value measure.

The study relied on extensive judgments about magnitudes of benefits in individual application areas that, while assisted by detailed examination of many applications, go well beyond the quantitative information available from the case studies and reported literature and interviews. Also, for most applications assumptions are made about the extent of adoption of the techniques in the absence of information about adoption. While the framework for assimilating the estimates is unusually complete, the conclusions depend heavily on these many assumptions.

While adding less well-measured influences in a second scenario doubles the aggregate impact of spatial information on GDP, there are far smaller differences between the two scenarios for almost all individual industries. The difference between the aggregate and the specific industries may significantly be attributable to a large impact assumed for government programs. The scenario for government that includes unmeasured productivity gains showed three times the impact of the narrower one (1.05% vs. 0.34%). The study notes that:

> "A productivity benefit of 1.05% was assumed for the realistic scenario based on observed impacts of spatial information on functions across whole of government, including asset management, resources management, reduced costs of service delivery, improved services, infrastructure planning, defence and emergency preparedness, risk management, compliance and regulation."[55]

Value of Nautical Charts

Kite-Powell examined the value of paper and electronic nautical charts to commercial and recreational boaters, along with chart use, using survey data from 2005-2006.[56] The main concept of benefits for the study is consumer surplus, which measures the value of the charts to users *above* what they pay. The study did not measure benefits above those that would exist if there were no NOAA nautical charts.

Results of mail and email surveys of recreational and commercial boaters were scaled up to the national recreational boating population.[57] The study found national spending of $13 million by recreational boaters for chart products as a whole, excluding hardware and software for digital chart displays. Of this, about $1.8 million was spent on NOAA paper charts. The estimates include spending for both coastal and inland waterways.

Rather than estimate the value of currently available charts to users, the study calculated that boaters would be willing to pay $42.8 million per year for "ideal" chart products. The author states that there is little difference between what would be preferred in ideal charts and the nature of actual charts. A large difference was that the preference was strong for electronic charts at a time when use of paper charts was

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[55] *Ibid*., pp.128-129.
[56] Hauke Kite Powell, *Use and Value of Nautical Charts and Nautical Chart Data in the United States*, report to the NOAA Office of the Coast Survey, Woods Hole Oceanographic Institute, August 2007.
[57] The response rates to the survey are very low, covering 9% of the ships and 17% of the tug/towboats operating in U.S. waters. There is no discussion of how response bias could affect the estimates.

more extensive. Benefits were $15.3 million per year for recreational users and $27.5 million per year for commercial users. For commercial users, producer surplus, the value to producers above their costs, is also estimated, taken as equal to the value of net margins. This is an additional benefit of $2 million per year. Estimates are considered by the author to be "lower bound."

The primary measure of benefits that is used in the Kite-Powell is the value to users of "ideal" chart products *above* what they pay for the then currently available chart products. The value is obtained by subtracting an estimate of what users pay from their amounts of "willingness to pay." This would be consumer surplus if the value of ideal charts were related to the cost to users of the "ideal" charts rather than the cost of currently available products. The formulation answers the question: "What *additional* value would ideal charts have over the purchase price of current charts?"

Gross value, the measure used in the present study, is not presented. However, gross value of ideal charts can be calculated from the data provided, assuming they would cost the same as current charts. For recreational boaters, cost of map sets adds $8.1 million to benefits, resulting in a total of $23.4 million. For commercial ships and tug/towboats the cost is $7.8 million, bringing total benefits to $24.1 million. The combined gross benefits of recreational and commercial vessels are therefore $47.5 million.

The estimates do not include the value to commercial fishing vessels and military users, the benefits to shipping and boating beyond those to immediate users, or benefits to the broader society. For example, for recreational users the benefit estimates do not reflect that some boaters who use fewer or do not use nautical charts benefit when boaters using nautical charts show the way or report hazards. The value of the mapping information in port construction, shoreline improvement, environmental monitoring, marine resource management and other functions is not measured. Consequently, more comprehensive benefit estimates would be much larger.

Benefits of the NOAA Physical Oceanographic Real-Time System (PORTS)

NOAA's Physical Oceanographic Real Time System (PORTS) provides near real-time information about water levels, currents, salinity, wind speed and direction, air gap and other information, and forecasts, at specific points in 18 port areas for safe navigation. Kite-Powell estimated benefits of the PORTS system in Tampa Bay, Houston/Galveston, the Columbia River and New York.[58]

Benefits were defined to include avoidance of groundings of commercial vessels and distress calls from recreational vessels, increased cargo carried per ship call and reduced delays, improvements in hazardous material spill response, environmental restoration/conservation activities, recreational experiences, and weather and coastal marine conditions products, and use of ports for scientific research and education. Benefits were estimated with varying degrees of confidence, depending on their extent of reliance on data and uncertainty surrounding the many assumptions.

[58] Hauke Kite-Powell, *Estimating Economic Benefits from NOAA PORTS® Information: A Case Study of Tampa Bay*, Tampa Bay Harbor Safety and Security Committee, July, 2005, Hauke Kite-Powell, *Estimating Economic Benefits from NOAA PORTS® Information: A Case Study of Houston/Galveston,* The Port of Houston Authority, March 2007, Hauke Kite-Powell, *Estimating Economic Benefits from NOAA PORTS® Information: A Case Study of the Columbia River*, Port of Portland and NOAA, June 2010, and Hauke Kite-Powell, *Estimating Economic Benefits from NOAA PORTS® Information: A Case Study of the Port of New York/New Jersey*, Report prepared for the Center for Operational Oceanographic Products and Services (CO-OPS), National Ocean Service, NOAA, May 2009. Subsequent unpublished tables compare benefits with costs, adjusting the data from the various years for general inflation through 2010.

The study estimates were as follows:

> Tampa Bay: High confidence annual benefits were $2.4-$4.8 million, lower confidence benefits were $2.2 million and potential or speculative benefits were another $2.2 million in 2005.
>
> Houston/Galveston: Benefits in the three categories in 2006 were $11.9 million, $2.2-$3.7 million and $1.8-$2.8 million. The two ports handled about 10% of the tonnage of all U.S. water ports in 2006.[59]
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> Columbia River: The study of the Port of Portland found high confidence benefits of $4.9 million, lower confidence benefits of $2.5 million, and potential or speculative benefits of $0.1 million, based on data for 2008.
>
> New York/New Jersey: High confidence benefits were $9.9 million, lower confidence benefits $0.4 million, and potential or speculative benefits $2.3 million, based on data for various years from the mid-late 1990s.

Value of Coasts and Ecosystems

Studies of market and non-market values of attributes of coasts provide a sense of the magnitudes of increases in value that may be possible with activities that lead to improvement or prevent deterioration. Many of those activities involve mapping and spatial information. Since the coastline is so valuable, even attributing small percentages to mapping and spatial information can lead to benefit values that are quite large.

A number of studies are available which gauge the value of wetlands, including studies specifically of wetlands in coastal areas. Costanza, *et. al*. estimated that coastal wetlands in the U.S. provide $23 billion per year in hurricane protection services based on damage averted in year 2004 dollars.[60] Petrolia and Kim examined respondents' willingness to pay for restoration of barrier islands in Mississippi. They found a willingness to pay of $22 per respondent to maintain the existing footprint over a 30-year period, $152 to restore 2,338 acres to their pre-1969 footprint, and $277 per respondent to restore 5,969 acres to their pre-1900 footprint.[61] Meta-analyses – studies that integrate findings of numerous other studies, synthesize more extensive evidence on benefits of wetlands.[62] Other studies deal with additional coastal features and environmental aspects.

Value of U.S. Ports

Martin Associates examined the economic impacts of U.S. deepwater ports in 2006 using an input-output approach which takes account of purchases from other industries and purchases of other industries from

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[59] U.S. Department of Transportation, Bureau of Transportation Statistics, *National Transportation Statistics, 2009*, 2009, Table 1-51 http://www.bts.gov/publications/national_transportation_statistics/pdf/entire.pdf

[60] Robert Costanza, *et. al*., "The Value of Coastal Wetlands for Hurricane Protection, "Swedish Academy of Sciences, *Ambio* (June 2008), pp.241-248.

[61] Daniel R. Petrolia and Tae-Goun Kim, "What are Barrier Islands Worth?: Estimates of Willingness to Pay for Restoration," *Marine Resource Economics* Vol. 24 (2009), pp.131-146.

[62] A. Ghermandi, *et. al*., "The Economic Value of Wetland Conservation and Creation," Nota Di Lavoro, 79, 2008; Richard T. Woodward and Yong-Suhk Wui, "The Economic Value of Wetland Services: A Meta-Analysis," *Ecological Economics*, 37 (2001), pp.257-270.

the subject industry. The firm estimated direct economic output of the port sector at $71 billion and local purchases of 26 billion. These supported $1.9 trillion of direct, induced and indirect economic output of importers and exporters.[63] The economic multiplier used is exceptionally high compared to other studies.

National Ocean Economic Program and National Ocean Watch

The 2009 National Ocean Economics Project report on the state of the U.S. ocean and coastal economies notes that in addition to its contribution to GDP, the nation's ocean and coastal economy (including coastal and inland) generates non-market economic value as measured by consumer surplus "at a minimum of tens of billions of dollars per year, and likely over $100 billion."[64] It points out that coastal states account for 83% of the U.S. economy.[65]

Tourism and recreation account for half of ocean economy GDP and three quarters of all jobs. Transportation and minerals represent another third of GDP.

The National Ocean Economic Program Web site http://www.oceaneconomics.org/ provides detailed information on the coastal and ocean economies in interactive form, relying heavily on the *U.S. Economic Census*. It also provides references on many benefit studies, cataloged according to the methodologies they used. However, much of the economic information is for 2007 and prior years since Economic Censuses are five years apart, and most of the studies cited are much earlier.

The reporting of ocean and coastal economic data (not listing and categorization of studies) is being continued by the Economics National Ocean Watch (ENOW) program in NOAA's Coastal Services Center at http://www.csc.noaa.gov/digitalcoast/data/enow/index.html

[63] Martin Associates, *The Local and Regional Economic Impacts of the U.S. Deepwater Port System*, prepared for the American Association of Port Authorities, September 5, 2007.
[64] Judith T. Kildow, Charles S. Colgan, and Jason Scorse, *State of the U.S. Ocean and Coastal Economies, 2009*, National Ocean Economics Project, 2009, p.6 http://www.oceaneconomics.org/ For most of the components the study assumed that benefits were 1% of revenue.
[65] *Ibid*, p.7.

Order of Magnitude Estimates of the Value of CMP Products and Services

Calculation of Benefit Estimates

Benefits of CMP Products above Alternatives

Benefits are those above those what would be obtained with alternatives. In the absence of CMP, users would have to do the mapping by themselves, rely on private vendors or go without the information. Considerations in assessing benefits above alternatives are explored in the earlier section on methods.

When alternatives are compared in the quantitative analysis that follows, the assumption is made that government and private users would not provide the information for themselves. Private vendors would be used to supply information with 80% of the direct economic value per use of what CMP provides and at 25% higher costs.[66] Higher costs are assumed to lead to 15% less use. With these assumptions (or any combination that produces the same result), half of the direct economic benefits of CMP products would be available without CMP and half of the benefits of CMP products are the additional value of CMP products. For the Change Analysis Program a 50% reduction is used to allow for the contribution of satellite data. No reduction in benefits for the availability of alternatives is made for Digitally Reproduced Historic Imagery or for the energy components of Boundary Determination and Legal Aspects because of the absence of comparable alternatives.

Allowance for Use of Satellite Data

In addition to the reduction in benefit estimates for alternatives that would be expected in the absence of CMP. About 20%-25% of the data that CMP uses is satellite data from other sources. However, CMP provides processing, interpretation and dissemination in addition to collection of data. Consequently, a reduction of 8% is applied to allow for CMP's use of satellite data. This adjustment is applied to the total of benefits of all of the products since there is no basis for allocation among the individual products.

Designation of Uncertainty in the Benefit Estimates

Ranges based on alternative assumptions are used to reflect uncertainty in the component benefit estimates. A convenient method which has been used in project management and business decision-making is to assume a triangular distribution in which the point estimate is the mode, the lower and upper bounds are a given percentage (e.g. 20%) from the mode, and the heights of points on the distribution are determined by straight lines between the mode and the extremes.[67] With the triangular distribution, three-fourths of the likelihood is within the middle half of the range. With ±20%, which approximates the range in the sum of the ranges of the component estimates of economic benefits, three-fourths of the likelihood is within 10% of the mode. This is a wider range than has been used in other economic research studies.

If direct economic benefits are calculated as the sum of benefits for several products, and if it can be assumed that errors are as likely in each direction, then averaging of errors can occur. The Law of Large Numbers prescribes that the range of error in the total of many values will be less than the sum of the ranges of the components. This would make the range of error in the total even less than the triangle distribution prescribes.

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[66] Higher costs of alternatives count as higher benefits of CMP relative to alternatives.

[67] Molly K. Macauley and Jhih-Shyang Shih, *Assessing Investment in Future Landsat Instruments: The Example of Forest Offsets*, Discussion Paper RFF DP 10-14, Resources for the Future, March 2010, p.16. Some other studies have used 10% for the range.

The triangular distribution of values is an alternative to adding the range extremes of all of the cases in that it specifies that values are likely to be in the middle half of the range of the total. The range of error is assumed to be within 10% of the sum of the ranges of the components. This concentration of likelihood is applied to direct economic benefits, total economic benefits and to the sum of economic and non-economic benefits. Of course, other assumptions in making the component estimates would lead to different results.

Direct Economic Benefit Estimates

Direct benefits are those that accrue only to users of the product or service. Benefits are above those that would be expected from alternatives in the absence of CMP. Where applicable, benefits are allocated between CMP products and the efforts of other organizations involved in the product's production.

While benefits are estimated for specified activities and product categories, the focus should be on the total benefits of CMP. That is because benefits of some products fall into other product categories as a result of the interdependence of the products and the nature of the estimation.

Estimates of benefits are midpoints of ranges. Ranges of benefits are indicated for component estimates and sums of ranges of components of total CMP benefits are calculated. However, totals of CMP benefits are assumed likely to be in ranges of ±10% as discussed previously. These ranges are shown in presenting the estimates for CMP as a whole.

Nautical Chart Production

For Nautical Chart Production, estimates of benefits for commercial and recreational boating are adapted from the work of Kite-Powell.[68] Estimates for commercial fishing are related to those benefit estimates as well. Benefits are based on annual willingness to pay for nautical charts, adjusted for inflation, together with current numbers of vessels. After consideration of total benefits of nautical charts, a portion of benefits is allocated to CMP for its contribution to the program.

Willingness to pay, when added to the cost of the charts to users, gauges the gross direct benefits to the immediate users. The subsequently applied multiplier for indirect and induced benefits incorporates the benefits that other users derive from the nautical charts as well as broader effects.

The measure of benefits used is willingness to pay for "ideal charts." The traits desired do not differ dramatically from charts available at the time. Some of the desired improvements have come since the time of the study, especially with the switch to electronic charts. Improvements have been made in the charts over the last few years, including the most desired feature of commercial mariners of updates of electronic navigation charts via the Internet. Consequently, there may not be a large bias from using values of ideal charts as values for actual charts in use today. Nevertheless, a lower range estimate is included to allow for the possibility that current charts differ in value from what were considered "ideal charts" a few years ago.

The values implicitly include the value that the mariners attach to improved safety resulting from their ownership of the charts. Broader benefits, including safety benefits to other users, are considered later.

[68] Hauke Kite Powell, *Use and Value of Nautical Charts and Nautical Chart Data in the United States*, report to the NOAA Office of the Coast Survey, Woods Hole Oceanographic Institute, August 2007.

The subtraction of benefits obtainable with alternatives is made after the benefits are estimated for commercial vessels, recreational boaters and commercial fishing.

Commercial Vessels

Kite-Powell obtained average willingness to pay for ideal nautical charts from a 2005-2006 survey of mariners. For commercial vessels he found an average stated valuation of $2,600 per vessel per year. The values were $3,200 for self-propelled ships and $1,850 for tug/tows.[69] These values are updated for inflation from 2005-2006 to 2011 with increases of 13.3%. The overall value becomes $2,946, with $3,626 for self-propelled ships and $2,096 for tugs/tows.

On December 31, 2009 there were 2,223 self-propelled and 1965 towboats among U.S. flag passenger and cargo vessels operating or available for operation on the U.S. coasts and Great Lakes (Table 10). Multiplying the willingness to pay values by these counts (assuming 100% using U.S. nautical charts) .results in willingness to pay for self-propelled vessels of $8.1 million and for towboats $4.1 million, for a total for U.S. carriers of $12.2 million.

There were about 7,600 foreign-flag ships operating in U.S. waters, according to the U.S. Coast Guard.[70] All of these are assumed to navigate the coasts or Great Lakes. Using the willingness to pay of self-propelled vessels of $3,626, the value of nautical charts to foreign-flag ships is $27.6 million.

Combining the U.S. and foreign-flag estimates leads to a value of nautical charts for commercial vessels of $39.8 million per year. An alternative estimate that is 10% lower or $35.8 million is also used to reflect the possibility that current nautical charts have less value than earlier ideal charts. Thus, benefits are estimated to be in the range $35.8-$39.8 million before deducting the value of alternatives.

Recreational Boating

Kite-Powell found an average annual willingness to pay for nautical charts by recreational boaters (including recreational fishing) of $49.70 per year.[71] Updating for inflation yields a value of $56.31.

The National Marine Manufacturers Association provides data on the number of recreational boats by state.[72] The national total in 2010 was 16.7 million, including 12.8 million registered boats and 3.9 million unregistered. The registered number for coastal and Great Lakes states was 10.2 million, 80.7% of the registered total.

The total of registered and unregistered boats included 8.24 million outboard boats, 1.08 million inboard boats, 1.52 million sterndrive boats and 1.53 million sailboats (motor and non-motor). Applying the coastal and Great Lakes percentage to each of these counts for the purpose of calculating total carriage of nautical charts yields 6.6 million outboard boats, 0.9 million inboard boats, 1.2 million sterndrive boats, and 1.2 million sailboats. Actual shares in the coastal and Great Lakes states will differ among types of boats.

Charts are assumed for the purpose of calculating the total to be carried by 30% of outboard boats, 50% of inboard boats, 40% of sterndrive boats and 10% of sailboats.[73] Using these percentages with the numbers

[69] *Ibid*., p.23.
[70] *Ibid*, p.23.
[71] *Ibid*., p.14.
[72] National Marine Manufacturers Association, *2010 Recreational Boating Statistical Abstract*, *Summary*, NMMA, 2011, Table 6.1 http://www.nmma.org/statistics/publications/statisticalabstract.aspx
[73] Based loosely on the rates of chart carriage found by Kite-Powell which were classified differently.

of boats of each type results in total nautical chart carriage of 3.0 million boats. This count is next reduced by 20% to exclude use of recreational boats in coastal and Great Lakes states on lakes other than the Great Lakes. This produces a count of 2.4 million coastal and Great Lakes recreational boats using nautical charts. The number would be higher if the percentage of chart users increased in recent years.

Willingness to pay for charts of $56.31 per user is multiplied by the 2.4 million coastal and Great Lakes recreational boats to obtain estimated benefit of $135.1 million. An alternate estimate is added that is 10% lower for nautical charts having a lower value than earlier ideal charts. This results in a benefit range of $121.6-$135.1 million before deducting the value of alternatives.

Commercial Fishing

The annual willingness of commercial fishing mariners to pay for nautical charts is assumed to be half of that of commercial boaters or $1,473 per year. The lower rate is used because many are small enterprises compared to commercial boats, and because they are seasonal.

The number of documented commercial fishing vessels in coastal and Great Lakes states is derived from U.S. Coast Guard tabulations for 2008. It is not provided by state. The "undocumented" counts are reported by state from state records. Federally documented vessels were allocated to states proportionally. The vessel count calculated for the coastal and Great Lakes states is 59,442, 76.5% of the total.[74]

Multiplying the willingness to pay of $1,473 per year by the vessel count of 59,442 and assuming 100% use results in a coastal and Great Lakes benefit of nautical charts for commercial fishing of $87.6 million. Including an alternate 10% lower value of current charts than earlier ideal charts yields a range of benefits of $78.8-$87.6 million before deducting the value of alternatives.

Combined Direct Benefits above Alternatives

The estimates of direct annual benefits to users of nautical charts to mariners by type are summarized in Table 12. The $236.2-$262.5 million in benefits (before deducting the value of alternatives that could arise in the absence of the program) compares with total revenue in the three boating sectors of about $110 billion. It is about ¼% of revenue and ½% of value added (revenue less purchased inputs).

Table 12. Direct Annual Benefits of Nautical Charts to Mariners, by Sector, 2011

Sector	**Benefits** (millions)
Commercial boating	35.8-39.8
Recreational boating	121.6-135.1
Commercial fishing	78.8-87.6
Total	***$236.2-$262.5***
Benefits above alternatives	**$118.1-$131.3**
Note: Benefits of all contributing organizations	

Benefits are reduced by half to roughly exclude benefits that would be obtainable with alternatives such as private vendors providing charts with less information and/or less geographic coverage and fewer charts being used because of higher costs. This results in benefits of NOAA nautical charts of $118.1-$131.3 million. This is the incremental value of the public provision of charts. The number will be reduced further in determining the CMP contribution.

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

Broader Benefits of Nautical Charts

The willingness of mariners to pay for nautical charts includes the value to mariners for their safety and trip management from their own use of charts. Other mariners also benefit in improved safety from their use. The benefits go far beyond that, however, since nautical charts are used for:

- Guiding ships and boats for safety and efficiency
- Managing ports and their construction
- On-shore economic development
- Offshore energy exploration and production and on-shore support
- Planning and operations of companies and governments
- Coastal resource management – habitat, inundation monitoring, sustainable development, and other aspects of assessing and managing environmental change
- Disaster and emergency response
- Adjunct scientific and engineering purposes

Benefits of nautical charts to ports are covered in the estimate for the Change Analysis program.

Allocating Benefits of Nautical Charts to CMP

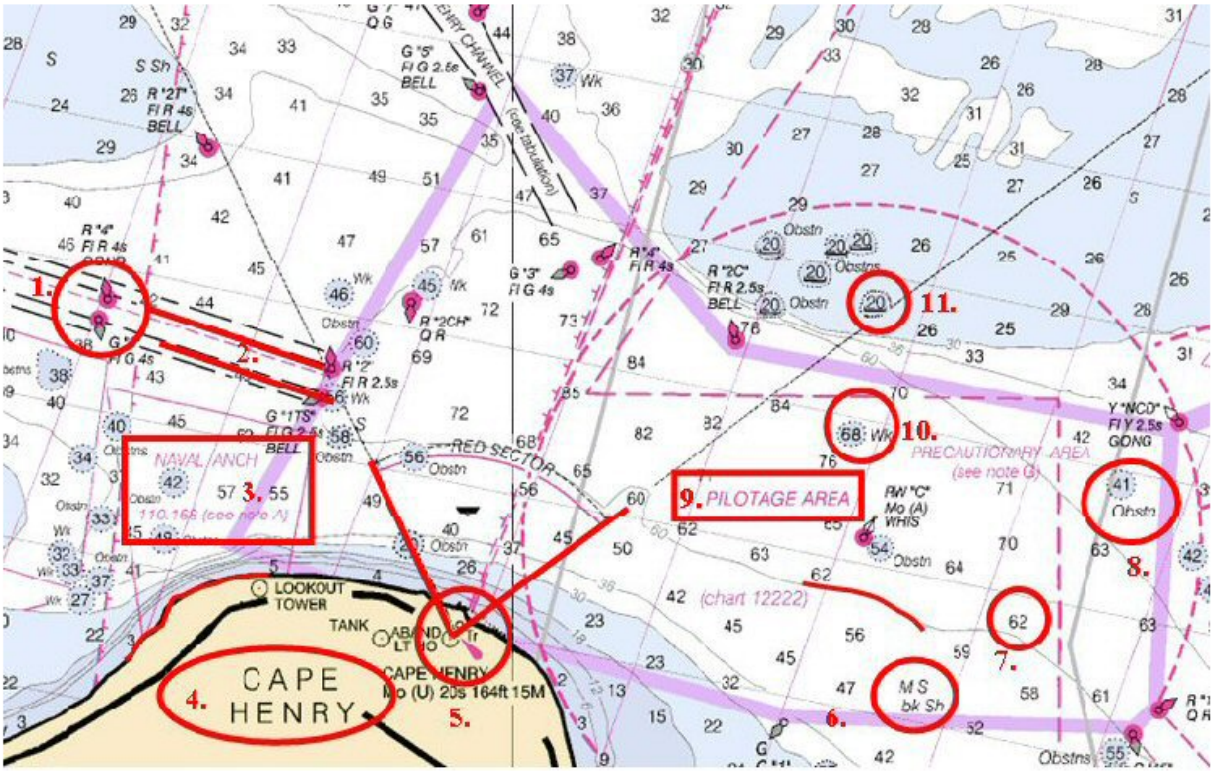
The remote sensing and mapping efforts of CMP provide a foundation on which other information is displayed. They also provide specific features of nautical charts. Figure 4 shows an example of ways in which CMP data, hydrographic, bathymetric and other data from other parts of NOAA, and information from the U.S. Coast Guard, the Army Corps of Engineers, and the Global Positioning System come together.[75] The components will vary among charts, depending on the features in the area.

[75] The chart is from http://www.nauticalcharts.noaa.gov/mcd/learnnc_sourceinfo.html

Figure 4

Source Information on Nautical Charts

The nautical chart conveys a wealth of information to the mariner. The graphic below illustrates a sample of the type of information that appears on nautical charts.



1. Floating **aids to navigation** established and maintained by the U.S. Coast Guard mark channels and other features such as wrecks and obstructions.
2. The U.S. Army Corps of Engineers dredges **channels** so that deep draft vessels can transit into and out of ports. Mariners must know the position and depth of these channels.
3. Nautical charts delineate the location of **anchorages** for military, commercial, and recreational vessels.
4. NOAA shows official **geographic names** in conformance with the U.S. Board of Geographic Names.
5. Fixed **aids to navigation** , such as lighthouses maintained by the U.S. Coast Guard, help mariners navigate safely.
6. Mariners need to know **bottom characteristics** in order to determine where adequate holding grounds for anchoring are located.
7. **Depths** determined by NOAA surveys are critical to safety of navigation.
8. Mariners must know where underwater hazards and **obstructions** are located. The chart shows the precise position and depth of water over the obstruction.
9. Most commercial ships entering a harbor need to know where **pilotage** areas are located. These areas are used for taking on and leaving off marine pilots.
10. Mariners need to know the position and depths of **dangerous wrecks** , so they can lay out a track to avoid these features.
11. **Wire drag cleared depths** show the safe navigation depth. This charting symbol indicates that there was at least 20 feet of depth available over the top of the obstruction located here.

The value of the charts depends on inputs from different organizational units that complement each other. A rough approximation of the CMP contribution is made based on the components each organization contributes. Charts are composed of vertices that make up the shape of each feature. An analysis of vertices in several types of charts conducted by Doug Graham of CMP for this project found that CMP directly contributed about 25% and partially contributes (is one of a few sources) about 71%. Using this data, the CMP contribution to the value of nautical charts is taken to be on the order of magnitude of 35%-40% of the total value of the charts.

Applying 35%-40% to the direct annual benefits to mariners above alternatives leads to a direct benefit from nautical charts attributable to CMP of $41.3-$52.5 million, with a midpoint of $46.9 million.

The estimated benefit from nautical charts attributable to CMP includes the direct value of the Shoreline Mapping and the Change Analysis programs to mariners.

Change Analysis

Benefits to Port Construction

It would be useful to know explicitly what the effects of improved chart information are on the efficiency of port operations and the volume and value of shipping ports can and do handle, whether associated with construction or not. This has many dimensions. There can be cost savings in port operations and for shippers as a result of faster turnaround or accommodating larger ships. Expansion of shipping activities can permit savings as shifts occur from less efficient ports or from other modes of transportation. The volume of internal and/or international trade can be increased if there are capacity limits in the national or local systems. Examining these relationships requires extensive analysis. For this study the contribution of the Change Analysis Program to port construction serves as a proxy for the value of some of the broader impacts on ports and shipping.

The Change Analysis Program provides updated nautical chart information to most of the 175 ports that the U.S. Army Corps of Engineers covers. CMP updated charts for 30 port areas in FY2011 and analyzed 29 ports for change.

Ports need to make changes to their facilities and/or operations when shorelines and their features change or when demands of more and/or larger ships or shifting mixes or volumes of cargos require adaptation. A major use of the Change Analysis information is in port construction, facilitating design and planning, even making the difference in whether a project is feasible.

The nation's 125 public ports alone invest more than $2 billion in their facilities each year.[76] That averages $16 million per port. If the Change Analysis Program served 100 ports in the coasts and Great Lakes and their investment in facilities averaged $16 million per year, the total annual investment in those facilities would be $1.6 billion per year. Assuming the direct economic benefit including consumer surplus to those ports from the Change Analysis Program (above the benefit they receive from nautical charts without revision from the Change Analysis) is 1%-2% of their investments, the benefit is $16-$32 million per year.

Reducing the value by half to allow for the value of alternatives such as private remote sensing yields direct economic benefits to ports of $8-$16 million per year.

The Change Analysis Program also has benefits for public and private coastal engineering and development, planning and operations of companies and governments, coastal resource management and emergency response. The benefits to mariners are included in the estimates for the nautical charts program.

[76] Jean C. Goodwin, "Impact of the 112th Congress on the Port Industry, American Association of Port Authorities, April 7, 2011, p.6 http://aapa.files.cms-plus.com/AAPAPresentations/Jean%20Godwin%20presentation%20to%20WISTA%204-7-11.pdf

Allocating Benefits of the Change Analysis to CMP

A portion of the benefits of the Change Analysis Program is attributable to use of satellite data with which the aerial remote sensing data is compared. Assuming half of the benefit is attributable to CMP, the CMP portion of the benefit of the Change Analysis Program is $4-$8 million per year, with a midpoint of $6 million.

Boundary Determination and Legal Aspects

The estimate for Boundary Determination and Legal Aspects is developed by combining estimates for avoidance of delays in offshore oil and gas production with savings in the costs of title insurance. The two components provide only a minimum estimate of the benefits to all types of uses.

Avoidance of Delays in Offshore Oil and Gas Production

A critical application area for coastal boundary determination is offshore oil and gas exploration, development and production. Most production takes place in the Central and Western Gulf Coast. Boundary disputes between the states and the federal government and between governments and private interests can delay exploration, development and production offshore and activity in the onshore facilities that support it. Negotiations and law suits can drag out for many years. RSD's efforts at boundary determination and the official legal status of those boundaries results in fewer disputes and project delays.

The Bureau of Ocean Energy Management, Regulation and Enforcement (BOEMRE), formerly called the Minerals Management Service, estimated the net benefits of as yet undiscovered and unleased oil and gas on the outer continental shelf of the Central and Western Gulf of Mexico at $144 billion in dollars of year 2007 purchasing power, using a 40-year production period and a 7% discount rate.[77] The measure of net benefits includes a deduction for environmental costs and a value for consumer surplus from the additional production lowering the price that energy consumers pay. The study does not include a multiplier effect for benefits to the rest of the economy.

The data are based on a 2006 assessment. It assumes an oil price of $46 per barrel (vs. prices in 2011 largely above $80 per barrel) and a natural gas price of $6.96 (vs. 2011 gas prices averaging around $4.00). The data from the study needs to be adjusted to reflect higher oil prices, lower gas prices, greater than usual current delays in federal permitting (unrelated to boundaries) and other regulatory responses to the Deepwater Horizon oil spill, and the potential for greater discoveries with new technologies than estimated in 2006. Also, the small environmental deduction needs to be removed in considering economic benefits. The oil price increase is the largest factor. The assumption is made that adjustment for all of the factors would result in a current value for the 40-year benefit of $200 billion. The estimate applies only to the outer continental shelf and does not include alternative energy.

Table 13 shows the percentage by which the present value of a stream of benefits over the next 40 years would be reduced by delays of 2, 4 and 6 years, using discount rates of 3%, 5% and 7%. At a 7% discount rate the present value of benefits with a four year delay would be reduced by 2.2%. This value will be used to estimate the savings from reduced delays in federal permitting and local approvals.[78] No allowance is included for the value of reduction in uncertainty to business.

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[77] U.S. Department of the Interior, Bureau of Ocean Energy Management, Regulation and Enforcement, *Revised Program, Outer Continental Shelf Oil and Gas Leasing Program, 2007-2012*, December 2010.

[78] Production is only counted if it occurs during the next 40 years. If production ended 40 years after it started regardless of the delay, the difference in present value with and without delay would be negligible.

Table 13. Percentage Change in Value from Delays in a 40-Year Production Period at Alternative Discount Rates			
	Number of Years Delay		
Discount Rate	2	4	6
3%	-2.7%	-5.5%	-8.6%
5%	-1.7%	-3.6%	-5.6%
7%	-1.0%	-2.2%	-3.6%

If 5%-8% of the production area is affected by improved boundary information from the Boundary Determination and Legal Aspects Program, its production would have a value of $10-$16 billion (5%-8% of $200 billion). At 2.2%, the benefit of avoided delay from CMP information *in all years* would be $220-$352 million. This is a discounted value of a stream of benefits over 40 years. At 1/40 of the total, the average annual benefit of the CMP Boundary Determination and Legal Aspects Program to reducing delay in permitting in offshore oil and gas production in the Central and Western Gulf is $5.5-$8.8 million.[79] No reduction is made for alternatives to the CMP program because of the official nature of the boundaries.

Avoidance of Delays in Offshore Wind Power

Offshore wind power has great potential but also has many hurdles to overcome to become large. The importance of CMP's contribution to resolving boundary disputes depends on how much of that potential materializes and how far off in time it is.

The National Renewable Energy Laboratory noted in a 2010 report that:[80]

> "The United States leads the world in installed, *land-based* wind energy capacity, yet has *no offshore* wind energy generating capacity to date…."
>
> "…about 20 projects representing more than 2,000 MW of capacity are in the planning and permitting stage…."
>
> "Untested regulatory and permitting requirements in federal waters (outside the three-nautical-mile state boundary) have posed major hurdles to development, but recent progress is clarifying these projects."

It goes on to say:[81]

> "The definition of offshore areas is complex, involving the interpretation of physical characteristics of an area as affected by various treaties and international and domestic law. The

[79] If the CMP contribution were concentrated in the early years, with later efforts largely dealing with changes that alter boundaries, the benefit of current efforts would be higher than 1/40 of the present value of production. However, if the permitting process is greatly stretched out, the use of CMP information also would be stretched out.
[80] National Renewable Energy Laboratory, *Large-Scale Offshore Wind Power in the United States: Assessment of Opportunities and Barriers*, NREL/TP-500-40745, NREL, September 2010, p.2.
[81] *Ibid.*, p.63.

> BOEM and the National Oceanic and Atmospheric administration are working to establish this information by defining a baseline of the mean lower low (MLLW) water line….From the MLLW, the state and federal administrative zones are derived,…These data are still under development."

The study also reported that: "Several projects are now in early permitting stages under BOEM regulations and developer's [sic] estimate that approvals may take as long as 7 to 10 years, longer than permitting approvals for most other types of energy facilities.[82]

Issues that must be overcome for large scale development to succeed include technology for operating far offshore, cost, regulatory processes, environmental concerns, transmission infrastructure, radar interference, and public concerns about appearance, noise, property values, tourism, and marine safety.

Because of the great uncertainty about the prospects for offshore wind energy, the benefits of CMP boundary determination efforts are estimated conservatively. Benefits of CMP efforts in all parts of the country are taken to be one-tenth of the CMP contribution to benefits of offshore oil and gas in the Central and Western Gulf of Mexico, or $.6-$.9 million. In a very optimistic scenario such as used by the Department of Energy in promoting the program, [83] the benefits would be much larger.

Reduction in the Cost of Title Insurance

Reduction in the cost of title insurance is one consequence of better and official boundary information. Title insurance premiums, fees and charges were $10.1 billion in calendar year 2010, according to the American Land Title Association.[84] The assumption is made that shore areas in coastal and Great Lakes states accounted for 5%-10% of national premiums, fees and charges or $0.5-$1.0 billion.

Improved boundary information could have made it less costly for title insurance companies, real estate developers and agents, lawyers, and others to obtain title information. The information also can have produced lower premiums and fees by increasing competition in what has been an uncompetitive industry.[85] Assuming the savings were 4%-5% of premiums and fees in shore areas of coastal and Great Lakes states compared to alternatives without the program, they would be $20-$50 million per year.[86] In some cases private surveying, state maps or other sources can provide an alternative if the Boundary Determination and Legal Aspects Program didn't exist. Reducing the value by half to measure the value above alternatives leads to benefits of $10-$25 million. Savings would be even greater in a more robust housing and commercial construction market.

Combined Direct Benefits of the Boundary Determination and Legal Aspects Program

Combining the estimates for energy and title insurance yields a range of benefits of $16.1-$34.7 million (Table 14), with a midpoint of $25.4 million.

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[82] *Ibid.*, p.7.
[83] U.S. Department of Energy, *A National Offshore Wind Strategy: Creating and Offshore Wind Energy Industry in the United States*, February, 2011.
[84] http://www.alta.org/industry/financial.cfm
[85] J. Robert Hunter, "Title Insurance Cost and Competition," testimony before the House Committee on Financial Services, Subcommittee on Housing and Community Opportunity, Consumer Federation of America, April 26, 2006.
[86] The share of premiums and fees in shore areas reflects the high values often associated with properties near the shore as well as the prevalence of properties that could benefit. The savings are assumed to be small because limited competition in the title insurance industry can prevent larger savings from being passed on in lower premiums and fees. The estimate allows for efforts of other agencies in setting the official boundaries.

Table 14. Boundary Determination and Legal Aspects Direct Economic Benefits by Component, 2011 (millions)	
Oil & gas	5.5-8.8
Wind power	0.9-0.9
Title insurance	10.0-25.0
Total	**$16.1-$34.7**

Shoreline Imagery

The value of shoreline imagery estimated here is in addition to its value that is implicitly included in the estimates for other CMP products.

Page requests from the NOAA Shoreline Data Explorer were made at an annualized rate of 26,089 in 2011 (Table 4). These are assumed to have an average value to users of $100 each (including consumer surplus), resulting in an annual value of $2.6 million. The value is reduced by half to obtain the value above alternatives, resulting in a benefit estimate of $1.3 million.

Digitally Reproduced Historic Imagery

Historic imagery is used by lawyers and insurance companies to determine what was physically present before accidents or natural disasters. It is also used for historical, archaeological, cultural and other purposes.

The number of downloads of historic imagery is included in data for the Photo Ordering System and on the Notable Photographs Web page, and is not available separately. It is assumed that 5,000 digital historic images are downloaded annually and that the value to users is $100 per image, including consumer surplus. The value per image is an average that includes both high value uses such as settling insurance claims and lower value uses such as those for personal historical interest. Direct economic benefits are estimated at $500,000 per year. No reduction is made for the value of alternatives since it is assumed that good alternatives are generally not available.

Emergency Response Imagery

Extensive use of CMP's Emergency Response Imagery is made by media of all kinds, largely for weather-related events. A portion of what studies have shown people are willing to pay for weather information is used as a basis for estimation of the program's benefits.

A survey by Lazo *et. al.* estimated the value of weather forecasts and information to households in 2006 at $31.5 billion. The value is much higher than an earlier estimate by Lazo and Chestnut which used a preferred "willingness to pay" methodology.[87] The willingness to pay study found an annual value of existing weather forecasts of $11.4 billion in 2001 dollars. In addition to methodology, the difference may be that the 2006 study was influenced by the experience of Katrina in 2005. The assumption is made that that a "willingness to pay" methodology would result in benefits to households in a typical year of $18

[87] Jeffrey K. Lazo and Lauraine G. Chestnut, *Economic Value of Current and Improved Weather Forecasts in the U.S. Household Sector*, Stratus Consulting, November 22, 2002.

billion in year 2011 dollars.[88] This value is doubled to $36 billion to allow for benefits of weather information to businesses and governments.[89]

The Emergency Response Program covers high value events, but an event covers only part of the country. The value related to events that the Emergency Response Imagery Program covers is assumed to be 3%-4% of the total value or $1.1-$1.4 billion. Taking the Emergency Response Imagery Program's contribution as 4%-5% of that, its value is $43-$72 million.[90] These values are taken to include the contribution of CMP's shoreline imagery to pre- and post-event planning and operations.

Some of what the program does might be done by private firms offering remote sensing services, but costs would be higher because they would be spread over a smaller, paying, customer base. Private firms would not have an incentive to cover all the areas or users that the Emergency Response Imagery Program does because there would be fewer paying users than CMP has. Also, without the program there might be more ground observation by public or private entities. If the benefits of the program *above* the benefits of alternatives are half of the total direct benefit, the benefits are $22-$36 million.[91] The midpoint is $29.0 million.

Summary of Direct Economic Benefit Estimates

Direct Economic Benefit Summary

The orders of magnitude of direct economic benefits for the Coastal Mapping Program are summarized in this section. Benefits are specific to the geographic areas the programs cover. All benefits are those above benefits that would be expected with alternative sources, except for Digitally Reproduced Historic Imagery and the Boundary Determination and Legal Aspects Program, for which alternative sources that do not simply replicate the same activities are not applicable. Consumer surplus is included.

Benefits of individual products depend on the components used in estimation. Many applications are not included, which makes the benefits a minimum estimate. Benefits of some products largely appear under other products that make use of them. The applications for which direct economic benefits of the CMP products are estimated are shown in Table 15.

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[88] The consumer portion of the benefit estimate includes some safety benefits.

[89] This includes the value of public weather information distributed to emergency and restoration personnel and others through official channels rather than the media.

[90] By way of comparison, the 2007 Centrec study of GOES products examined gains from protection and evacuation of hurricanes and tropical storms in 213 coastal and border counties along the Gulf and Atlantic seacoasts. Areas receiving warnings to protect property and evacuate were assumed to be reduced by 5% in length with improved forecast information. Citizens and decision-makers were assumed to be about 25% more responsive with improved information. On this basis improved forecasts result in $506 million less in property damage and $9 million less in the cost of unnecessary evacuation, while reducing the cost of property protection by $142 million and the cost of evacuation by $3 million. There also is a reduction in the loss of life and cost of injury. See Centrec Consulting Group, LLC, *An Investigation of the Economic and Social Value of Selected NOAA Data and Products for Geostationary Operational Environmental Satellites (GOES)*, Report to NOAA's National Climactic Data Center, February 28, 2007.

[91] An alternative approach involves calculating the avoided cost of surveys that would have to be done if the imagery was not available. Costs per image and therefore savings would likely be higher than if the private sector provided imagery. At present there is no data on the number of emergency response image downloads to apply an average cost savings. Only the number of gigabytes is available and determining an accurate average image size to estimate downloads would be difficult.

Table 15. Basis of Component Estimates of Direct Economic Benefits of CMP
Nautical Chart Production
Commercial vessels – willingness to pay
Recreational boating– willingness to pay
Recreational fishing– willingness to pay
Change Analysis
Benefits to ports based on construction
Boundary Determination and Legal Aspects
Avoidance of delays in offshore oil and gas production
Avoidance of delays in offshore wind power
Reduction in the cost of title insurance
Shoreline Imagery
Value of page requests
Digitally Reproduced Historic Imagery
Value of page requests
Emergency Response Imagery
Contribution to willingness to pay for weather forecasts

Benefits are gross. They do not exclude the costs incurred to obtain the benefits by CMP. Benefits are only to immediate users. Benefits to other parts of the economy are taken into account in the section on direct, indirect and induced economic benefits.

The estimates are based on the current program. They do not indicate what the benefits would be if remote sensing were done more frequently, if improved technologies were deployed, or if demand for the products increased.

The estimates of the benefit totals (sum of the midpoints of the ranges) are reduced by 8% to allow for the use of satellite data from other sources.

The estimate of direct economic benefits of Coastal Mapping Program products and services in 2011 is $100.4 million. The 10% range is $90.4-$110.4 million (Table 16). These are the portion of benefits attributable to CMP activities after allowing for contributions of other organizations that are also involved in production of the products and the value of alternatives in the absence of CMP are subtracted.

The values for the individual products do not include reductions for the use of satellite data. Benefits of some products are included in the estimates for other products and some non-economic benefits are included in economic benefits because of the nature of the estimation. Benefits as estimated are concentrated in Nautical Chart Production, Boundary Determination and Legal Aspects, and Emergency Response Imagery. Most Shoreline Imagery benefits are included in the benefits of those products. Some of the benefits of the Change Analysis are included in the benefits of Nautical Chart Production.

Table 16. Order of Magnitude of Direct Economic Benefits of CMP, 2011 (millions of dollars)	
Nautical Chart Production	41.3-52.5
Change Analysis	4.0-8.0
Boundary Determination and Legal Aspects	16.1-34.7
Shoreline Imagery	1.3
Digitally Reproduced Historic Imagery	0.5
Emergency Response Imagery	22.0-36.0
Sum of Ranges of CMP Direct Economic Benefits	*85.2-133.0*
Midpoint of Sum of Ranges	*109.1*
Total CMP Direct Economic Benefits (midpoint of sum -8%)	**$100.4**
Range of CMP Direct Economic Benefits (total ±10%)	$90.4-$110.4

Comparison of Direct Economic Benefits with CMP Costs

The budget of the Coastal Mapping Program roughly was about $6.49 million in FY 2011. This includes salaries of CMP personnel, fringe benefits, contractor costs, equipment purchases, and overhead services provided by other parts of NOAA[92]. Allowing $300,000 for aircraft costs, the cost of the program is $6.8 million. Direct economic benefits alone are 15 times the cost of the CMP program.

Direct, Indirect and Induced Economic Benefits

Indirect economic benefits, which include demand generated in supplier and using industries, can come about in many ways. Increased safety with nautical charts can lead to additional recreational boating and fishing and increased shore and other supporting activities, along with more boating and equipment purchases. Faster transit times and avoidance of accidents with nautical charts in commercial shipping can raise demand for industries shipping goods and their suppliers. Greater certainty and information from the Change Analysis Program can facilitate onshore economic development. Authoritative boundaries can allow public and private projects to move ahead more quickly with fewer disputes. Shoreline imagery can facilitate economic development as well as contribute to nautical chart production, change analysis and legal boundary determination. Digitally Reproduced Historic Imagery can accelerate insurance payments and their economic impacts. Emergency Response Imagery can be used to reduce disruption of economic activity and provide a foundation for reconstruction and restoration.[93]

[92] The position of the CMP budget in the NOAA budget is given by the following budget table:

NOAA
National Ocean Service
Operations, Research, & Facilities (ORF)
Navigation Services
Mapping &Charting
Mapping &Charting Base (CMP receives 8.5% of the total)
Shoreline Mapping (CMP receives 100% of this appropriation)

[93] Ironically, the use of imagery in preventing damage and avoiding the need for reconstruction lessens its direct economic impact when measured by GDP concepts since reconstruction adds to economic activity and GDP is not reduced by the loss from destruction of facilities.

Indirect benefits also include contributions of the products to productivity and innovation beyond using industries. Remote sensing data, maps and charts also can overcome bottlenecks to moving forward, such as allowing construction or shipping to proceed.

Induced benefits include demand effects as spending by using industries and their employees generates activity in other parts of the economy.

The effects of indirect and induced economic benefits are taken into account by applying a multiplier to direct benefits. For present purposes a single multiplier is used that incorporates both indirect and induced effects.

The comprehensive study of the value of spatial information in Australia by ACIL Tasman, discussed in the literature review section, provides multipliers that, while crude, are for products akin to those examined here.[94] The value of spatial information is defined to include the difference in economic performance with vs. without spatial information. The total multiplier of direct impacts, the ratio of the total effect on GDP to the direct effect, is calculated from data in the study as the sum of the secondary effects on household consumption, investment, and net exports. The total multiplier ranges from 1.81 in the "lower bound" case to 1.89 in the less accurate "realistic" case.[95] All of the productivity effects are included in direct effects. If allowance were made for innovation in the broader economy as a result of expansion and innovation in spatial information using industries, the multiplier would be higher.

The 2002 DRI-WEFA study of impacts of civil aviation in 2000 used an input output framework built into an econometric model of the U.S. economy that captures extensive effects, including limits to the capacity of the economy. The study used a ratio of total effects to direct effects (the ratio of direct plus indirect and induced effects to direct effects) of 2.6.[96] The 2.6 is composed of two components: 1) the ratio of direct plus indirect to direct benefits and 2) the ratio of direct plus indirect plus induced benefits to direct plus indirect benefits.

The DRI-WEFA study noted from its review of other studies that the ratio of direct plus indirect to direct benefits for industries (i.e. without induced effects) is generally about 2.0. It is estimated at 1.7 in aviation because of high labor costs. It also noted that the second ratio, direct plus indirect plus induced effects to direct plus indirect effects, has been found in more recent studies to be considerably lower than the 2.0 or higher used by many previous studies. It therefore used a value of 1.5 for the second component. The product of 1.7 and 1.5 results in the multiplier used of 2.6. [97]

The total multiplier for benefits of CMP is taken as 2.0, which is consistent with that found in the study of spatial information in Australia.[98] Total annual economic benefits which are double direct economic benefits are shown in Table 17.The total economic benefit of CMP is $200.8 million, with a range of $180.8-$220.8 million. Total economic benefits are 30 times the cost of the CMP program. The estimates are rough orders of magnitude. They are a minimum since not all activities that benefit are included. As noted, benefits of some products are included in the estimates for other products.

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[94] ACIL Tasman, *The Value of Spatial Information*, prepared for the Cooperative Research Centre for Spatial Information and ANZLIC – The Spatial Information Council, March 2008.
[95] *Ibid*., pp.135-136.
[96] DRI-WEFA, *The National Economic Impact of Civil Aviation*, July 2002 http://www.aia-aerospace.org/stats/resources/DRI-WEFA_EconomicImpactStudy.pdf
[97] *Ibid*, p.29.
[98] The estimates in the present study are calculated using a long run economic multiplier that reflects the impact in an economy in average condition. However, with underutilization of capacity in a weak economy, cyclical increases in output can occur as well.

Table 17. Order of Magnitude of Total Economic Benefits of CMP, 2011 (millions of dollars)	
Nautical Chart Production	82.6-105.0
Change Analysis	8.0-16.0
Boundary Determination and Legal Aspects	32.2-69.4
Shoreline Imagery	2.6
Digitally Reproduced Historic Imagery	1.0
Emergency Response Imagery	44.0-72.0
Sum of Ranges of CMP Total Economic Benefits	*170.4-266.0*
Midpoint of Sum of Ranges	*218.2*
Total CMP Total Economic Benefits (midpoint of sum -8%)	**$200.8**
Range of Total CMP Economic Benefits (total ±10%)	$180.8 - $220.8

Non-Economic Benefits

Non-economic benefits are estimated as the sum of health and safety benefits associated with nautical charts and the Emergency Response Imagery Program, plus an illustrative value for environmental benefits based on the value of wetlands.

Nautical Charts for Commercial and Recreational Boating and Fishing

Safety benefit estimates for nautical charts are made based on fatalities and injuries in commercial and recreational boating and fishing.

> The waterborne transportation industry had 41 casualties and 648 injuries in 2010.[99] The numbers for coastal and Great Lakes states, assuming they are 80% of the total, are 33 and 518.
>
> Recreational boating had 736 casualties and 3358 injuries in 2009.[100] At 80%, the coastal and Great Lakes numbers are 589 and 2,686.
>
> Commercial fishing had 59 casualties in 2009.[101] In the absence of an industry total for injuries, 932 injuries are assumed based on the ratio of injuries to fatalities for waterborne transportation.
>
> The combined totals are 681 casualties and 4,134 injuries.

Assuming casualties and injuries would be 5%-10% higher with alternatives to the CMP products, the number of fatalities averted by CMP and other contributors to the products it provides are 34-68 and averted injuries are 207-413.

Five million dollars is used as the value of a statistical life. This is at the low end of the range of values used by government agencies. Valuation is based on applying small probabilities to large numbers of people. It is not a value of any one life.

It was previously assumed that 15%-20% of the benefits of nautical charts are attributable to CMP. Using those percentages, 5-14 fatalities averted and 31-83 injuries

[99] U.S. Department of Transportation, Bureau of Transportation Statistics, *National Transportation Statistics, 2009*, Washington: 2009, Tables 2-45 and 2-46.
[100] *Ibid.*, Table 2-47.
[101] Bureau of Labor Statistics, "Fatal Occupational Injuries by Industry and Event or Exposure, All United States, 2009," table http://www.bls.gov/iif/oshwc/cfoi/cftb0241.pdf

averted are attributable to CMP.

Five million dollars is used as the value of a statistical life. This is at the low end of the range of values used by government agencies. [102] Valuation is based on applying small probabilities to large numbers of people. It is not a value of any one life. This yields a benefit of avoided fatalities of $25-$70 million.

The valuation of injuries must take into account loss of income, medical costs to the injured and to insurance companies and their customers, and pain and suffering. For some injuries these costs continue for years and are in the millions. However, most injuries may be relatively low in cost. Assuming an average of $50,000 per injury yields a benefit of reduced injuries of $1.6-$4.2 million.

Combining the estimates for fatalities and injuries yields a benefit of $26.6-$74.2 million.

Willingness to pay used for benefits of the Nautical Chart Program already includes what users would pay to reduce their own risk of death and injury through chart purchases. It does not include the value to other boaters of having users navigate more safely with the charts. Non-economic benefits are reduced by 40% to roughly allow for what is already in willingness to pay in the calculation of economic benefits, resulting in an estimate of benefits for fatalities and injuries of $16.0-$44.5 million.[103]

Emergency Response Imagery

Non-economic benefits of the Emergency Response Imagery Program are estimated as the value of a reduction in fatalities and injuries from hazardous weather events. An average of the years 2008-2010 is used because of the wide variation in impacts from year-to-year. The three-year average of fatalities from the total of selected types of events was 144 fatalities and 1,385 injuries (Table 18).

[102] After telling agencies to pick a number between $1 million and $5 million for the value of a statistical life, OMB subsequently warned agencies that it would be difficult to justify numbers under $5 million. In 2010, EPA raised its value from $6.8 million to $9.1 million and the FDA raised its value from $5 million to $7.9 million. See Binyamin Appelbaum, "As U.S. Agencies Put More Value on a Life, Businesses Fret," nytimes.com, February 16, 2011http://www.nytimes.com/2011/02/17/business/economy/17regulation.html?_r=1&ref=binyaminappelbaum Also see Appendix B to Leveson Consulting, *Socio-Economic Benefits Study: Scoping the Value of CORS and GRAV-D*, January 2009 http://www.ngs.noaa.gov/PUBS_LIB/Socio-EconomicBenefitsofCORSandGRAV-D.pdf

[103] A larger reduction would not be consistent with the magnitude of willingness to pay for nautical charts, even after the multiplier has been applied.

Table 18. Average Fatalities and Injuries in Natural Hazard Events, 2008-2010				
	2008	**2009**	**2010**	**Average**
Fatalities				
Tornado	126	21	45	64
Thunderstorm wind	28	22	15	22
River flood	24	23	36	28
Coastal storm	15	0	0	5
Tropical storm/hurricane	12	2	0	5
Winter storm	21	21	20	21
Total	226	89	116	**144**
Injuries				
Tornado	1,714	351	699	921
Thunderstorm wind	271	189	325	262
River flood	16	10	127	51
Coastal storm	0	0	0	0
Tropical storm/hurricane	24	1	0	8
Winter storm	0	394	33	142
Total	2,025	945	1,184	**1,385**
Source: NOAA National Hazard Statistics http://www.nws.noaa.gov/om/hazstats.shtml				

The assumption is made that in the absence of the Emergency Response Imagery Program the numbers of fatalities and injuries would be higher by ½%-1%. This is taken to be the net effect of the program after allowing for alternatives that would arise in its absence, other existing sources of information, and the contribution of emergency response programs in federal and local agencies. The figure is only illustrative in view of the absence of quantitative information and the difficulty of separating the contribution of NGS from that of other programs.

The average savings is illustrated as 0.7-1.4 lives, valued at $5 million per life, with a benefit of $3.5-$7 million. Assuming a cost of lost income, medical care, and a value for pain and suffering totaling $50,000 per injury, the benefit of 7-14 fewer injuries is $350,000-$700,000. The combined benefit of avoided fatalities and injuries is then $3.9-$7.7 million.

These values are reduced by 40% to exclude comparable benefits that are already included in the direct economic benefit estimate for the Emergency Response Imagery Program. The resulting additional non-economic benefit is $230-$4.6 million.

Combined CMP Safety and Health Benefits

Combining the illustrative estimates for averted fatalities and injuries for nautical charts and emergency response imagery yields benefits of $18.3-$49.1 million.

Environmental Benefits

Environmental benefits can come about because of improvements in amenities or ecological conditions or in prevention of their deterioration. CMP information contributes to managing environmental resources in the coasts and great lakes in a variety of efforts, both directly concerned with the environment and integral to other activities.

Many studies try to estimate the value of aspects of the U.S. coastal and ocean environment in particular locations. These vary widely in date, method, and scope. Attempts to estimate the effects of non-regulatory activities designed to influence the U.S. coastal environment to determine their impacts are scattered among case studies that are not easily aggregated or applied more broadly.

Costanza, *et. al.* estimated that coastal wetlands in the U.S. provide $23.2 billion per year in hurricane protection services based on damage averted in year 2004 dollars.[104] Raising the value by 20% to year 2011 dollars yields $27.8 billion.

The environmental benefits of the CMP products are assumed to be 0.025%-0.05% of the value of coastal wetlands alone. This results in a conjectural value of $7.0-$13.9 million. The actual value could be higher.

Combined Non-Economic Benefits

The sum of total illustrative benefits for CMP safety and health) and the environment (not included in economic benefits after adjustment for the use of satellite data is $25.3-$63.0 million, with a midpoint of $44.1 million. Reducing it by 8% for the use of satellite data by CMP yields and estimate of CMP non-economic benefits of $40.6 million (Table 19).

Table 19. Summary of Non-Economic Benefits of CMP Not Included in Economic Benefits, 2011
(millions)

Safety and Health	
Nautical Charts	16.0-44.5
Emergency Response Imagery	2.3-4.6
Total Safety and Health	***18.3-49.1***
Environment	7.0-13.9
Sum of Ranges of Total CMP Non-Economic Benefits	*25.3-63.0*
Midpoint of Sum of Ranges	*44.1*
Estimate of CMP Non-Economic Benefits (with 8% reduction)	**$40.6**
Range of Total CMP Non-Economic Benefits (±10%)	$36.5-$44.7

Total Economic and Non-Economic Benefits

The order of magnitude of total economic and illustrative non-economic benefits of CMP in 2011 is $241.4 million (Table 20). The 10% is $217.4 million to $265.5 million.

[104] Robert Costanza, *et. al.*, "The Value of Coastal Wetlands for Hurricane Protection, "Swedish Academy of Sciences, *Ambio* (June 2008), pp.241-248.

Table 20. Summary of CMP Benefits, 2011 (millions of dollars)		
	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, with 8% adjustment and 10% range)	$40.6	$36.5-$44.7
Total Benefits	**$241.4**	**$217.4-$265.5**

An Illustration of Future Direct Economic Benefits of CMP

The present value of benefits, if they were to continue over the next 15 years, is shown with discounting to the present using a 7% discount rate, as OMB recommends. Discounting reflects the fact that the further away a benefit is, the less it is worth, because resources can be invested today in ways that lead to added returns later. The 7% value recommended by OMB reflects an average return above inflation on private business investments. The results of using 5% and 3% also are shown.

Fifteen years is chosen to illustrate one set of possibilities. A longer period is not used because new technologies, for example microsatellites at lower altitudes and linked satellites, as well as other photographic techniques, could lead to different ways of doing things and different producers or benefits. If the value of current programs did not last as long, discounted benefits would be lower. However, if new technologies and a growing economy and population made benefits larger over time, the discounted value would be greater.

The value of direct economic benefits of $100.4 million, if it continued for 15 years, discounted at 7%, is $914 million. With a 5% discount rate it is $1.0 billion and with a 3% discount rate it is $1.2 billion.

Estimate of Jobs Supported by CMP Products and Services

The number of jobs supported is calculated based on total (direct, indirect and induced) economic benefits for the CMP products. Benefits are divided by a measure of average revenue per worker, which includes employee compensation and all other costs, to obtain the number of jobs supported.

The usual practice is to use a multiplier that reflects the long run effect on jobs. When there is a lot of slack in the economy, the impetus from spending that is stimulated can be a lot greater when gains come from cyclical increases in utilization of capacity as well as from the trend in capacity. However, in a persistently weak economy, productivity gains facilitated by CMP products may more often be used to reduce costs rather than to increase output, and increased demands in other sectors may be met with fewer jobs, muting the overall impact. The two effects are assumed to offset one another under present circumstances, making the short run and long run multipliers equal.

Before jobs supported is estimated, total economic benefits are adjusted to roughly take out benefits to safety and the environment that are implicitly included in willingness to pay, particularly for nautical charts and emergency response imagery. Total economic benefits of CMP programs are preliminarily estimated at $200.8 million, with a range of $180.8-$220.8 million. These are reduced by 25%, which yields $150.6 million, with a range of $135.6-$165.6 million.

Revenue per job is determined for the national economy by Net National Product per person engaged in production, a measure of revenue per worker.[105] Persons engaged in production includes public and private workers and the self-employed. Employees are in full-time equivalents. Net National Product per person engaged in production is approximately $102,000 in 2011.[106] This value is divided into adjusted total economic benefits. The order of magnitude of full-time equivalent employee and self-employment jobs supported by CMP is estimated at 1,476, with a range of 1,329-1,623. This does not include jobs in the CMP program.

> …an order of magnitude estimate of full-time equivalent employee and self-employment jobs supported by CMP of 1,440-1,758, with a midpoint of 1,599.

The number of full-time equivalent CMP jobs is about 40. The estimate of CMP employment allows for the fact that some CMP employees also have duties in the Aeronautical Survey Program. It includes an estimate of employment in CMP contractors based on dividing their revenue by Net National Product per person engaged in production and also NOAA Corps jobs funded by CMP in full-time equivalents.

[105] Net National Product includes compensation of employees and all other expenses of business and governments. It includes an implied average wage per FTE of $54,000, total compensation including benefits per FTE of $69,000, and average compensation of self-employed of $100,000.

[106] Based on estimated 2011 Net National Product of $13.4 trillion and persons engaged in production of 131 million. The number of full-time equivalent workers counts part-time jobs based on their percent of full-time hours. The persons engaged in production data is part of the National Income and Product (GDP) Accounts.

Next Steps and Methodologies to Expand and Refine the Analysis

Several components would be useful for inclusion in a full study to better measure and understand the nature and magnitudes of CMP customers and benefits. Components suggested can benefit from being part of a package of analyses that relies on related data, methods and interactions with experts and users.

Benefits of the National Shoreline, Nautical Charts and Change Analysis

Before and After Comparisons of Map and Chart Updates to Measure Benefits to Mariners

Benefits to mariners from the National Shoreline, Change Analysis and Nautical Charts products can be examined by comparing groundings, accidents and other measures before and after remote sensing information in each location was updated. Much of the data needed for this part of the analysis is available from the Coast Guard. Separate analyses can be conducted for changes in commercial shipping and recreational boating activity.

Measures of the impact of CMP products on both the economy and resource management can be considered as well. Economic impacts can be assessed by examining the numbers and types of construction, new business formation and other activities that took place before and after map and chart updates in an area.

Possible acceleration in resource management efforts can be examined in reviewing projects and in discussions with resource managers.

Outcomes can be compared among similar areas. A pooled multiple regression analysis of changes across geographic areas can be performed to examine the effects of updates and to control for other factors. The number of opportunities for comparisons increased with updates done in 2009 using funding from the Economic Recovery Act.

The value of the changes can be measured by the amount of economic activity and by assigning values to changes in resource management efforts based on existing studies that rely on willingness to pay and other valuation measures.

Before and after comparisons have the advantage of providing evidence on causal links. The case studies they include express stories that help understand the nature of the benefits and the ways they come about.

Before and After Comparisons of Chart Updates to Measure Benefits to Ports

A quantitative assessment can be made of the impact of updated maps and charts in the National Shoreline, Change Analysis, and Nautical Charts programs in facilitating port operations and construction projects. This would be based on before and after comparisons where remote sensing surveys were done. Interviews with port managers can supplement data collection.

- The impact of reduced delays in construction can be measured in ports that are willing to provide data on construction spending.

- Any extent of more efficient operations and reduced accidents as a result of operational or construction changes that were enabled can also be assessed.

- Impacts on the volume, value and type of shipping (e.g. domestic vs. international) can be examined.

- Results potentially can potentially be extrapolated from case studies to other ports covered by CMP products.

Valuation of economic changes can be based on efficiencies achieved, the amount of construction that was enabled and the amount of additional shipping activity that resulted. System-wide effects of changes in individual or several ports can be examined. Multiplier effects can be considered based on existing econometric studies. Reduced accidents and fatalities can be valued based on reduced costs of lost work and medical care, a value of a statistical life, and consequences for shipping and port equipment and operations.

Examining Many Uses of CMP Products

Additional work could shed light on many more types of users of CMP products and services, their applications and the nature and magnitude of the benefits to users and society. Among the uses that could be included are on-shore economic development, use imagery and Lidar for offshore energy exploration and production and on-shore support, planning and operations of companies and governments, coastal resource management and disaster and emergency response.

One approach to accomplishing this is through interviews and quantitative analysis, using data obtained from users and industry organizations. Cooperation of industry and professional organizations would be helpful in obtaining access and information. Alternatively,, unstructured information can be elicited through a Web site (see text box).

Interactions Permitted without Being Subject to Paperwork Reduction Act (PRA) Review

Interactions not subject to prior approval from OMB include:

- General requests for comments, including on Web sites.
- Questions without selection of answers from a list of choices.
- Hosting public meetings and Webinars.
- Ratings or rankings of postings or comments on a Web site.
- Tests of knowledge of persons.
- Agency collections from agencies or employees of the United States.
- Identical questions posed to fewer than 10 persons in any 12-month period.

For more information, see Cass R. Sunstein, “Social Media, Web-Based Interactive Technologies, and The Paperwork Reduction Act,” OMB Memorandum, April 7, 2010 and Cass R. Sunstein, “Information Collection under the Paperwork Reduction Act,” OMB Memorandum, April 7, 2010.

Use of CMP Data Learned from Web Site Visitors

Those who download imagery from the NOAA Shoreline Data Explorer and other data distribution Web sites could be offered a link to a Web page in which they are asked to discuss how they use the imagery and what other imagery they use. Examples of productivity improvements users have achieved with CMP products and innovations they made possible could be elicited. Visitors also can be asked to provide comments on what they would like to see in CMP products, distribution, and training.

Expansion of CMP Services

In addition to refining the estimates of benefits of the present level of services, a follow-on study can examine the benefits of expansion of CMP products and services. The Hydrographic Services Review Panel 2010 update report recommended expansion in many areas. The study can provide rough order of magnitude estimates of the benefits if many or all of HSRP proposals for CMP products and services were implemented. It could include examining the potential benefits of new technologies, benefits of delivering updates more quickly, and benefits of increasing information to navigation and non-navigation communities. Benefits could be calculated for meeting alternative percentages of CMP or HSRP goals. A variety of valuation techniques could be used, depending on the product and availability of information.

A full study can improve understanding of customers and their applications and requirements and inform decisions about the allocation of resources among programs.

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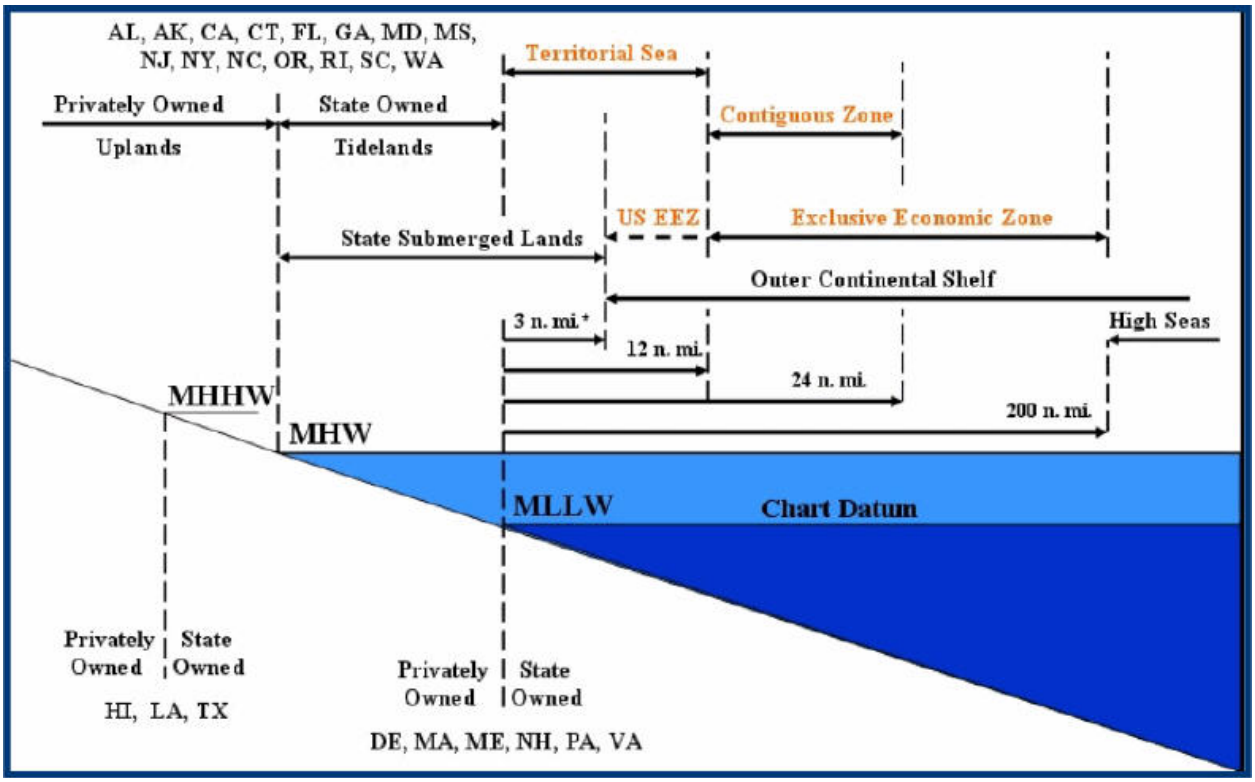
Appendices

Appendix A. U.S. Maritime Limits

Figure A1. U.S. Maritime Limits



Appendix B. Recommendations of the Hydrographic Services Review Panel

The Hydrographic Services Review Panel of NOAA's Coastal Services Center strongly recommended that NOAA:[107]

- "Aggressively map the nation's shorelines and navigationally significant waters.
- Integrate coastal mapping efforts and ensure federally mandated channels, approaches, and anchorages are surveyed to the highest standard.
- Modernize heights and implement real-time water level and current observing systems in all major commercial ports.
- Strengthen NOAA's navigation services emergency response and recovery capabilities.
- Disseminate NOAA's hydrographic services data and products to achieve greatest public benefit."

[107] Hydrographic Services Review Panel, *Most Wanted Hydrographic Services Improvements*, Federal Advisory Committee Update Report, 2010, p.1 http://www.nauticalcharts.noaa.gov/ocs/hsrp/docs/2010_Most_Wanted_%20Hydrographic_Services_Improvements.pdf

Appendix C. The Value of Information as a Reduction in Uncertainty

One approach in economics views the value of information as the reduction in uncertainty which it enables. In other words, information is valuable when it results in better choices.

To apply this value of information approach it must be possible to define specific choices. It is necessary to know or assume the probabilities of different outcomes.[108] That has not been possible in the present study because it deals at a level that aggregates over many applications and decisions.

Some analysts have used a rule of thumb suggested by William Nordhaus that the value of perfect information is "on the order of one percent of the value of output." [109] [110] The Nordhaus article stated that the approximation was based on early examples in weather for some crops, and on energy. However, subsequent studies have found a very wide range of values. Moreover, there is no reason to believe that a similar magnitude applies to such elements as consumers' willingness to pay for recreation, safety and health, or environmental amenities or conditions. Consequently, the Nordhaus rule of thumb is not used in the present study.

[108] Hauke Kite-Powell, *et. al.*, "Estimating the Economic Benefits of Regional Observing Systems," Marine Policy Center, woods Hole Oceanographic Institution, November 2004, p.19-23.
[109] William Nordhaus, "The Value of Information, in *Policy Aspects of Climate Forecasting*, edited by Richard Krasnow, Washington: Resources for the Future, 1986.
[110] For example, Hauke Kite-Powell, *op. cit.*, pp.24 and 26.

Appendix D. Mentions of Terms of Interest in Google Search

Interest in RSD programs and the subjects CMP covers is evident in the numbers of mentions on other Web sites that were returned on Google searches. Table D1 shows the results for many terms of interest using the Advance Search feature to search on exact terms. Results cumulate over time rather than being for a single year, and are not limited to the U.S. Results vary widely and depend on the specific term used.

Table D1. Results of Google Searches with the Exact Term

Term	Results (mentions)	Term	Results (mentions)
noaa	34,400,000	shoreline data explorer	7,200
national oceanic and atmospheric administration	6,490,000	noaa shoreline data explorer	2,990
national ocean service	533,000	coast and shoreline change analysis program	1,880
noaa national ocean service	140,000	shoreline boundary	6,750
national geodetic survey	472,000	shoreline boundaries	3,740
remote sensing division	25,800	navigation charts	2,530,000
noaa remote sensing division	5,340	nautical charts	1,060,000
ngs remote sensing division	3,210	U.S. nautical charts	22,800
coastal mapping	79,200	noaa navigation charts	19,100
coastal mapping program	48,100	emergency response imagery	2,600
noaa coastal mapping program	2,830	hurricane imagery	7,840
shoreline mapping	44,200	tornado imagery	3,690
shoreline mapping program	17,200	storm imagery	18,000
noaa shoreline mapping	5,870	disaster imagery	17.100
national shoreline	30,100	disaster response imagery	2,100
noaa national shoreline	7,580	historic aerial imagery	16,100
		coastal management	1,540,000

Note: Capitalization doesn't affect results. Results are labeled "about."

A study by Sherman-Morris examined Google searches in hurricane information-seeking. Not surprisingly, the study found that the most popular search terms at the national level prior to landfall dealt with forecast track and evacuation information, while after landfall they were related to hurricane damage. Local searches included gas prices and traffic.[111]

[111] Kathleen Sherman-Morris, Jason Senkbeil, and Robert Carver, "Who's Googling What?: What Internet Searches Reveal about Hurricane Information Seeking," *Bulletin of the American Meteorological Society* (August 2011), pp. 975-985.

Acronyms

AVIRIS	Airborne Visible and Infrared Imaging System
BOEMRE	Bureau of Ocean Energy Management, Regulation and Enforcement
BP	British Petroleum
CMP	Coastal Mapping Program
CORS	Continuously Operating Reference Stations
DHS	Department of Homeland Security
EEZ	Exclusive Economic Zone
ENC	Electronic Navigation Chart
ENOW	Economics National Ocean Watch
EPA	Environmental Protection Agency
FEMA	Federal Emergency Management Agency
FWS	Fish and Wildlife Service
GDP	Gross Domestic Product
GIS	Geographic Information System
GPS	Global Positioning System
GRAV-D	Gravity for the Re-definition of the Vertical Datum
HSRP	Hydrographic Services Review Panel
IfSAR	Inferon Metric Sythetic Aperture Radar
IOCM	Integrated Ocean and Coastal Mapping Initiative
Lidar	Light Detection and Ranging
MHW	Mean High Water
MLLW	Mean Lower Low Water
NGS	National Geodetic Survey
NOS	National Ocean Service
NOAA	National Oceanic and Atmospheric Administration
NPS	National Park Service
NSRS	National Spatial Reference System
PORTS	Physical Oceanographic Real-Time System
RNC	Raster Navigation Chart
RSD	Remote Sensing Division
TAWS	Terrain Alerting and Warning System
UNCLOS	United Nations Convention on the Law of the Sea
USACE	United States Army Corps of Engineers
USCG	United States Coast Guard
USGS	United States Geological Survey

About Dr. Irving Leveson

Dr. Leveson has strong analytical skills in the fields of economics and social science and extensive experience in analyzing programs, markets and technologies. His background includes strategic and economic consulting and research in private industry, non-partisan think tanks, and government. For the last eight years Dr. Leveson has assisted NOAA on diverse subjects and has worked extensively on cost-benefit analyses, GPS, and analyses of critical trends and issues. Dr. Leveson has been an independent consultant since 1990. He has served as a consultant to the Aerospace Corporation and is an Adjunct Fellow at the Hudson Institute.

Dr. Leveson holds a Ph.D. in economics from Columbia University. He previously served as Director of Economic Studies of the Hudson Institute, Senior Vice President and Director of Research of Hudson Strategy Group, Assistant Administrator for Health Systems Planning for the New York City Health Services Administration, and as a research director for the New York City Planning Commission. He also served as economist with the RAND Corporation and analyst with the National Bureau of Economic Research. Dr. Leveson is a member of the Institute of Navigation, the American Meteorological Society, the American Economic Association and the National Association for Business Economics.

His publications include *Economic Security*, iUniverse, 2011, *American Challenges: Business and Government in the World of the 1990s*, Praeger Publishers, 1991, *The Future of the Financial Services Industry* (main author), Hudson Institute, 1982, and *Western Economies in Transition* (co-editor), Westview Press, 1980.

His recent work includes:

A scoping study of the socio-economic benefits of CORS and GRAV-D for NGS.

Strategic cost-benefit analyses of modernization of the Global Positioning Satellite System focusing on applications, markets and benefits, conducted for the U.S. Departments of Transportation and Commerce and the Interagency GPS Executive Board.

A study of alternative financing for positioning, navigation and timing for the U.S. National Space-Based PNT Coordination Office.

Examining opportunities for utilizing modernized GPS systems in the NOAA.

Analyzing scientific and technical workforce trends for U.S. intelligence agencies.

Estimating benefits of the National Polar Orbiting Environmental Satellite System for the National Environmental Satellite Data and Information Service.

Assessing societal impacts of high impact weather for the U.S. National Weather Service.

Analyzing public-private partnership issues for the U.S. National Oceanic and Atmospheric Administration.

A comprehensive examination of external trends affecting NOAA, including technology, business models and public/private sector roles, and their implications for NOAA decisions.

Providing assistance to NOAA over several years in applying social science to issues and programs through workshops, educational materials, research plans, participation in the NOAA Research Council Social Science Committee and guiding Web site development.