# 3D Nation Elevation Requirements and Benefits Study
# Benefits Examples

This tutorial has three sections:

- Section 1 describes the categories of benefits used in the 3D Nation Requirements and Benefits Study for both current and future benefits.
- Section 2 describes methods for estimating monetary and other tangible benefits in terms of hours saved, costs saved or reduced, or revenues earned.
- Section 3 provides example benefits pertaining to operational improvements, customer service improvements, and other societal benefits. Note that we are not attempting to capture dollar values for societal benefits. However, several examples of ways that elevation data provide societal benefits are included because we do want to know about these benefits from a qualitative perspective.

## 1. Categorizing current and future benefits

Within the questionnaire, we ask participants to categorize their current and future benefits using the following categories.

### 1.1. Operational Benefits:

Operational benefits may fall into several categories including direct dollar savings; reduced labor costs; annual savings or percent improvement in operational efficiency or effectiveness; or improvements to mission critical programs. Examples may include:

**Time Savings:**

- Hours saved from faster field visits/inspections and/or avoided field visits/inspections
- Hours saved through more efficient modeling, reviews, reporting, data dissemination, mapping, or other procedures
- Hours saved from reduced or avoided data manipulation (e.g., combining data from multiple sources; changing projection, datum, etc.)
- Hours saved from reduced or avoided data errors
- Hours saved through in-office project planning or monitoring
- Hours saved from more streamlined operations (e.g., permitting processes, offshore boundary determinations, etc.)

**Cost Savings or Cost Reduction:**

- Data acquisition costs saved, reduced, or available to spend on other projects
- Materials saved (e.g., fertilizer, pesticides, water, irrigation systems, pond design, beach/dune restoration, building/construction materials, etc.)

**Cost Avoidance:**

- Data processing avoided (e.g., classifying point clouds, quality control, hydrotreatment, etc.)
- Data errors avoided
- Property not lost due to natural hazards or disaster events
- Avoidance of accidents caused by human error due to lack of information (e.g., crashes, aviation incidents, marine accidents, oil spills, etc.)

**Increased Revenues:**

- Improved harvest yields (e.g., timber, agriculture, fisheries, etc.)
- Increased cargo carrying capacity
- New products, services, or applications/apps sold

**Mission-Driven Performance Improvements:**

- Increased program effectiveness
- Improved ability to carry out mission
- Improved decision making due to better data, modeling, etc.

### 1.2. Customer Service Benefits:

Customer service benefits may be similar to operational benefits, but would be experienced by your customers through using improved data or products that you deliver to them and that would improve their ability to accomplish their mission. Examples may include:

**Value Added to Products or Services:**

- New products, services, or applications/apps (e.g., solar or green roof potential, GPS navigation, recreation opportunities, etc.)
- Improved accuracy of products or services (e.g., navigation charts, nautical charts, shoreline delineation, flood hazard maps, etc.)

**Improved Response or Timeliness:**

- Faster reviews and approvals (e.g., permitting approval, boundary determinations, etc.)
- Faster response to an incident or event (e.g., faster access to impacted areas, faster response and recovery operations, etc.)
- Faster recovery after an event (e.g., faster port reopening after hurricane, faster identification of damaged structures, faster information about Advisory Base Flood Elevations, etc.)
- Improved customer assistance (e.g., use of data allows virtual view and support via phone, email, chat)
- More up to date services or products (e.g., nautical charts, navigation charts, flood hazard maps, etc.)
- Improved projections of at-risk locations and/or faster warning to the public of impending natural or man-made hazards (e.g., flood, fire, tsunami, active shooter, etc.)

**Improved Customer Experience:**

- Increased customer confidence in products or services
- New services, tools, or applications/apps
- Better data availability (e.g., faster downloads, data are all in one place, etc.)

### 1.3. Societal Benefits:

Societal benefits may fall into categories such as improved education or outreach, environmental benefits, or public safety, including life and property. Examples may include:

**Education or Outreach:**

- Better informed citizens due to public outreach using data, maps, visualization tools, etc.
- Teaching materials, lesson plans, hands-on exercises for K-12 students that encourage STEM education, curiosity, and creativity

**Environmental:**

- Enhancements to the environment from restoration of watersheds, stream banks, wetlands, forests, grasslands, habitat areas, etc.
- Reduced point and non-point source pollution

**Public Safety:**

- Improved safety of citizens by using 3D elevation data for improved decision making, e.g., to avoid natural or manmade disasters
- Safer and more resilient communities by taking proactive steps to mitigate risks by informed siting of infrastructure facilities or future residential development

## 2. Methods for estimating monetary and other tangible benefits

For USGS's prior *National Enhanced Elevation Assessment* (NEEA), USGS documented the range of cost benefits that would result from enhanced elevation data and justified expanded budgets for the current 3D Elevation Program (3DEP) without adversely impacting the budgets of those agencies that indicated they would receive major time/cost savings as well as improved operational benefits and customer service benefits from enhanced elevation data they considered to be mission critical.

Similarly, for this 3D Nation Elevation Requirements and Benefits Study, we need questionnaire participants to translate the benefits to their Mission Critical Activities into tangible benefits where possible. Questionnaire participants should think in terms of tangible benefits that yield quantifiable cost savings, reduced hours spent, mission-driven performance improvements, products and service improvements, and customer experience benefits. Do not include dollar benefits for societal benefits (improved education and outreach, environmental benefits, or public safety).

The following are ways you may be able to quantify your benefits.

### 2.1. Direct correlation method (hours)

This method may apply to time savings, cost avoidance, mission-driven performance improvements, value added products or services, improved response or timeliness, or improved customer experience.

In every organization, there should be some reasonable method for estimating hours reduced or cost savings from digital 3D elevation data. For example, in estimating the benefits of 3D elevation data for your organization, the following direct correlation methodology might be used, starting with key questions:

1. What technical tasks, performed for your program, require 3D elevation data for effectiveness or efficiency?
2. What did you do prior to the advent of lidar a decade ago or multibeam sonar?
3. How much longer did it take you to do it the old way?
4. Do you return to older methods today for areas where you do not have suitable 3D elevation data?
5. If you did not have high resolution digital 3D elevation data, how many people would perform such tasks, or similar tasks, and how long would it take them to do it the old way?
6. If 3D elevation data allows you to perform some tasks that previously required field visits or field surveys and you can now perform some or all of these tasks from your desktop, you may

be able to estimate how many person-hours are saved by not having to go out into the field as frequently.

7. A similar construct can be used for other types of time savings from having the required 3D elevation data available, such as hours saved on data manipulation; data errors avoided; or more efficient modeling, reviews, reporting, data dissemination, mapping, or other procedures.
8. Annual cost savings = number of tasks/person/month or year x number of persons x hours saved/task. This can be reported in hours or can be converted to dollars by multiplying the hours x average hourly pay and benefits (or similar calculations).
9. Repeat for other organization personnel with differing requirements and savings.

## 2.2. Direct correlation method (dollars)

This method may apply to cost savings or cost reduction, cost avoidance, increased revenues, mission-driven performance improvements, value added products or services, improved response or timeliness, or improved customer experience.

1. How much money has your organization saved on data acquisition, or been able to spend on other projects because data acquisition is no longer necessary?
2. Can you estimate the value and quantity of materials saved on construction, agricultural, or other projects due to the availability of the required 3D elevation data?
3. Can you estimate the value of real estate, public infrastructure, or other property that would not be lost due to natural or man-made hazards through having the required 3D elevation data to better model the hazards and make decisions about future land use planning or construction?
4. Would your organization be able to realize increased revenues if the required 3D elevation data were available to help you improve your business processes, increase your harvest or extraction yields, or market new products or services?

## 2.3. Value multiplier method

Some organizations estimate monetary benefits in terms of percent improvements in productivity or efficiency, or increased profits from using a better process for accomplishing their operational mission. These percent improvements result in value multipliers, e.g., a 50% improvement in efficiency might yield a $500,000 benefit for a $1,000,000 program that is totally dependent on the efficiency of the new or improved business process.

## 2.4. Do not attempt to value societal benefits

We will <u>not</u> attempt to quantify the value of societal benefits but instead allow you to respond by indicating if 3D elevation data for your MCA has major, moderate, minor, or no relevance to education or outreach, the environment, or public safety.

# 3. Example Benefits

## 3.1 Example Operational benefits

### 3.1.1. Time and cost savings

#### *3.1.1.1. Time and cost savings through automation of hydrologic and hydraulic analyses*

This example pertains to Business Use #15 (Flood Risk Management) but could pertain to other Business Uses that include modeling that can now be automated using high resolution digital 3D elevation data.

Over the last ten to fifteen years, GIS and lidar have transformed water resource modeling. Previously, hydrologic and hydraulic engineering was performed through a manually intensive process of integrating expensive field survey information into computer models and drafting the results on mylar. This process was not only labor-intensive but was also subject to human error and inaccuracies. With the advent of lidar, the modeler can now remain in a seamless GIS environment and perform tasks using automated digital processes. Digital 3D elevation data is now stored, visualized, and computed without having to create traditional products, like contours, that a human needs to understand the dataset. Relying on these newer technologies, FEMA has greatly reduced the requirements, and cost, for field survey cross-sectional data. Engineering models are now produced through a series of automated processes that can fully exploit the lidar elevation backbone.

For example, FEMA's contractors produce thousands of digital Flood Insurance Rate Maps (FIRMs) annually, supported by engineering and mapping systems that feature H&H automation processing from lidar (see Figures 1 and 2 for an example of one such system).

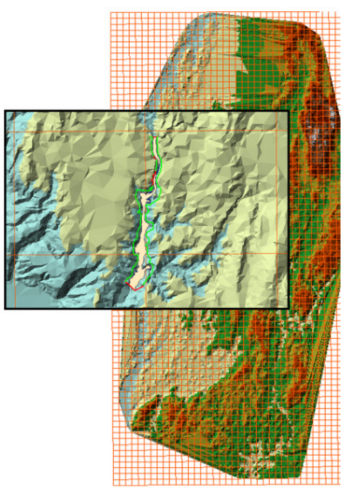


***Figure 1. Using lidar to build an ESRI Terrain, engineering tools now seamlessly model an entire county without having to break up the data.***

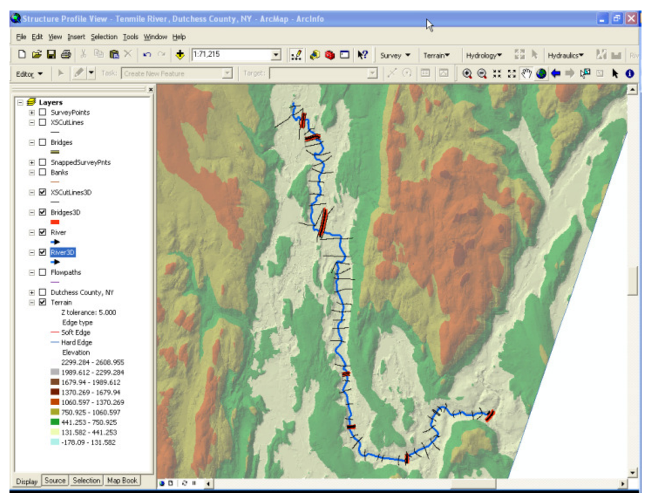


**Figure 2. The engineering and mapping system integrates lidar and bridge survey data into hydraulic modeling tasks and automates calculations from the underlying lidar elevation data.**

#### *3.1.1.2. Time and cost savings by automation of soils mapping and analysis*

This example pertains to Business Use #6 (Natural Resources Conservation) but could pertain to other Business Uses that utilize soil maps.

Soils mapping has always been a core mission of the Natural Resources Conservation Service (NRCS). Soils maps in the past were largely produced by photo analyses of slope and aspect (Figure 3). Today, computer models use slope, aspect and curvature (all elevation derivatives) for semi-automated soils mapping that is faster, far less expensive, and more accurate than soils maps of the past.

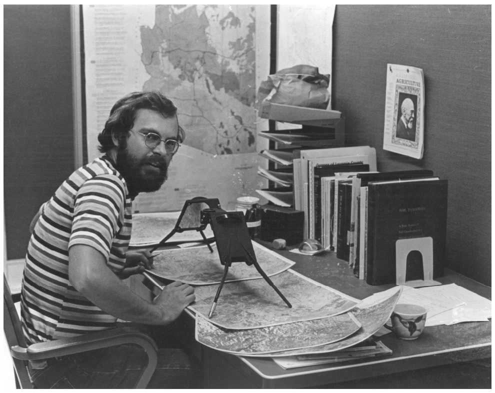


**Figure 3. The "old way." Complex stereo image analyses plus tedious soil line placement on mylar is now rarely used for soils mapping, preferring high-resolution elevation data derivatives, i.e., slope, aspect and curvature which are now computed from lidar data with the push of a button.**

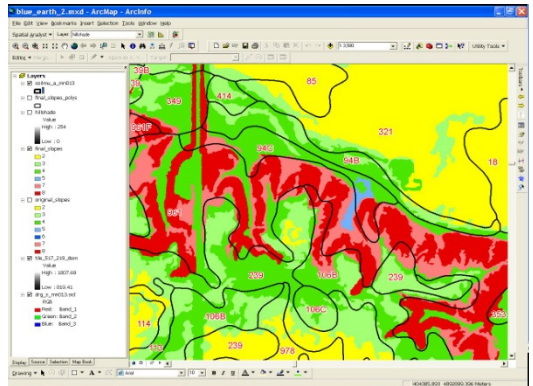



**Figure 4. The "new way." Soils mapping is now semi-automated and are more accurate. The differences between polygons with black outlines and those with different colors show discrepancies between old and new soil survey techniques.**

Figure 4 provides an example of how NRCS' LiDAR Enhanced Soil Survey (LESS) techniques yield more accurate soils maps through automation (using elevation derivatives and objective criteria) than NRCS' manually-compiled soils maps of the past using subjective stereo image analysis (Figure 3). The differences between the polygons with black outlines and the polygons with different colors show discrepancies between old and new techniques. Soils engineers generally agree that the newer techniques yield better accuracy in soils mapping.

### *3.1.1.3. Time and cost savings by virtual visits instead of on-site visits*

This example pertains to Business Use #6 (Natural Resources Conservation) but could pertain to any Business Use that includes on-site visits.

The Natural Resources Conservation Service (NRCS) works with private landowners through conservation planning and assistance designed to benefit the soil, water, air, plants and animals that result in productive lands and healthy ecosystems. From the beginning of its existence as the Soil Conservation Service, much focus has been placed on slope analyses for control of soil erosion and on methods to retain water on the land so that it does not cause floods elsewhere. To provide needed technical assistance, NRCS sends specialists on-site to meet with individual landowners and assess their land (see Figure 5); whereas this has advantages, NRCS would need many additional employees to satisfy all demands for on-site consulting. Alternatively, far fewer NRCS specialists can cost-effectively analyze digital orthophotos and elevation data (Figures 6 and 7) and make better science-based recommendations for conservation of natural resources in efficient, smart and sustainable ways. Every landowner that can be helped by telephone, email or online saves many hours of non-productive travel time and expenses for on-site visits to remote areas, and science-based GIS technology is superior for many of the required tasks. When using remote sensing products such as lidar datasets, it should not be difficult to estimate cost savings by minimizing the need for on-site visits and by providing better science-based advice to more landowners.

Figure 5. On-site visits take precious time and resources; far fewer customer needs are served. Travel time/expense is wasteful.

Figure 6. Produced from image and elevation data, orthophotos allow efficient image analysis of habitat, wetlands and vegetation/crops.

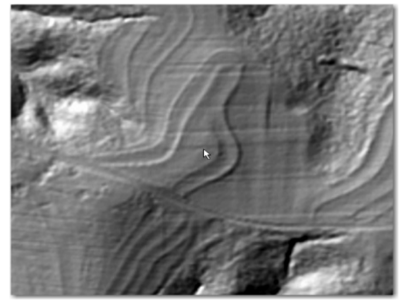


Figure 7. Elevation datasets allow mission-critical expert analyses of terrain surfaces and drainage not visible on the orthophoto.

### *3.1.1.4. Cost savings by aerial surveys instead of field surveys*


Figure 8. Field survey costs may be a hundred times more expensive, yet less valuable than aerial surveys from lidar or photogrammetry.

This example pertains to Business Use #22 (Infrastructure and Construction Management) but could pertain to any other Business Use that currently uses field surveys.

Compared with ground surveys, aerial surveys are much less expensive and are often superior. Richland County, SC used existing lidar data to avoid a $140,000 cost for a land surveyor to perform a topographic survey of a single 150-acre site considered for development, to assess the elevation, slope, aspect and drainage characteristics of this site. The lidar data was used to determine the amount of earth-moving/grading to be performed for site preparation of a new facility to be built and to estimate costs for site drainage structures. Such cost avoidance is a major benefit to many Federal, State and local agencies and private users of digital 3D elevation data. Other potential construction or engineering sites nationwide are candidates for similar cost avoidance.

Also consider the aerial surveys of routes for planned construction of new roads by State and county DOTs, new cell phone tower locations (where elevation is critical) or new pipelines or power lines (Figure 8). Lidar is ideal for thousands of topographic survey projects, and comparative cost savings can be quantified with relative ease.

### *3.1.1.5. Cost efficiencies*

**Cost Efficiencies for Oil and Gas Industry**

This example pertains to Business Use #13 (Oil and Gas Resources).

One energy firm reported: "We use lidar data to help us with our planning and construction processes. The lidar helps us calculate slope which is a vital piece of information for locating well sites, facilities and pipelines. Using the lidar we can pre-select suitable locations via the GIS in the office in a much quicker, safer and cost effective manner than having to send ground crews into the field to search for suitable well locations and pipeline routes. This is a huge benefit to us. Another big use for us is in our Seismic programs. We also use the full feature lidar to get an understanding of the land cover in the area. We use it to calculate the amount of timber that we may have to cut. In fact when we combine it with air photos we can further select locations and routes which minimize required tree cutting." This company partnered with the State by providing $200,000 for lidar data of two counties, so obviously the lidar data is considered by them to be of very high monetary value.

**Multibeam Mapping for Seabed Oil Exploration**

This example pertains to Business Use #13 (Oil and Gas Resources).

The Center for Coastal and Ocean Mapping/Joint Hydrographic Center at the University of New Hampshire, a cooperative partner with NOAA, developed technology that maps the water column as well as the seabed to identify underwater seeps. Using multibeam sonar data, they have been able to integrate bathymetry, seabed imaging, and full water column analysis and develop new tools and technologies that support a new industry of ocean oil exploration. Initial cost-benefit analyses indicate that the value of such data to U.S. companies and industries is $70 million per year and expected to grow at about 25% per year. Using this new technology represents significant cost savings and safety improvements over traditional marine seismic data acquisition. And using these new techniques for seep hunting and geochemical analysis reduces risk and improves the success of drilling by determining if a reservoir holds exploitable oil. It also provides an environmental baseline for the safer development of oil exploration and development monitoring.

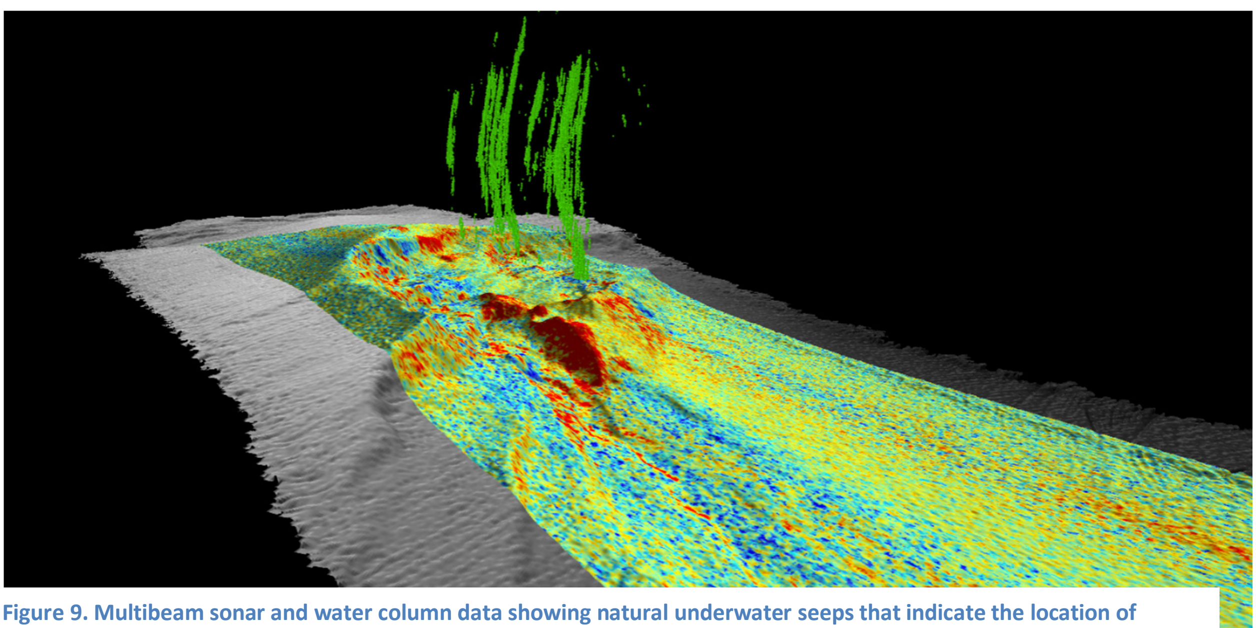


**Figure 9. Multibeam sonar and water column data showing natural underwater seeps that indicate the location of potentially exploitable oil resources.**

**Multibeam Mapping for Renewable Energy Siting and Marine Mineral Mining**

This example pertains to Business Use #11 (Geologic Resource Mining and Extraction).

The Bureau of Ocean Energy Management (BOEM) manages the development of U.S. Outer Continental Shelf energy and mineral resources in an environmentally and economically responsible way. BOEM is committed to using the best available science to make decisions about offshore energy siting (BOEM 2018) and marine mineral extraction (BOEM 2018), and often requires bathymetric information and sea floor characterization to make informed decisions about the Nation's ocean resources. Through leases issued by BOEM, over 146 million cubic yards of sand have been used to help restore and protect over 321 miles of coastline. To date, BOEM has issued thirteen commercial wind energy leases on the OCS, including those offshore Delaware, Maryland, Massachusetts, New Jersey, New York, Rhode Island, Virginia, and North Carolina.

**Efficiency Improvements for Siting Aquaculture Farms**

This example pertains to Business Use #9 (Fisheries Management and Aquaculture).

Technological innovation has made it possible to grow marine finfish in the coastal and open ocean. The U.S. has everything required to develop a significant marine finfish aquaculture industry including excellent locations, scientific expertise, state-of the-art technology, innovative equipment and feed manufacturers and willing investors. Detailed information about site specific hydrology, bathymetry, and local nutrient dynamics are used to provide insight into long-term processes over large areas and potential impacts from offshore aquaculture (Price and Morris 2013).

**Efficiency Improvements for Replenishing Fish Stocks**

This example pertains to Business Use #9 (Fisheries Management and Aquaculture).

To support fisheries, resource managers need a better understanding of spatial distribution of economically important fish, their key habitats and associated fishing effort. Bathymetry is critical for understanding these distributions. In a study performed in the Hawaiian Islands, areas with high recovery potential were identified using bathymetry by comparing current targeted fish distributions with those predicted when fishing effort was removed. The study determined that spatial protection of these areas would aid recovery of nearshore fisheries (Stamoulis et al. 2018) and support the Nation's blue economy.

**Efficiency Improvements for Precision Farming**

This example pertains to Business Use #8 (Agriculture and Precision Farming).The "National Height Modernization Study: Report to Congress," prepared by NOAA in 1988, estimated that high resolution DEMs combined with a nationwide differential GPS network would have estimated value to constituents of $1.7 billion for precision farming for planned application of water, fertilizer, pesticides, etc. This NOAA study predicted that, with GPS-based precision farming technology, farmers would be able to go from farming by the acre to farming by the square meter while also reducing a major source of non-point pollution.

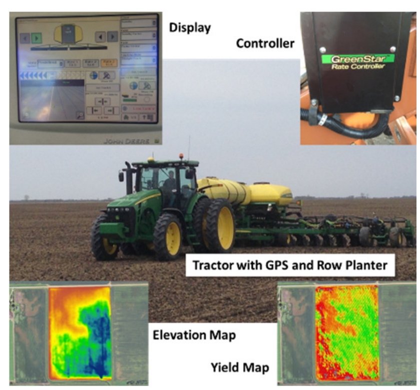



**Figure 10. Topographic data, plus GPS receivers on farm machinery or backpacks, enable precision farming by the square meter rather than by the acre or hectare.**

Precision farming systems gather data on tillage, seeds planted, weeds, insect and disease infestations, cultivation and irrigation, and *location-stamp* that data with GPS information. Using these data, farmers can micromanage every step of the farming process. For example, a farm GIS database might include layers on field topography (DEMs), terrain slopes, soil types, surface drainage, sub-surface drainage, soil testing results, rainfall, irrigation, chemical application rates, and crop yield. Once this information is gathered, farmers can analyze it to understand the relationships between the different elements that affect crop yields. The *National Enhanced Elevation Assessment* (NEEA), published in 2012, documented precision agriculture conservative cost savings of over $2B annually from lidar data of agricultural areas. Figure 10 shows elevation data loaded in the computer that guides the farmer and his machinery used for precision agriculture.

**Improved Farm Pond Design**

This example pertains to Business Use #6 (Natural Resources Conservation) or Business Use #2 (Water Supply and Quality).

GIS is the optimal business decision support tool to improve the decision-making process or work flows for farm pond design because it is a computer-based technology capable of running multiple scenarios and options efficiently and rapidly. Figures 11 and 12 demonstrate commercial Pond Planning GIS software that uses digital elevation data to design farm ponds and to accurately estimate the cost of construction and related expenses such as farm fencing surrounding the pond. Without even needing to visit the farm site, a GIS analyst with commercial software can use DEMs and digital orthophotos to provide landowners with over a hundred pond options within 15 minutes, while using the landowner's criteria to select the optimum pond design. Without DEMs, such detailed pond design and cost estimating would be prohibitively expensive in most cases.

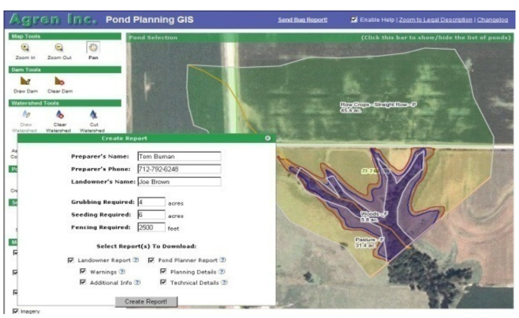
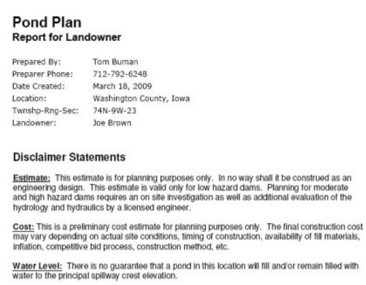



Figure 11. With a DEM, pond planning software took 15 minutes to develop 100+ design options for pond size/depth, dam height, drainage areas, pipe size, fencing costs, etc.



**Pond Plan**
**Report for Landowner**

| | |
|---|---|
| Prepared By: | Tom Buman |
| Preparer Phone: | 712-792-6248 |
| Date Created: | March 18, 2009 |
| Location: | Washington County, Iowa |
| Twnshp-Rng-Sec: | 74N-9W-23 |
| Landowner: | Joe Brown |

**Disclaimer Statements**

Estimate: This estimate is for planning purposes only. In no way shall it be construed as an engineering design. This estimate is valid only for low hazard dams. Planning for moderate and high hazard dams requires an on site investigation as well as additional evaluation of the hydrology and hydraulics by a licensed engineer.

Cost: This is a preliminary cost estimate for planning purposes only. The final construction cost may vary depending on actual site conditions, timing of construction, availability of fill materials, inflation, competitive bid process, construction method, etc.

Water Level: There is no guarantee that a pond in this location will fill and/or remain filled with water to the principal spillway crest elevation.

Figure 12. The landowner accepted the best low-cost option and was given the Pond Plan that included engineering design and accurate cost estimates.

**Improved forest/timber metrics**

This example pertains to Business Use #5 (Forest Resources Management).

Firms in the timber industry manage millions of acres of forest. They face tough decisions that affect their bottom lines as well as the environment. High-density lidar point cloud data are widely used to map the forest canopy (lidar first return) and the ground beneath the forest (normally the lidar last return). As shown in Figures 13 and 14, such data also provide accurate metrics for estimation of timber yields.

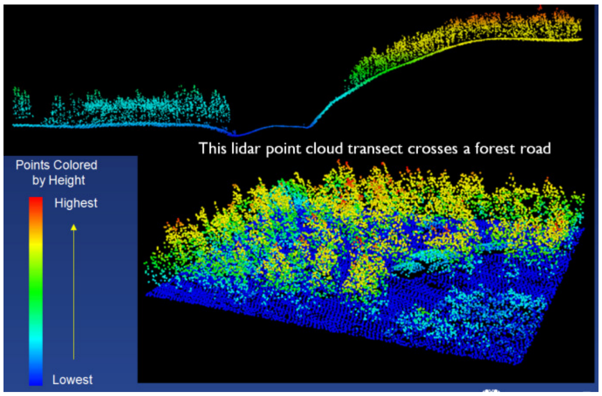



**Figure 13. Lidar point cloud with transect (cross-section) crossing a forest road. Only lidar can map the forest floor in dense forests.**

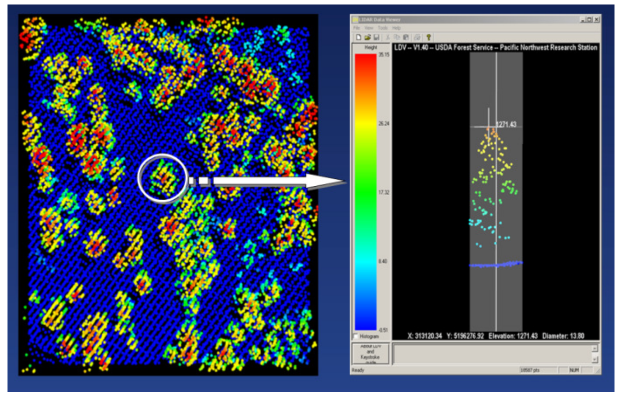


**Figure 14. Software tools allow many types of measurements of individual trees and also summarize timber metrics over large areas.**

**Cost Savings for Shipping**

This example pertains to Business Use #20 (Marine and Riverine Navigation Safety).

Commercial shipping relies on current and accurate nautical charts to maximize their time efficiency. Good charts allow pilots to determine the most direct routes between ports, reduce the number of pilots needed, decrease the number of groundings thereby reducing insurance rates, and allow deeper draft vessels that can carry more cargo to be used. In a 2000 study, NOAA reported that one additional foot of draft may account for $36,000 to $288,000 of increased profit per transit into a single port – Tampa, FL. In a separate 2007 study, NOAA cites a U.S. Coast Guard estimate that about 7,600 foreign-flag ships and 400 U.S.-flag ships operate in U.S. waters, making on average about 10 ports of call in the U.S. per year.

If all 10 U.S. ports of call for the 8,000 commercial vessels could accommodate even one additional foot of draft as a result of improved data, this could result in savings to carriers of $2.8 to $23 million per year.

### 3.1.2. Mission-Driven Performance Improvements

#### *3.1.2.1. Aviation Safety*

This example pertains to Business Use #21 (Aviation Navigation and Safety).

Both the Federal Aviation Administration (FAA) and the International Civil Aviation Organization (ICAO) have requirements for digital elevation data at specified accuracy levels for aviation safety. As shown at Figure 15, lidar data are also used at airports to ensure that designated flight paths for airfield approaches are safe and free of obstructions.

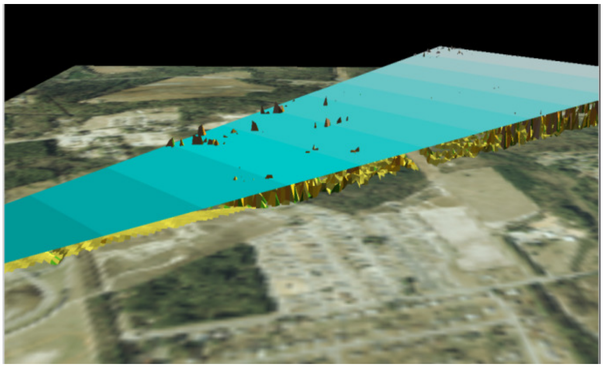


Figure 15. Flight path obstructions, mapped with lidar.

### 3.1.2.2. *Improved geologic assessment*

These examples pertains to Business Use #10 (Geologic Assessment and Hazards Mitigation).

The Florida Geological Survey has been mapping areas in the state where the geology for sinkhole formation is favorable. Field geologists used existing and publicly available lidar data as a base layer to identify possible sinkholes prior to beginning field work. The data proved to be very useful in helping to direct the field crews to potential sinkhole targets. The data were also used as a navigation aid in areas where the terrain made it difficult to access potential sinkhole features, and it was useful for locating sinkholes where the visibility was obscured by trees or structures. In addition to locating potential targets and areas prone to sinkhole activity, field geologists could determine slope, depth, and diameter of the preexisting features utilizing the lidar-derived terrain models and avoid potentially dangerous situations while working in hazardous landscapes.

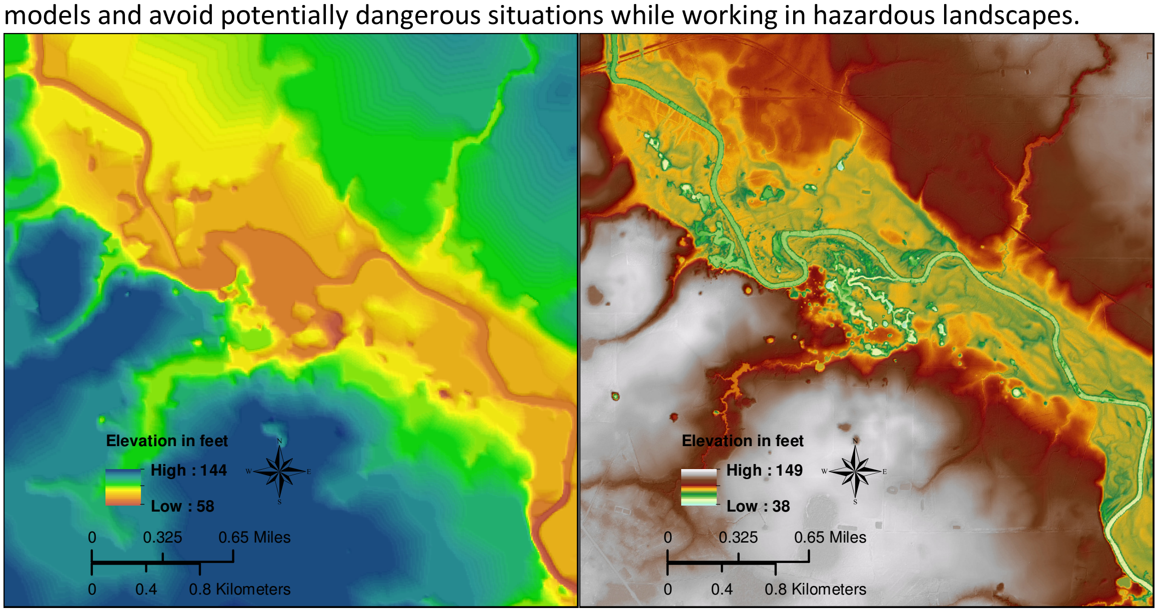



Figure 16 shows areas of the Alapaha River in North Central Florida with substantial sinkhole development. The image on the left is a terrain model developed from the USGS 1:24,000 scale topographic maps. The image on the right is a five-foot resolution lidar surface. The area is pockmarked with sinkholes that are underrepresented on the topo derived surface but very clear on the lidar terrain model.

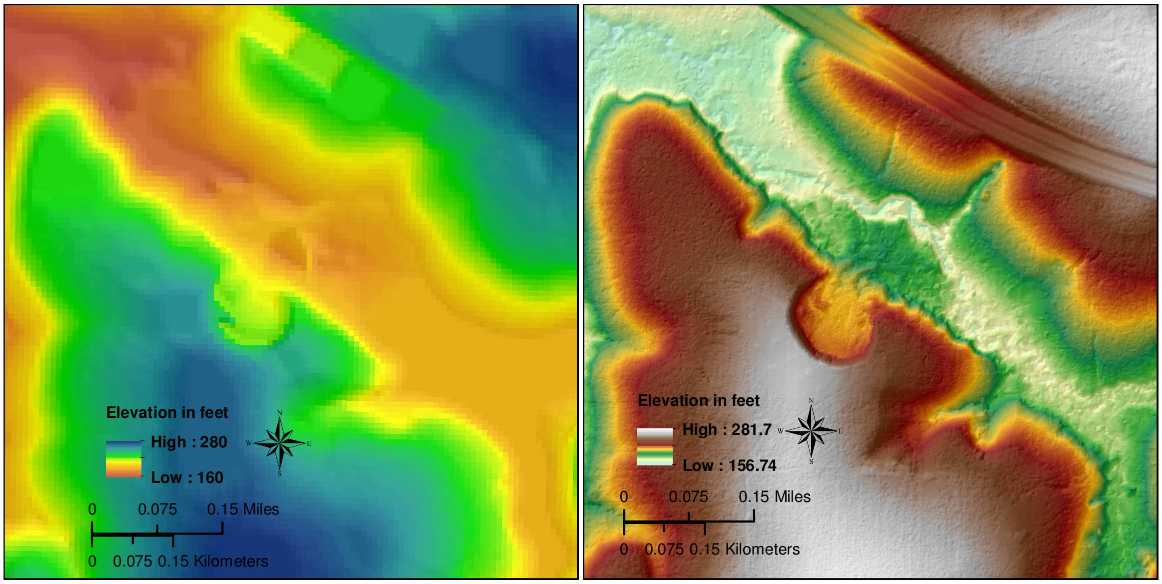



**Figure 17 depicts an area in the panhandle of Florida with a documented landslide not associated with sinkhole development. The image on the left is a terrain model developed from the USGS 1:24,000 scale topographic maps. The image on the right is a five-foot resolution lidar surface from 2006. The feature and debris field are easily identifiable in the lidar image. This is an example of a false sinkhole which was not apparent from the topo maps.**

The Florida STATEMAP program, a cooperatively funded surficial geologic mapping initiative within the FGS' Geological Investigations Section, uses lidar to improve surficial geologic mapping and to search for geologic contacts within a study area. Prior to beginning field work, Florida STATEMAP staff locate, gather, and stitch together sections of lidar data to create a topographic base map. It can be difficult to manage many of the data sets they accumulate since some are of different resolutions and quality levels, and in many instances, a portion of the study area does not have any data. Much like the sinkhole group, Florida STATEMAP geologists use lidar prior to scheduling any field work to optimize their time in the field. They also use the data to map potential geological contacts and geomorphic features by noting consistent and apparent elevation changes.

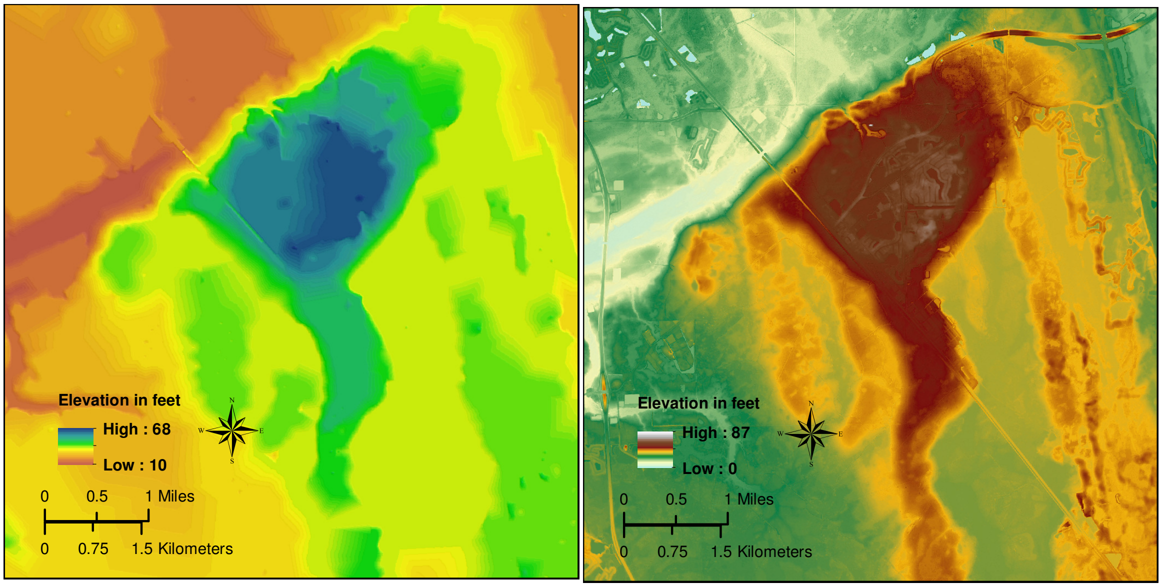



**Figure 18 shows a coastal feature in the Durbin area, south of Jacksonville, in northern Florida. The elevated feature is an aeolian augmented feature beach ridge and it is being dissected by Julington Creek. The image on the left is a terrain model developed from the USGS 1:24,000 scale topographic map while the image on the right is a five-foot resolution lidar surface. Florida STATEMAP geologists used this lidar elevation model to more accurately map and describe the geomorphology of the study area.**

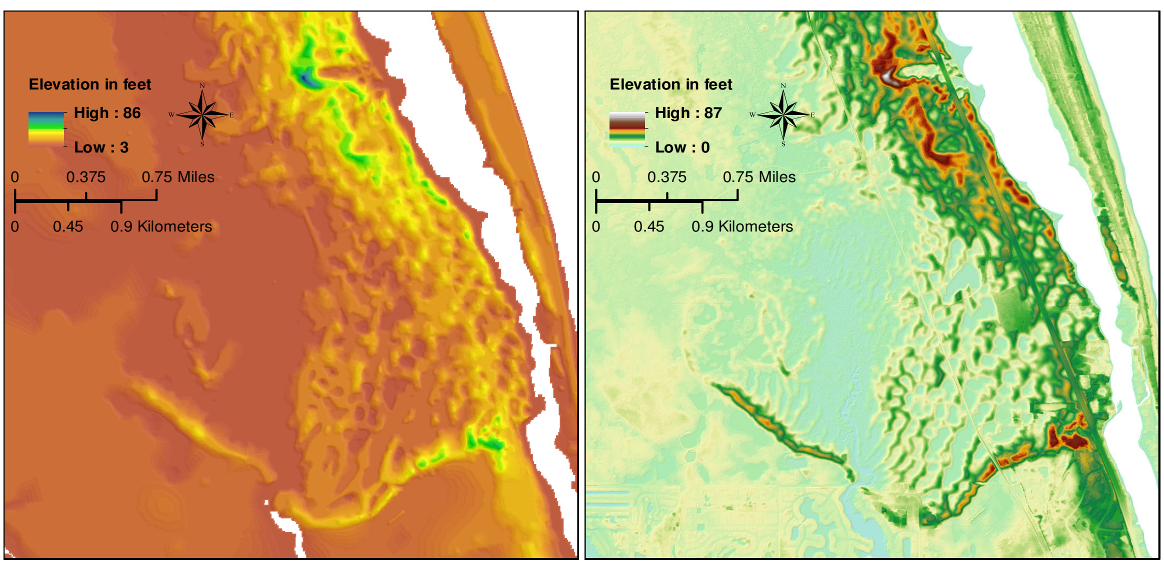



**Figure 19 is from a large dune field in Martin County. The image on the left is a terrain model developed from the USGS 1:24,000 scale topographic maps while the image on the right is a five-foot resolution lidar surface. While the topo derived surface accurately captures the extent of the feature it misses many of the subtle dune features that make up the unique terrain of the area.**

The FGS' Applied Geoscience Services (AGS) Section has been using terrestrial lidar near the Florida Big Bend coastline to locate and document several small springs. In this low-lying area, staff geologists use the lidar-derived terrain models to locate small streams that originate as springs. The models help the geologists navigate the thick brush and swamps and avoid marshy areas. In addition, the AGS uses lidar to organize and plan dye-trace studies for select springs and swallets. The lidar is used to identify sample points during attempts to trace the flow of surface water as it descends underground through swallets and eventually emerges at a spring vent further down gradient.

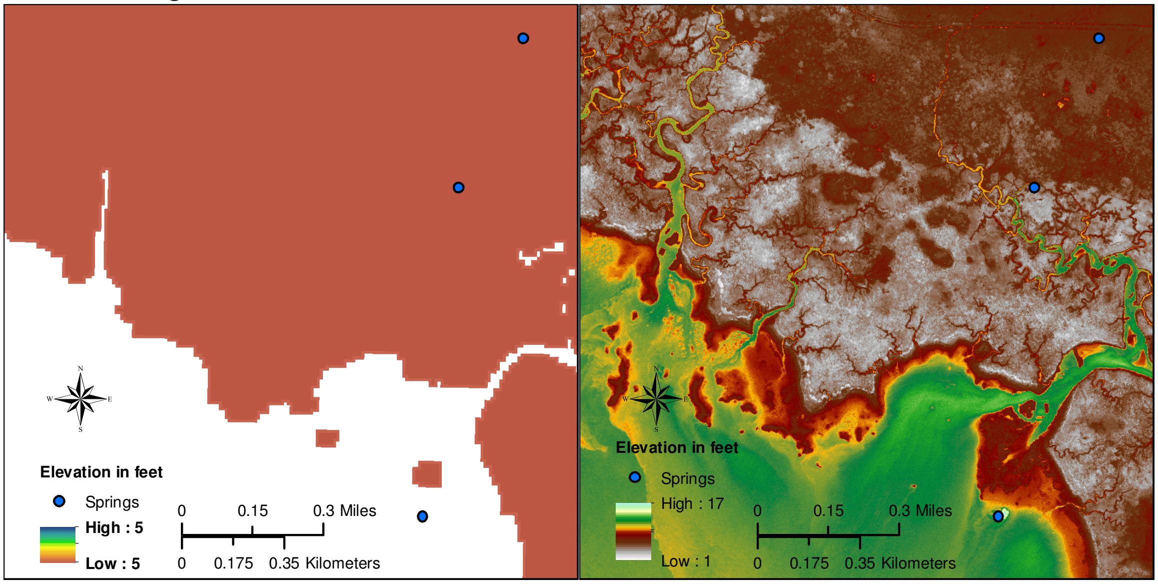



**Figure 20 is from coastal Taylor County in the big bend area or north Florida. The image on the left is a terrain model developed from the USGS 1:24,000 scale topographic maps while the image on the right is a five-foot resolution lidar surface. The topo derived surface is unusable as a tool for locating streams emanating from seeps and springs. Field geologists at the FGS use the lidar surface to help locate and navigate to potential spring locations.**

## 3.2. Example Customer Service Benefits

### 3.2.1 Products or Services

#### *3.2.1.1 New value-added services*

These examples pertain to Business Use #23 (Urban and Regional Planning), Business Use #18 (Homeland Security, Law Enforcement, Disaster Response, and Emergency Management), and Business Use #12 (Renewable Energy Resources).

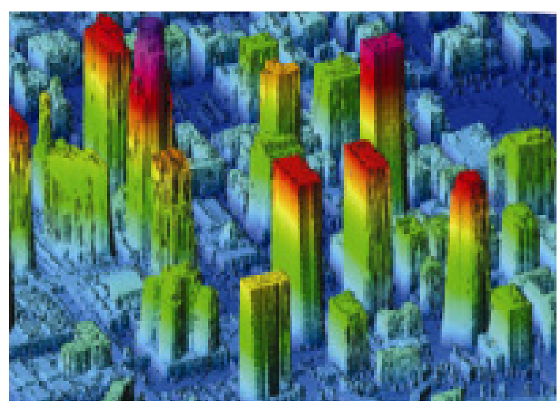


**Figure 21. Color-enhanced 3-D model of downtown Los Angeles. Such models are used for Homeland Security applications as well as diverse government and commercial applications.**

3D city models from lidar are used to create virtual city models for homeland security and also for city governments and "3D fly-throughs" on the TV evening news. Whereas Figure 21 shows a lidar 3D model of downtown Los Angeles, it is now common to also project vertical and oblique imagery onto these 3D surfaces in order to develop virtual city models that are truly realistic and easier to understand and interpret. For homeland security purposes, officials perform line-of-sight analyses to determine "what can be seen (or targeted) from where;" lidar is ideal for this application. Lidar is also ideal for generation of building footprints, and to determine the aspect and slopes of roofs for potential solar panel efficiency, a popular new value-added service popular in Los Angeles County.

Some communities collect elevation data and collect user fees to recoup costs, without placing the data in the public domain. Other communities use elevation data or their derivatives (e.g., hillshades) as base maps for overlay of polygons that show risks of landslides, fire hazards, boundaries and other information, then sell these value-added products to the public or charge a user fee. Still others sell or license their data to commercial industry (e.g., oil and gas) for diverse purposes. In these ways 3D elevation data adds monetary value and increased revenue for new Business Uses nationwide for diverse applications.

#### *3.2.1.2 Improvements to the Nation's infrastructure*

This example pertains to Business Use #22 (Infrastructure and Construction Management).

The Nation's infrastructure must be maintained and improved, and doing so will depend on the availability of high-resolution 3D elevation data. Conservative estimates from the 2012 *National Enhanced Elevation Assessment* (NEEA) conducted by USGS in 2012 indicate that annual benefits for infrastructure projects are $170 million. This includes such activities as the following:

- Route, grade, line-of-sight, and utility surveys and corridor mapping
- Terrain and other obstruction identification for aviation
- Dam, levee, and coastal-structure failure modeling and mitigation
- Hydrologic and hydraulic modeling
- Evaluations of geologic, coastal, and other natural hazards, and geotechnical evaluations
- Permit application and construction plan development and evaluation
- Drainage issues and cut-and-fill estimate requirements
- Vegetation, topographic, and geomorphologic feature analysis
- As-built model development
- Preliminary engineering, estimate development, and quantity estimation activities
- Bridge site selection
- Base-map and elevation model creation

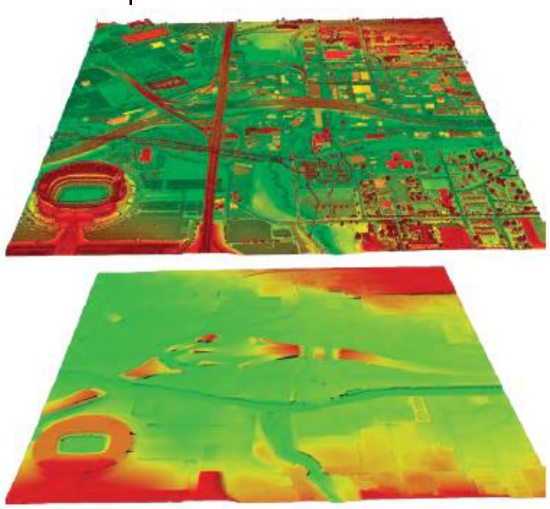


**Figure 22. Lidar point cloud (top) and a derived bare-earth digital elevation model (bottom) for Denver, CO.**

### 3.2.2 Response or Timeliness

#### *3.2.2.1 Improved customer service from seamlessly integrated bathymetric and topographic data along the coasts*

This example pertains to Business Use #3 (Coastal Zone Management).

In the 2012 *National Enhanced Elevation Assessment* (NEEA), NOAA reported benefits of $1.5 million/year for customer service benefits from users being able to download seamless data and perform their own analyses.

Public dissemination of NOAA's existing, unrestricted, high-resolution Digital Elevation Models (DEMs) of select U.S. coastal communities has greatly benefited scientists, Federal and State agencies, private companies, journalists, and the public. The coastal DEMs save users the intensive effort required to seamlessly integrate bathymetric and topographic data at the coast. To date, NOAA's thoroughly documented coastal DEMs have been downloaded more than 30,000 times in four years. A rough estimate can be made of the dollar savings to users downloading the data. While the careful assembly of each coastal DEM requires an average of three months by a highly-trained GIS specialist, it is assumed that a typical individual user would only spend one day to make an inferior product that still meets their needs. This equates to 120 man-years saved (i.e., 30 man-years annually or ~$1.5M/year) and does not include the additional savings for the subset of users that require the high quality DEM. The development and dissemination of additional unrestricted, accurate, high-resolution, integrated bathymetric-topographic DEMs to cover additional U.S. coastal communities would benefit countless other individuals, Federal and State agencies, and businesses in need of such products of other U.S. coastal communities to enhance their work.

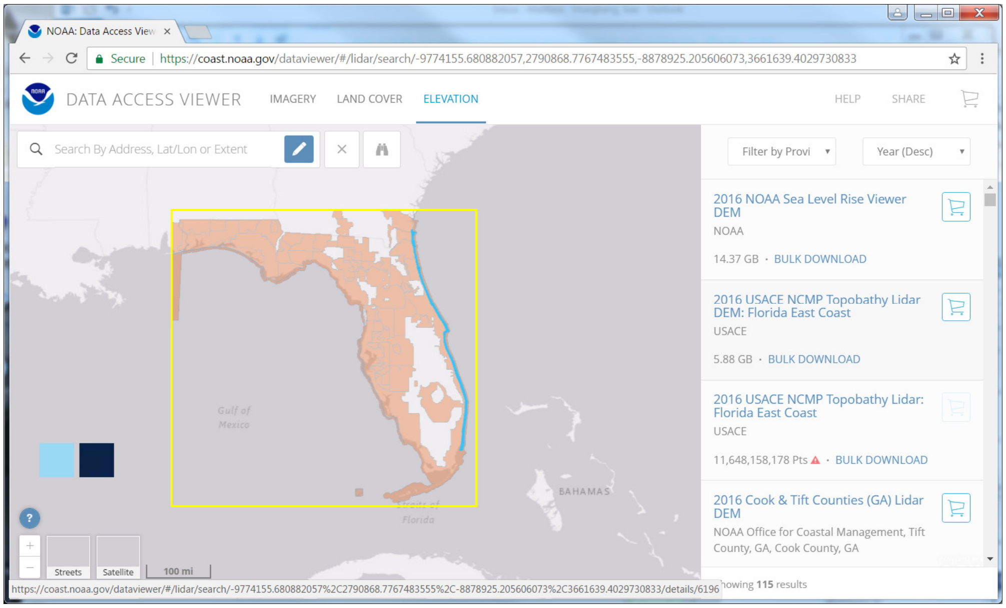


Figure 23. NOAA's Data Access Viewer.

### *3.2.2.2 Customer savings for surveyor costs*

This example pertains to, Business Use #6 (Natural Resources Conservation).

In another example from the 2012 *National Enhanced Elevation Assessment* (NEEA), the Iowa Department of Natural Resources (DNR) estimated that using lidar to determine elevations in floodplains for permits could save permittees about $250 each on surveyor costs. The DNR issues ~50 floodplain permits per year, saving its residents ~$12,500 per year.

## 3.2.3 Customer Experience

### *3.2.3.1 Improved Government services to taxpayers*

This example pertains to, Business Use #23 (Urban and Regional Planning), and Business Use #25 (Real Estate, Banking, Mortgage, and Insurance).

A county Assessor's department reported that they provide end users with the ability to view geospatial data via a Web-based viewer. They estimated 64,000 hours of staff time saved, avoiding over $4M in staff costs, but elevation data was only a small part of the geospatial data provided. They had other benefits for which they did not attempt to quantify cost savings:

1. Time reductions for customers for not having to wait in line to get their questions answered by a human or to process permits
2. Additional costs that would have been needed to add office space and staff to handle the increase in activity or visits to the public information counters (they previously served 190 customers per day, and those numbers kept growing)
3. Additional time that would be necessary to research more information with manual methods; they have added 14 additional GIS layers (e.g., digital orthophotos, elevation data, flood risk data) to be able to answer more questions on-line

4. The value of consistent and concise information delivered at all public information counters to the engineers, developers, consultants, and the public
5. Savings to other county departments that themselves use the information from the Assessor's departmental library of 23,000 standard graphics

Federal and State agencies can similarly convert Web site visits to work-hour equivalents to document efficiencies from Web map viewers.

An organization that serves as property manager for 70,885 acres of land within the Houston metropolitan area reported that their GIS information base, used for *virtual land management*, saves about $80,000 per year in land and right-of-way labor costs; but they did not specify what portion of such savings, if any, was attributable to elevation data.

## 3.3 Examples of Societal Benefits

### 3.3.1 Environmental

#### *3.3.1.1 Monitoring of environmental changes*

This example pertains to Business Use #4 (Coastal Zone Management).
USGS is using bathymetry to evaluate the impact of coral reef flattening on coastal zones and communities. Coral reefs protect shorelines and communities from storms, waves and erosion. The degradation of these ecosystems will lead to increased risk to coastal communities (Yates et al. 2017).

The Nature Conservancy is using lidar to examine the impacts of Lake Ontario's lake level drop on coastal habitat migration and to develop effective conservation and management strategies. Figures 24 and 25 illustrate areas of environmental concern.

**Figure 24. The lowering lake level of Lake Ontario is being tracked by The Nature Conservancy for environmental impacts.**

**Figure 25. Lowering lake levels have an adverse impact on coastal habitat migration. TNC is developing conservation management strategies to mitigate environmental impacts.**

#### *3.3.1.2 Improved characterization of benthic habits, vegetation and forest health*

**Vegetation and Forest Health**

This example pertains to Business Use #5 (Forest Resources Management)

Government leaders, the national media, and environmentalists have recognized elements of the timber industry for scientific accomplishments and environmental practices in advancing forestry science, including the use of lidar intermediate returns used to characterize vegetation and assess forest health, as shown in Figures 26 and 27. This is an example of a relatively new Business Use enabled by 3D elevation data.

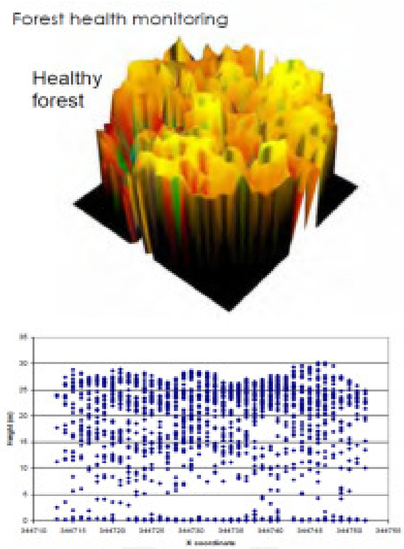



Figure 26. The intermediate returns from this lidar point cloud indicate a healthy forest according to one study.

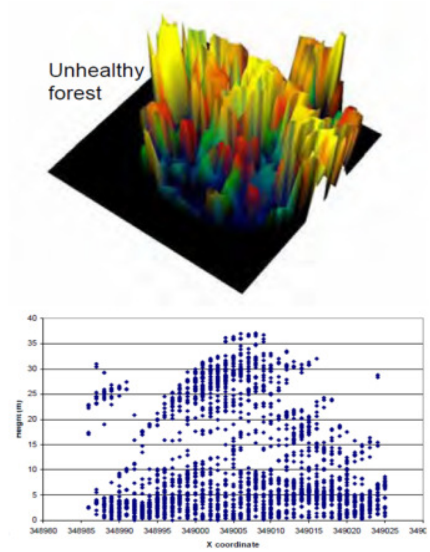



Figure 27. The intermediate returns from this lidar point cloud indicate an unhealthy forest by that same study.

**Benthic Habitats**

This example pertains to Business Use #07 (Wildlife and Habitat Management).

NOAA is routinely using bathymetry to characterize benthic habitats in marine environments. These benthic habitats are used for a variety of management applications, including supporting the blue economy by informing management plans that balance resource protection with ocean user needs and safety (SLUMP 2017).

### 3.3.2 Public Safety

#### *3.3.2.1 Reduced flood damage losses*

This example pertains to Business Use #15 (Flood risk management).

The National Flood Insurance Program (NFIP) relies on digital elevation data for hydrologic and hydraulic modeling of watersheds and floodplains and for mapping of flood hazards with Flood Insurance Rate Maps (FIRMs). See example at Figure 28. Floodplain maps define flood hazard zones and are used to determine whether flood insurance is required for buildings located near streams and rivers, for example, and to promote sound floodplain management practices within communities.

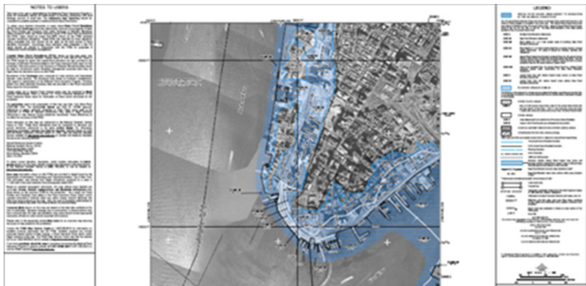


Figure 28. Modern digital FIRMs, produced with lidar data, are more accurate, improve public confidence in the legitimacy of flood risk assessments, cause communities to adopt and enforce floodplain management ordinances to reduce future flooding, and cause more homeowners to insure themselves against ever-increasing flood risks.

Today, FEMA largely relies on lidar for H&H modeling, for computation of water surface elevations for floods of specified frequency, to delineate flood hazard zones and predict flood depths. Using FIRMs, nearly 20,000 communities across the U.S. participate in the NFIP by adopting and enforcing floodplain management ordinances to reduce future flood damage. In exchange, the NFIP makes Federally-backed flood insurance available to homeowners, renters, and business owners in these communities. Flood insurance is designed to provide an alternative to disaster assistance to reduce the escalating costs of repairing flood damage to buildings and their contents. Flood damage is reduced through communities implementing sound floodplain management requirements and property owners purchasing flood insurance. Additionally, buildings constructed in compliance with NFIP building standards suffer approximately 80% less damage annually than those not built in compliance.

### *3.3.2.2 Mitigation of sea level rise and subsidence*

This example pertains to Business Use #16 (Sea Level Rise and Subsidence).

Land subsidence, the loss of surface elevation due to removal of subsurface support, is a costly problem that occurs in nearly every State in the U.S. Both lidar and IfSAR data are used for subsidence monitoring so that future losses due to subsidence can be mitigated. Furthermore, many national and State studies are using lidar to evaluate the impact of sea level rise. Figure 29 shows a USGS graphic that predicts losses of land and marshes for coastal Louisiana alone, with dire predictions during the next 50 years.

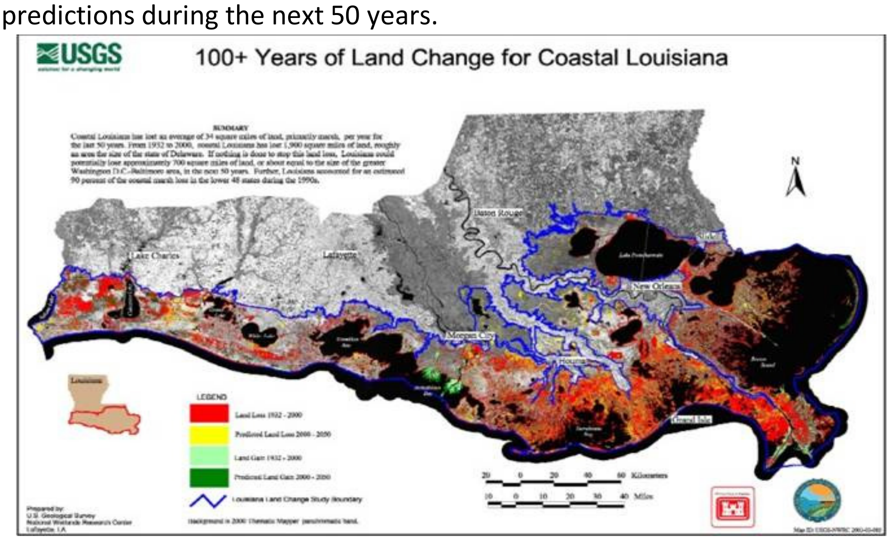



Figure 29. At predicted rates of subsidence and sea level rise, Louisiana is expected to lose very large areas annually during coming decades. Lidar will be vital in monitoring and analyzing such changes with major socio-economic implications.

The National Water Level Observation Network (NWLON), operated by NOAA, uses a nationwide tide station network to track long term changes in sea levels on all coasts, including the Great Lakes. Figure 30 shows the sea level rise for a tide station in North Carolina.

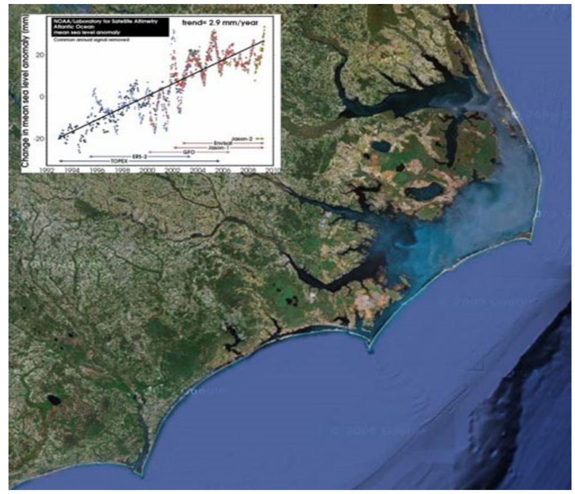



Figure 30. Monitoring of sea level rise in North Carolina.

With projected sea level rise trends, lidar data is widely used to predict areas of inundation from rising sea levels, as well as coastal inundation expected to occur from hurricane tidal surges, and in some cases, from tsunamis. Lidar is now used to prepare graphics that color-code the depth of flooding in addition to the boundaries of areas to be flooded.

Low-lying islands are susceptible to sea level rise, and are often overwashed during large wave events. The intrusion of salt water from overwash can reduce the amount of potable water and habitability of these islands. High resolution bathymetry is important to understand and quantify these overwash events, and to prepare for their negative impacts to coastal resources and infrastructure (Cheriton et al 2016).

### *3.3.2.2 Landslide recognition, hazard assessment, and mitigation support*

This example pertains to Business Use #10 (Geologic Assessment and Hazard Mitigation).

The USGS Landslide Hazards Program conducts landslide hazard assessments, pursues landslide investigations and forecasts, provides technical assistance to respond to landslide emergencies, and engages in outreach. All of these activities benefit from the availability of high-resolution, 3D elevation information in the form of light detection and ranging (lidar) data and interferometric synthetic aperture radar (IfSAR) data.

*"Landslide hazard assessment at local and regional scales contributes to mitigation of landslides in developing and densely populated areas by providing information for (1) land development and redevelopment plans and regulations, (2) emergency preparedness plans, and (3) economic analysis with the goal of (a) setting priorities for engineered mitigation projects and (b) defining areas of similar levels of hazard for insurance purposes."*
—Baum and others (2014)

Lidar data provides crucial input to slope-stability models that are used to identify where shallow landslides may mobilize into fast-moving, and potentially damaging and deadly debris flows. The data can also be used to plan for evacuations and staging areas in advance of a possible landslide event.

Lidar data can be used to create landslide inventory and deposits maps and estimate the shape and activity of landslides; determine fundamental and highly detailed descriptions of boundary conditions for landslide initiation; provide baseline information for change-detection comparisons, such as estimating sediment transport rates; and estimate landslide thickness and ages of landslide deposits.

**Figure 31. Baum and others (2014) showed that compared to other technologies, using 3DEP lidar data identified 3 to 200 times the number of landslides in densely forested areas.**

### *3.3.2.3 Dam and Levee Safety*

This example pertains to Business Use #18 (Homeland Security, Law Enforcement, Disaster Response, and Emergency Management) as well as Business Use #15 (Flood Risk Management).

Levee safety became a national priority following Hurricane Katrina with considerable loss of life and property. Levees fail for numerous reasons, including erosion and loss of soils used as berms, cracking and movement of structural components, and improperly managed vegetation. Lidar is a tool used in a national levee safety and certification process. Lidar data/surfaces from the current year can be compared with lidar data/surfaces from prior years to detect changes. The top of Figure 32 shows the location of a cross-section cut across the levee. The bottom of Figure 32 shows the height of the vegetation growing on the levee at that cross section; some vegetation undermines the structural integrity of dams and levees.

With aging infrastructure and potential terrorism, those who own, manage or maintain dams must also be prepared for a potential dam breach. Lidar data are now used to gather valley cross-section data representative of downstream conditions; to develop water surface profiles for each section; to calculate the breach flow rate; to route the breach flow rate down the valley; and to plot and analyze the results using GIS technology (Figure 33). Before lidar, cross-sections were determined by slow, costly and inefficient land survey techniques. Thus, lidar for dam and levee assessment provides a monetary benefit in addition to a societal benefit.

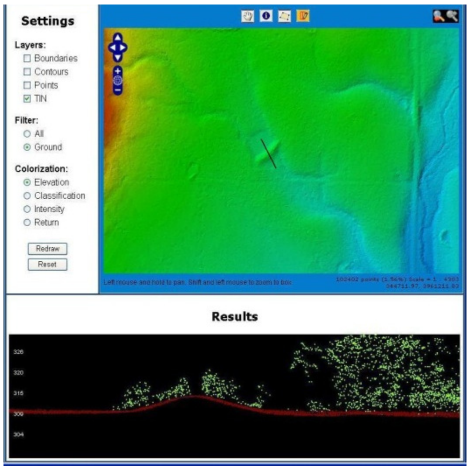



Figure 32. Lidar cross-sections measure the height of vegetation growing on dams and levees, signaling potential safety hazards.

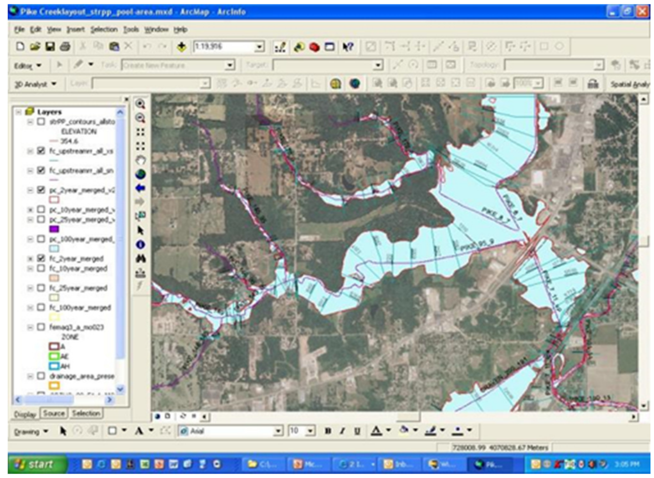


Figure 33. Lidar is ideal for dam breach modeling, to include valley cross-section data to model downstream conditions.

### *3.3.2.4 Near real-time warning systems*

This example pertains to Business Use #18 (Homeland Security, Law Enforcement, Disaster Response, and Emergency Management).

North Carolina, Louisiana and Florida are among the States that funded major lidar mapping programs used, in part, for mapping of coastal flood hazards and computer modeling of hundreds of potential surges from hurricanes that vary as a function of near-shore topography, tide stage, wind direction and velocity, and other factors. (NOAA has also done this for potential tsunamis in Hawaii.) Hurricane tidal surge and tsunami hazards do not just threaten property, but human and animal lives as well. These States use their lidar data for early identification of evacuation routes subject to flooding that could isolate people with no safe exit. North Carolina is also using its lidar data for a near real-time flood warning system along rivers by contacting homeowners to warn them in advance of coming floods and flood depths. Every minute of advance warning can avoid extensive flood losses by allowing homeowners to move people, animals and valuable items to safer locations and/or to sandbag their property.

### *3.3.2.5 Marine navigation and safety*

This example pertains to Business Use #20 (Marine and Riverine Navigation and Safety).

On January 8, 2005, the nuclear submarine *USS San Francisco* was proceeding at 38 miles per hour, 525 feet below the surface. Such vessels often travel in virtual blindness, foregoing radar and its telltale pings; the crew relied on seafloor charts to navigate. But the maps were not complete. About 360 miles southeast of Guam, the submarine hit an unmapped underwater mountain. The collision injured 100 of 137 crew members, and one died from a massive head wound. The commander was discharged and reprimanded for an "ill-advised voyage plan," but the lack of precise charts undoubtedly played a major role in the accident.

More accurate and up-to-date data of the seafloor is important not only for navigation. It is also vital for underwater recovery. When Malaysian Airlines Flight 370 went missing over the Pacific, it showed how little we know about the seafloor. In the area where the plane is thought to have crashed, the maps were nearly nonexistent; the only charts were based on satellite measurements. But these charts have a resolution of 1.5 kilometers (meaning one measurement is taken every 1,500 meters).

More than eighty percent of our oceans are unmapped, unobserved, and unexplored. Only about 10% have been mapped using modern technology. Another approximately 5% were mapped using lead lines and explosives, which provides only a general sense of the area. While we have indeed mapped the entire moon to 7-meter resolution and Mars to 20 meters, much of our own planet's seafloor is mapped at best to 5000-meter resolution using satellites that infer depth based on gravity anomalies.

Seabed mapping is critical to forecasting weather, tsunami and storm surge events; climate change projections; and the outlines of where living marine resources exist. It is the means to uncover the history of our fallen lost at sea and the framework for seabed mineral discovery. Accurate ocean depths are instrumental in connecting the world through safe navigation and transoceanic communication cables, and they are critical to emergency response on the high seas. Even if these benefits are difficult to quantify, they certainly should be considered as "Major."

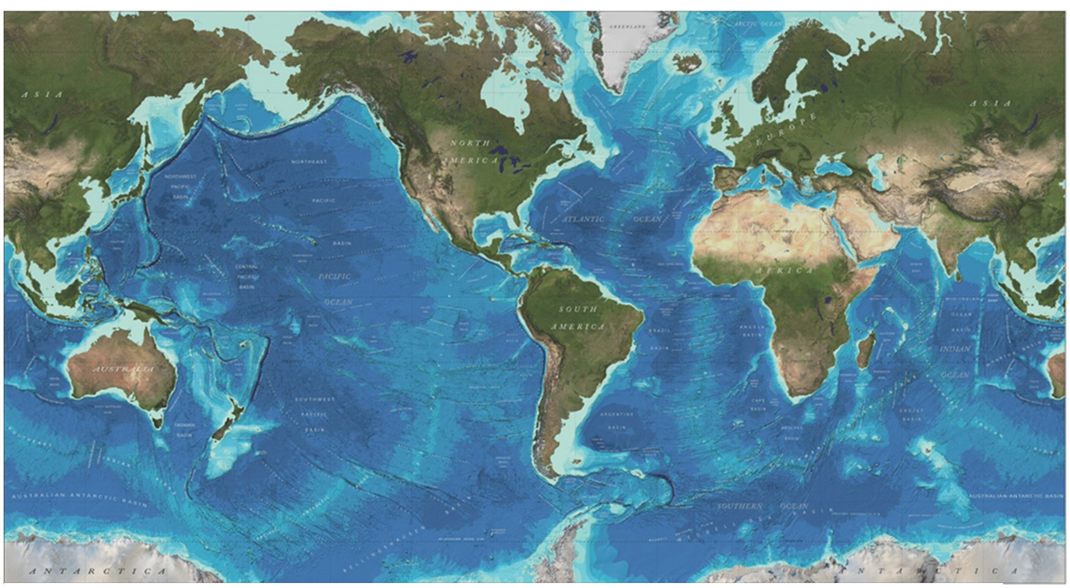



**Figure 34. General Bathymetric Chart of the Oceans (GEBCO) World Map 2014.**