Appendix 1. Federal Government Requirements and Benefits Data

The information in this appendix was generated from 358 responses to an online questionnaire completed by content experts and managers within 34 Federal agencies. Respondents were asked to detail their requirements for elevation data and to estimate the expected programmatic benefits that would result if these requirements were met. The agencies then participated in workshops where they had the opportunity to edit, consolidate, and validate their requirements and benefits data. In a significant number of cases it was not possible for agencies to approximate a dollar benefit associated with improved elevation data.

Bureau of Indian Affairs

Point of Contact: Wyeth (Chad) Wallace, (720) 407–0638, Wyeth.Wallace@bia.gov

The mission of the Bureau of Indian Affairs (BIA) is to enhance the quality of life, to promote economic opportunity, and to carry out the responsibility to protect and improve the trust assets of American Indians, Indian tribes, and Alaska Natives.

Divided into regions (fig. 1–1), the BIA is responsible for the administration and management of 55 million surface acres and 57 million acres of subsurface minerals estates held in trust by the United States for approximately 1.9 million American Indians and Alaska Natives, and 565 federally recognized American Indian tribes.

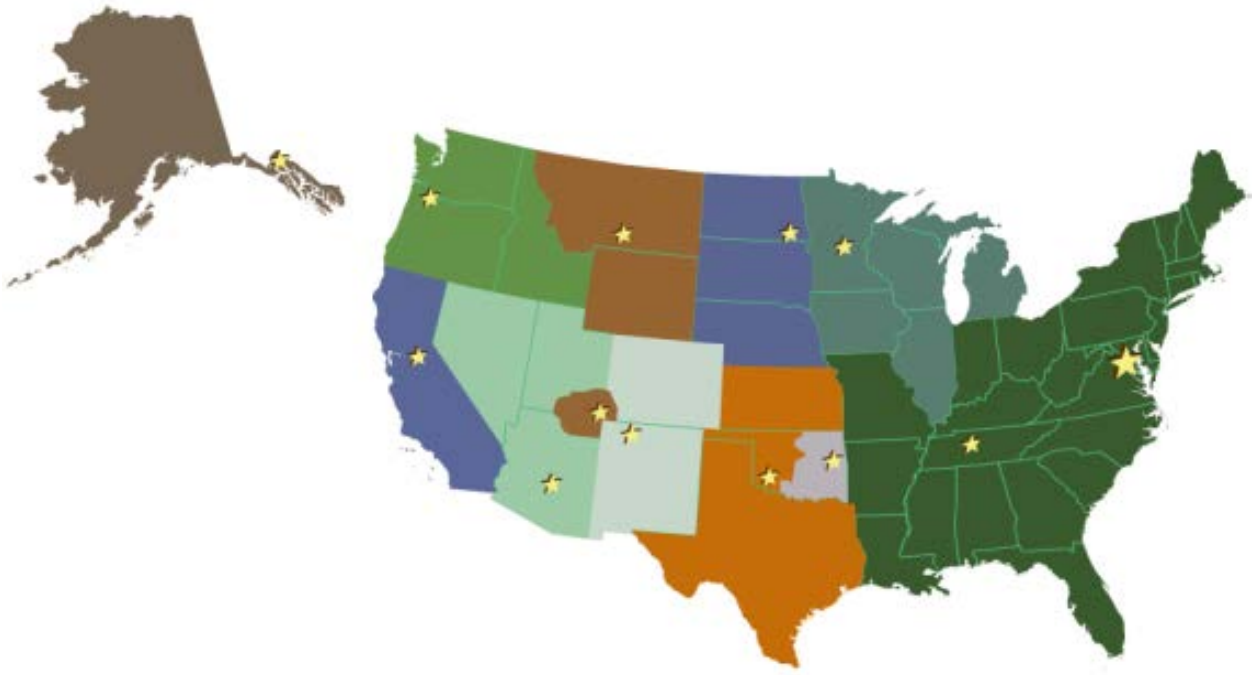


Figure 1–1. Map showing the regions of the Bureau of Indian Affairs.

The primary public policy of the Federal government in regards to Native Americans is the return of trust lands management responsibilities to those most affected by decisions on how these American Indian Trust (AIT) lands are to be used and developed. Enhanced elevation data, orthoimagery, and geographic information system (GIS) technology are needed to enable tribal organizations to wholly manage significant, profitable, and sustainable enterprises as diverse as forestry, water resources, mining, oil and gas, transportation, tourism, agriculture, and range land leasing and management, while preserving and protecting natural and cultural resources on AIT lands.

Accurate and current elevation data are especially mission-critical for management of forest and water resources. It is the mission of the BIA Irrigation, Power, and Safety of Dams (IPSOD) Program to promote self-determination, economic opportunities and public safety through the sound management of irrigation, dam, and power facilities owned by the BIA. This program generates revenues for the irrigation and power projects of $80 million to $90 million annually. Additionally, water rights, mitigation, and all that goes along with water from forestry to fishing are very important to native peoples and any increase in knowledge of those water sources, watersheds, and waterways is invaluable.

Similarly, forest products on native lands are harvested and sold through permits, and forest inventories are conducted to determine and record the volume and value of forest products harvested by ownership and to maintain records to document compliance. The wise stewardship of forests on AIT lands is critical because timber sales have exceeded $100 million annually. Light detection and ranging (lidar) provides vital timber and biomass metrics plus slope data needed for forest management plans and fire management plans. Timber is real property; volumes and

fair market values of the timber must be determined with a minimum sampling error of 15 percent as a part of realty appraisal and to enhance sustainable forest product sales.

BIA managers identified a single, all-inclusive functional activity with mission-critical requirements for enhanced elevation data:

- Protection and Enhancement of American Indian Trust (AIT) Assets, under multiple business uses, but primarily business use (BU) #1 (natural resources conservation)

BIA managers provided the following assessments of elevation data requirements and benefits received from the enhanced elevation data quality level that they identified as mission-critical. Summarized details are provided in the following pages.

Protection and Enhancement of American Indian Trust Assets

Mission-Critical Requirements

Quality level (QL) 3 lidar is required for management of forest and water resources on American Indian Trust (AIT) lands and watersheds flowing into and out from AIT lands.

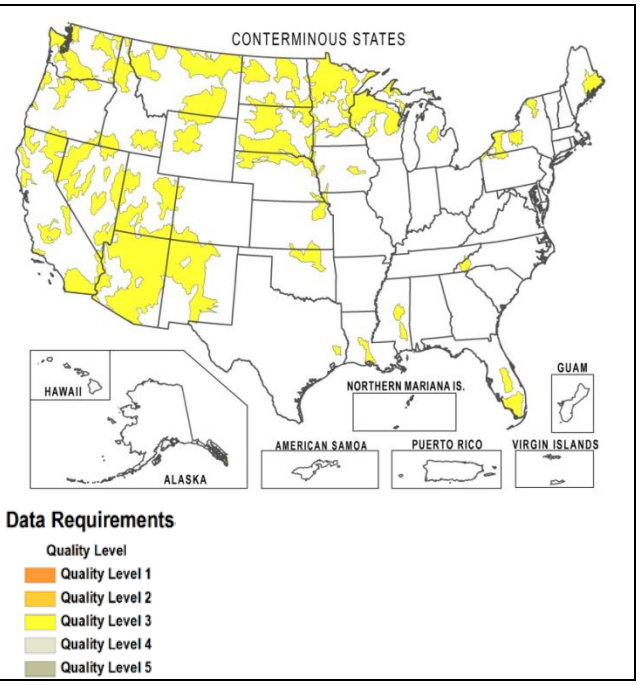
Update frequency: 6–10 years.

Business Use: Multiple business uses, but primarily Natural Resources Conservation, BU#1.

Estimated program budgets supported by elevation data: Unknown.

Quantifiable Benefits of Enhanced Elevation Data

Unable to estimate cost savings from improved management of forest and water resources.



Because it can accurately map the ground in dense forests while also mapping tree canopies, understory and biomass, lidar is the leading technology for detailed topographic mapping used for management of water and forest resources and for detecting subtle terrain features, such as cultural resources important to native peoples. Nationwide, foresters demand lidar for forest management to include science-based assessments of forest metrics and health. Furthermore, automated procedures for hydrologic and hydraulic (H&H) modeling are now performed, almost exclusively, with lidar data.

Operational benefits (internal) for the BIA of enhanced elevation data for this functional activity

Time/Cost Savings: Major	Mission Compliance: Major	$ Benefits: Unable to estimate

- Improved safety and efficiency in management of irrigation, dam, and power facilities owned by the BIA through accurate hydrologic modeling and dam breach modeling and assessments. The BIA monitors more than 430 dams in its IPSOD program with potentially major savings from lidar for dam safety assessments alone, but cost savings cannot be estimated.
- The BIA will not be replacing its continuous forest inventories (CFIs) and will continue to use existing programs and equations. However, lidar would supplement those efforts by assisting in computing forest metrics and biomass for estimation of timber volumes available for harvesting and sale. Furthermore, the BIA could inventory reservations that have limited resources, are remote, or are not actively managing their resources. Cost savings cannot be estimated.

- Accurate topographic mapping for other assessments (for example, wildlife habitat, environmental, agricultural, transportation, mining, and oil and gas development) on American Indian Trust (AIT) lands.
- Accurate and consistent elevation data across jurisdictional boundaries enables the BIA to perform its mission to protect and enhance AIT assets by efficient management of natural and cultural resources.
- Technology and data that enable the BIA to do more with limited staff and budget.

Customer service benefits (external) to the public from improved BIA products and services

Performance: Major	**Timeliness: Major**	**Experience: Major**	**$ Benefits: Unknown**

- Important decisions can be made more quickly when accurate data are available for analysis.
- Fire modeling across jurisdictional boundaries is effective and efficient with lidar.
- Tribes and tribal organizations can wholly manage significant, profitable, and sustainable enterprises when accurate and current topographic data are available and when they learn how to use such data with GIS tools for effective and efficient management of natural and cultural resources.
- Watershed mitigation on a large scale—yarder ground (generally more than 35 percent slope), cat ground (up to 35 percent slope) and helicopter ground (generally steep ground but usually inaccessible by other logging methods)—can be determined, from which timber values are determined and harvest boundaries set; tribes and tribal organizations can use lidar to plan for the future management of their forests.
- Irrigation and power projects would be more efficient when using enhanced elevation data for H&H modeling and assessments, but annual cost benefits cannot be estimated.
- For homesite lease preparation, lidar would better serve the tribes for right-of-way and leasing benefits.
- By embracing 21st century technology, including lidar and GIS, tribes and tribal organizations will be better able to preserve and protect natural and cultural resources for future generations.

Other benefits from BIA use of enhanced elevation data for this functional activity

Public/Social: Major	**Environmental: Major**	**Strategic/Political: Major**

- Lidar is mission-critical for executing AIT responsibilities to be wise stewards of AIT lands.
- Better protection of the natural environment and cultural resources on AIT lands.
- Technology transfer that enables tribal programs to stand-up applications of geospatial technology and by extending the reach of these applications by providing rich sources of elevation data from which informed decisionmaking can be enabled.
- Improved public interest and better public understanding of environmental issues confronting AIT assets. Better data improves the BIA's ability to relay information on management activity to the public so they can see what is being done instead of being told what is being done.

Bureau of Land Management

Point of Contact: Don Buhler, (202) 912–7353, Don Buhler@blm.gov

The stated mission of the Bureau of Land Management (BLM) is to sustain the health, diversity, and productivity of the public lands for the use and enjoyment of present and future generations. The BLM is responsible for stewardship of public lands of approximately 253 million surface acres, about one-eighth of the land area of the United States, as well as approximately 700 million acres of subsurface mineral estate underlying both Federal surface ownerships and privately owned lands. These public lands surface acres are primarily in 12 western States, including Alaska (fig. 1–2).

The BLM is committed to managing, protecting, and improving these lands in a manner to serve the needs of the American people. Management is based upon the principles of multiple use and sustained yield of our Nation's resources within a framework of environmental responsibility and scientific technology.

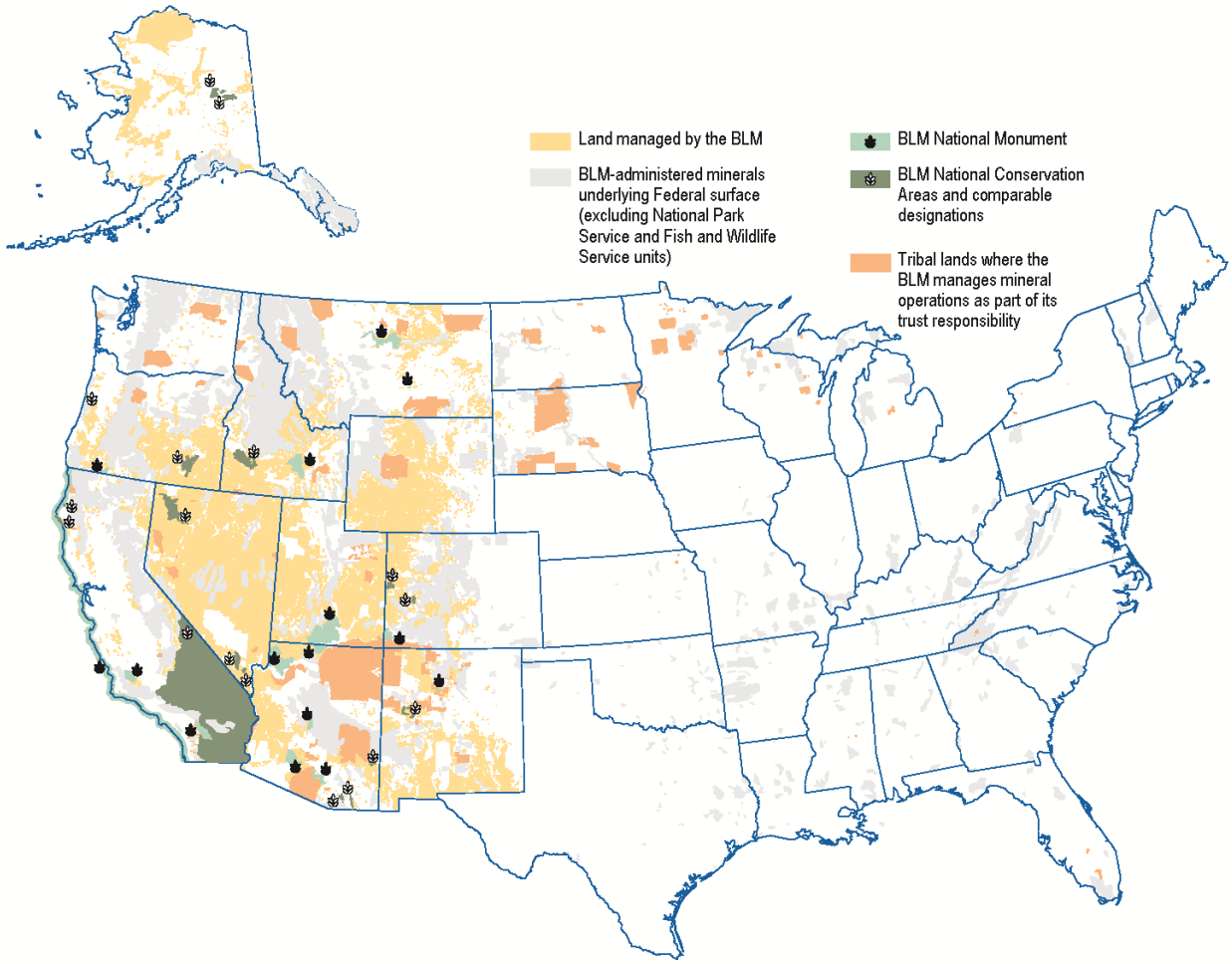


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Figure 1–2. Map showing the locations of land managed by the Bureau of Land Management.

Following is a list of some of the natural resource programs and projects currently managed by the BLM that are engaged in using or managing elevation data within the Bureau:

- abandoned mine lands
- forests and woodlands
- asset management

- hazardous materials management
- BLM enterprise architecture
- information resources management
- climate change
- invasive species
- cultural, paleontological resources, tribal consultations
- information technology transformation
- decision support, planning, and National Environmental Policy Act
- lands, realty and cadastral survey
- education, interpretation, and partnerships
- law enforcement and security
- emergency management programs
- minerals and realty management
- enterprise geographic information system
- national applications
- environmental quality and protection
- national landscape conservation system (NLCS) and community partnerships
- ePlanning
- rangeland resources
- fire and aviation
- recreation and visitor services
- fish, wildlife, and plant conservation
- renewable resources and planning
- fluid minerals
- solid minerals
- forest resource information systems
- wild horses and burros

The public lands provide significant economic benefits to the Nation and to States and counties where these lands are located. As an example, in 2009, public lands generated more than $6 billion in revenues that were transferred to the U.S. Department of the Treasury for use by the Federal Government.

Many land management issues do not end at the border of the public lands; therefore the BLM coordinates natural resource issues with other Federal agencies, State and local government, and private landowners. Examples of this coordination involve all of the programs and projects listed above.

All the programs and projects mentioned above would benefit from the most accurate geospatial framework data available, just as all natural resource programs managed by natural resource agencies would. Better precision and higher accuracy is always a plus, but there is no Bureau-wide effort for such data. The BLM's default elevation data for use by its programs is the National Elevation Dataset (NED) as managed by the U.S. Geological Survey (USGS). The BLM will benefit as the NED is improved and enhanced through work by the USGS and its partners. The NED by itself provides a constantly improving geospatial foundation layer that is critical for the BLM to use in meeting its on-the-ground mandates. The NED meets the majority of elevation needs of the BLM, with few exceptions where the NED does not satisfy all requirements. BLM managers identified the following functional activities with mission-critical requirements for enhanced elevation data:

- Wildland Fire Fighting, under BU#16, Wildfire Management, Planning and Response
- Multiuse Land Management in Alaska, under multiple business uses, including BU#1, Natural Resources Conservation

BLM managers provided the following assessment of elevation data requirements and benefits received from the enhanced elevation data quality level that they identified as mission-critical. Summarized details are provided in the following pages.

Wildland Fire Fighting

Mission-Critical Requirements

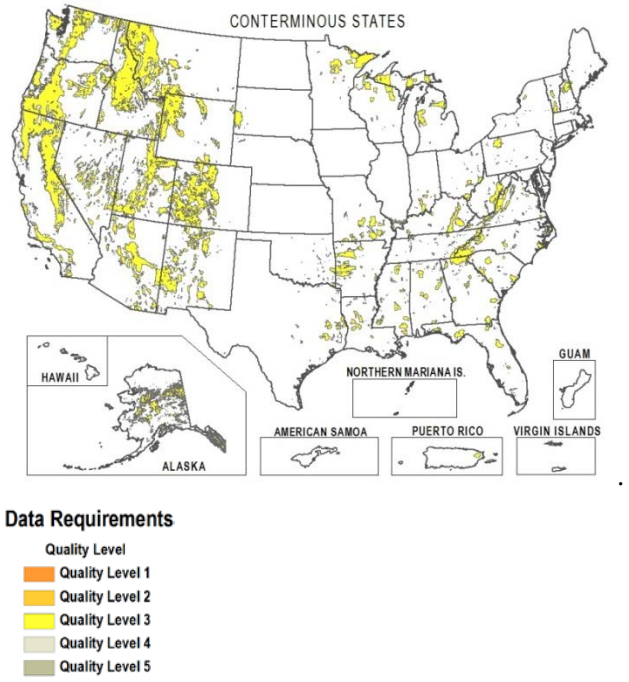
For the National Interagency Fire Center (NFIC), QL3 lidar data are needed for Federal forested lands nationwide for wildfire models that require: (1) digital elevation models (DEMs), (2) slope, (3) aspect, (4) canopy cover, and (5) fuel loading—all available from lidar—in addition to (6) weather, (7) wind, and (8) fuel moisture information, real-time parameters used in wildfire models. The forest canopy cover and fuel load (biomass) are not available from the NED although the NED does provide DEM, slope and aspect data. The BLM manages approximately 186 million acres that are non-forest but also require wildland fire modeling that lidar QL3 may not be appropriate.

Update frequency: Event driven.

Business Use: Wildfire Management, Planning and Response, BU #16.

Estimated program budget supported by elevation data: Unknown.

Quantifiable Benefits of Enhanced Elevation Data: Unable to determine.



The BLM is part of the National Interagency Fire Center (NFIC), the Nation's support center for wildland firefighting nationwide, located in Boise, Idaho. Eight different agencies and organizations are part of the NIFC. Decisions are made using the interagency cooperation concept because the NIFC has no single director or manager. The Boise Interagency Fire Center (BIFC) was created in 1965 because the BLM, the U.S. Forest Service, and the National Weather Service saw the need to work together to reduce the duplication of services, cut costs, and coordinate national fire planning and operations. The National Park Service (NPS) and the BIA joined BIFC in the mid-1970s. The U.S. Fish and Wildlife Service (FWS) joined in 1979. The BIFC's name was changed in 1993 from the Boise Interagency Fire Center to the National Interagency Fire Center (NFIC) to more accurately reflect its national mission. The U.S. Fire Administration of the Federal Emergency Management Agency (FEMA) joined the NIFC in 2003.

Operational benefits (internal) to the BLM of enhanced elevation data for this functional activity

Time/Cost Savings: Major	**Mission Compliance: Major**	**$ Benefits: Unknown**

- Wildfire models include the eight parameters indicated above, of which five parameters are provided by lidar data: (1) DEMs, (2) slope, (3) aspect, (4) canopy cover, and (5) fuel loads (biomass). Critical real-time information is input from the remaining parameters [(6) weather, (7) wind, and (8) fuel moisture information] to accurately predict the spread of wildfires and develop fire-fighting strategies.

Customer service benefits (external) to the public from improved BLM products and services

Performance: Major	**Timeliness: Major**	**Experience: Major**	**$ Benefits: Unknown**

- The customers are the American public who expect the NIFC to use the best available technology to save lives and property.

Other benefits from BLM use of enhanced elevation data for this functional activity

Public/Social: Major	Environmental: Unknown	Strategic: Unknown

- The public is best served when computer models accurately predict the spread of wildfires so that timely and effective firefighting strategies can be implemented.

Multiuse Land Management in Alaska

Mission-Critical Requirements

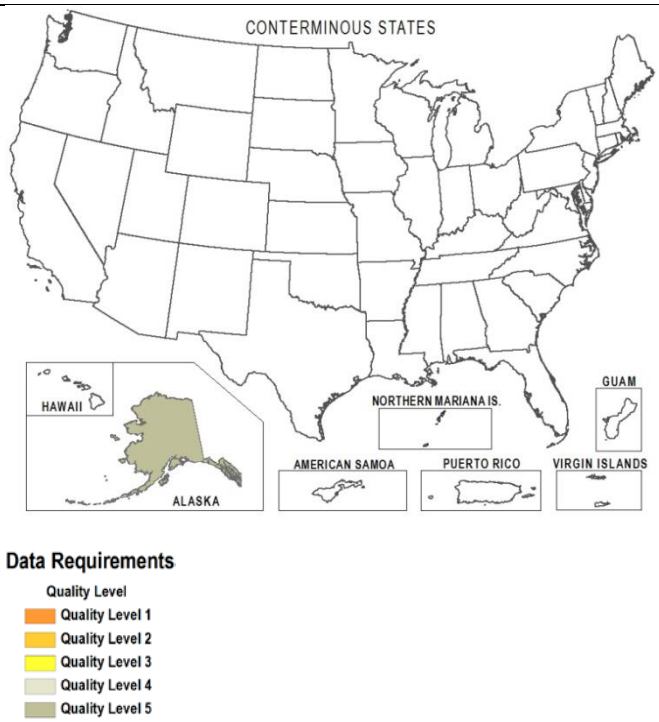
QL5 interferometric synthetic aperture radar (IFSAR) data are required for multiuse land management in Alaska, consistent with the BLM conveyance report and other requirements documented in the September 2008 report entitled "Digital Elevation Model (DEM) Data for the Alaska Statewide Digital Mapping Initiative."

Update frequency: More than 10 years.

Business Use: Primarily Natural Resources Conservation, BU #1.

Estimated program budget supported by elevation data: Unknown.

Quantifiable Benefits of Enhanced Elevation Data: Unable to determine.



In September 2008, the Alaska Geographic Data Committee (AGDC) published a report entitled "Digital Elevation Model (DEM) Data for the Alaska Statewide Digital Mapping Initiative" (http://www.alaskamapped.org/) which documented the following BLM requirements for QL5 interferometric synthetic aperture radar (IFSAR) data statewide in Alaska:

- Floodplain management, especially in coastal areas.
- Management of wetlands and other ecologically sensitive flat areas.
- Safe operations of light aircraft and helicopters in steep, mountainous terrain where elevation accuracy is critical, for performance of routine field operations.
- Delineation of rights of ways and easements, especially delineating Alaska Native Claims Settlement Act (ANCSA) §17b easements, and delineation of hard rock and placer mining planning, operations, and reclamation.
- Base maps for wild land fire suppression.
- Mapping of existing and potential oil and gas infrastructure areas, especially along proposed natural gas line routes, both intrastate and instate.
- Support to cadastral surveys in accurately delineating meander-lines for lakes, rivers, and coastlines. The BLM has the responsibility to survey and patent land selected under the ANCSA and the Alaska Statehood Act. As of 2008, the status of the workload was:
    - ANCSA (millions of acres): total entitlement (45.6), patented (24.4), transferred by interim conveyance (14.1), remaining entitlement (7.1).
    - State (millions of acres): total entitlement (104.5), patented (55), transferred by tentative approval (42), and remaining entitlement (7.5).

Operational benefits (internal) for the BLM of enhanced elevation data for this functional activity

Time/Cost Savings: Major	Mission Compliance: Major	$ Benefits: Unknown

- Alaska is the only State where BLM delineations cannot be performed from digital orthophotos. Alaska has no digital orthophotos because DEMs from the NED are too inaccurate for orthorectification, with some mountain ranges horizontally displaced by several miles. Stream and water boundary meander lines produced from inaccurate DEMs in the NED depict rivers climbing up and over mountains, and there is no accurate reference surface on which to resolve major discrepancies.
- IFSAR DEMs are necessary for BLM to accomplish its core mission in Alaska.
- NOAA has a multiyear program to update the datum in Alaska. IFSAR DEM data collected in the SDMI partnership is being accepted in a manner that will allow reprocessing to the new datum once NOAA completes the update.

Customer service benefits (external) to the public from improved BLM products and services

Performance: Major	Timeliness: Major	Experience: Major	$ Benefits: Unknown

- BLM could work more seamlessly with adjoining Federal, State, and local jurisdictions, all using the same authoritative IFSAR elevation data of Alaska for stewardship of natural resources, wildfire, and floodplain management, for example, where areas of interest cross jurisdictional boundaries.
- BLM could provide key data to the public through the Web; this provides enhanced services to the public and significantly reduces the workload on BLM staff for public requests for information.
- IFSAR data helps in evaluating permitting, regulatory compliance, more efficient project planning, and more effective land use management.
- IFSAR data are used for real-time fire modeling which benefits all affected by wildfires.

Other benefits from BLM use of enhanced elevation data for this functional activity

Public/Social: Moderate	Environmental: Moderate	Strategic: Unknown

- Social benefits include a better understanding of the rationale for resource decisions and better data to evaluate those decisions.
- Better interaction with concerned public groups. Ability to provide maps and models to back Bureau positions on resource management plans.
- Increased ability to educate the public, direct resource management plans and agency funding to cope with shifting ecosystem environments.

Bureau of Ocean Energy Management

Point of Contact: Doug Vandegraft, (703) 787–1312, Doug.Vandegraft@boemre.gov

Within the U.S. Department of Interior, the Bureau of Ocean Energy Management (BOEM) manages the Federal Government's offshore leasing program under 43 U.S.C. §1344. In support of this effort, the BOEM performs mathematical offshore boundary location computations and prepares Outer Continental Shelf (OCS) leasing maps, OCS official protraction diagrams, and supplemental official OCS block diagrams depicting OCS block information, the State seaward boundary, limit of "8(g) Zone", the boundary of the 200 nautical mile Exclusive Economic Zone (EEZ boundary), and corresponding areal measurements.

Before any offshore computations can be made, a series of baseline points representing the mean lower low water (MLLW) line in direct contact with the open sea must be marked on the appropriate nautical charts or hydrographic and topographic survey sheets. From these base materials, cartographers from the BOEM select isolated points and straight line segments along the shoreline where the baseline can be assumed to be a straight line in order to secure a mathematically describable line. Generally, Federal jurisdiction begins at 3 nautical miles from the baseline from which the territorial sea is measured (fig. 1–3).

These boundaries are relevant to the OCS Oil and Gas Leasing Program as well as nontraditional energy, alternative energy-related, and other activities on the OCS.

The BOEM managers identified a single functional activity with mission-critical requirements for elevation data:

- Mapping of Coastal Baseline Points, under BU#12, Oil and Gas Resources

BOEM managers provided the following assessments of elevation data requirements and benefits that would be received from QL1 lidar and (or) bathymetric lidar if these technologies are able to efficiently identify and map coastal baseline points.

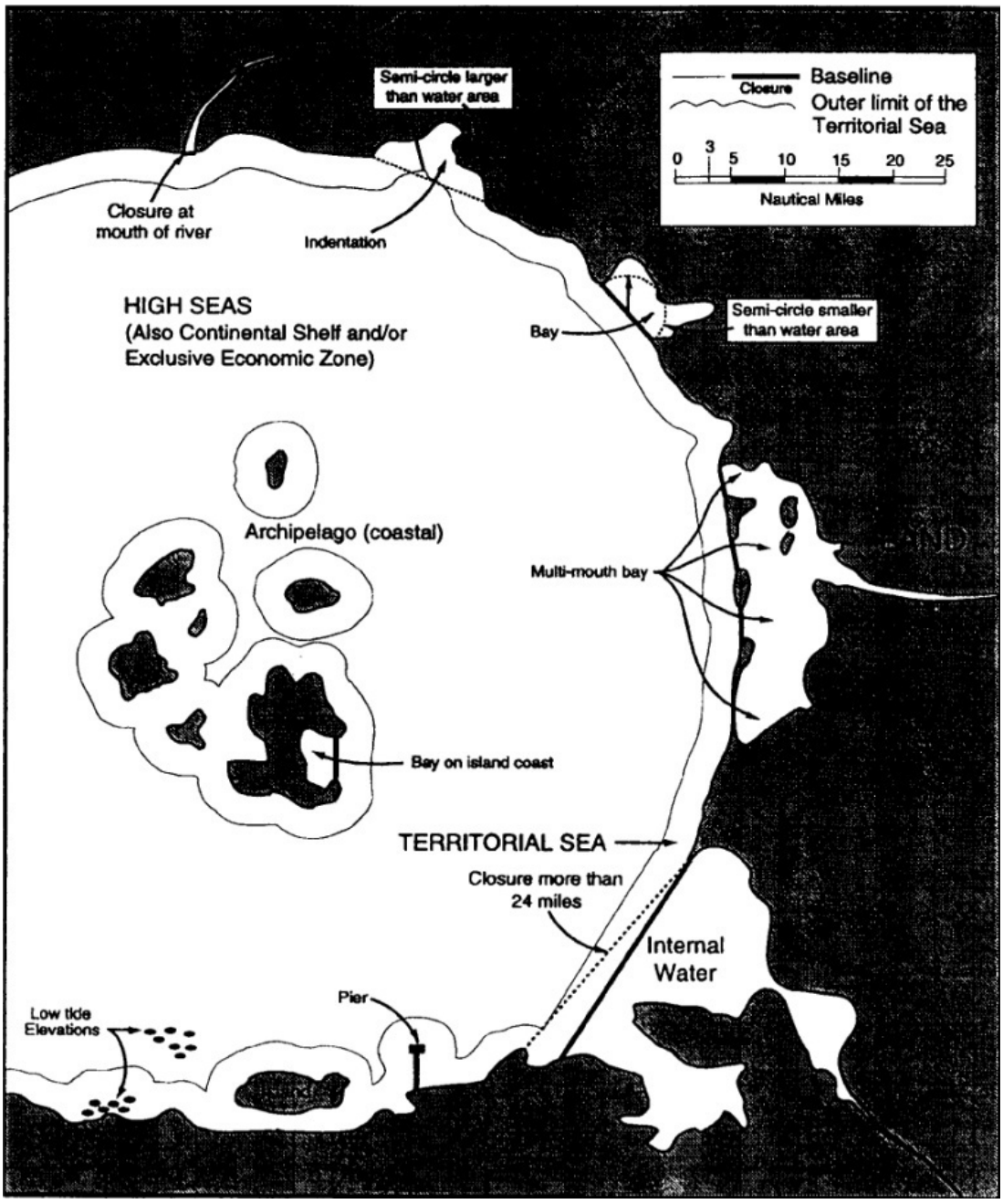


Figure 1–3. Schematic diagram of territorial and high seas.

Mapping of Coastal Baseline Points

Mission-Critical Requirements

QL1 lidar plus bathymetric data was requested to map the horizontal coordinates of all natural features (rocks, sand or gravel bars) that protrude above the water at MLLW tide levels along all coastal areas of the United States, including territories; however, because airborne elevation technologies will not succeed in this task, sonar is recommended during higher tide levels. Sonar requirements are beyond the scope of this assessment.

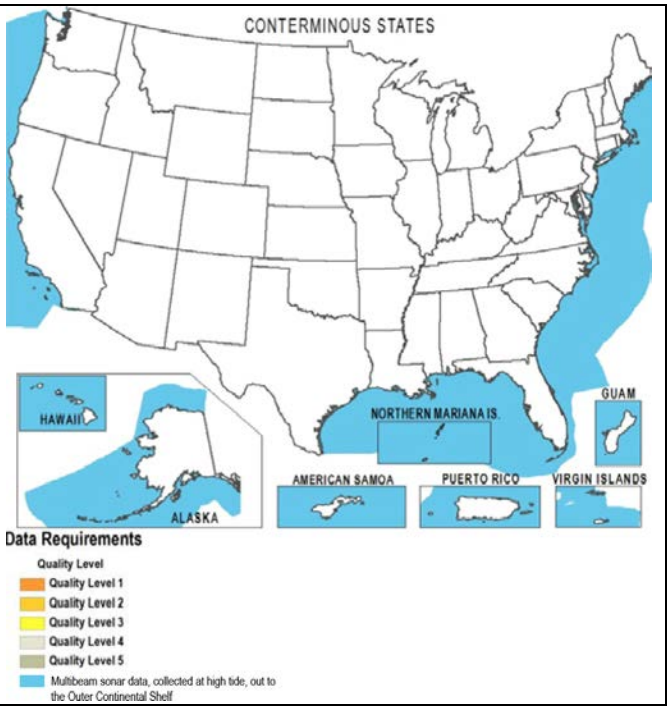
Update frequency: >10 years.

Business Use: Oil and Gas Resources, BU#12.

Estimated program budget supported by elevation data: $1.65 million per year.

Quantifiable Benefits of Enhanced Elevation Data

Benefits to either States or the Federal government could amount to billions of dollars from oil and gas leases or leasing of marine rights for wind, wave, or other alternative energy.



Operational benefits (internal) to the BOEM of enhanced elevation data for this functional activity

Time/Cost Savings: Major	Mission Compliance: Major	$ Benefits: Unknown

- Historically, the BOEM method of determining the elevations of natural features at low tide has been to conduct expensive, onsite investigations. Funding is unavailable for this everywhere needed. If this task could be performed with remote sensing [for example, airborne topographic and (or) bathymetric lidar], considerable costs savings could occur.
- If topographic and (or) bathymetric lidar could map national baseline points, this would reduce the time required to produce and (or) update the offshore digital boundaries and mapping products produced by the BOEM. However, mapping of even large features at MLLW is very expensive, and topographic and bathymetric lidar would probably not detect small features protruding above the water because of foam that occurs naturally along the very shorelines that need to be mapped. Because topographic and bathymetric lidar are least effective along shorelines, this BOEM requirement is more likely to be satisfied by a combination of vessel-deployed laser scanning and multibeam technology.

Customer service benefits (external) to the public from improved BOEM products and services

Performance: Major	Timeliness: Major	Experience: Major	$ Benefits: Unknown

- The location of Submerged Lands Act (SLA) boundaries between the various States and the Federal Government has been a matter of continuing litigation based upon different interpretations of the meaning of various treaties and international and domestic laws.
- Litigation can be extreme because coastal baseline points can determine whether States can issue offshore leases and reap the financial benefits.

Other benefits from BOEM use of enhanced elevation data for this functional activity

Public/Social: Minor	Environmental: Minor	Strategic/Political: Major

- The strategic and political benefits are major, with different Federal agencies potentially contending with multiple States and other Federal agencies to resolve conflicts.

Centers for Disease Control

Point of Contact: Carl Kinkade, (404) 498–2468, ckinkade@cdc.gov

The Centers for Disease Control (CDC) mission is to collaborate to create the expertise, information, and tools that people and communities need to protect their health through health promotion; prevention of disease, injury, and disability; and preparedness for new health threats.

The CDC seeks to accomplish its mission by working with partners throughout the Nation and the world to

- monitor health
- detect and investigate health problems
- conduct research to enhance prevention
- develop and advocate sound public health policies
- implement prevention strategies
- promote healthy behaviors
- foster safe and healthful environments
- provide leadership and training

The CDC identified two functional activities with requirements for enhanced elevation data:

- Human, Animal, and Environmental Health, under BU#23, Health and Human Services
- Waterborne Disease Prevention, under BU#23, Health and Human Services

CDC managers provided assessments of elevation data requirements and benefits received from the enhanced elevation data quality level that they identified as mission-critical. Summarized details are provided in the following pages.

Human, Animal, and Environmental Health

Mission-Critical Requirements

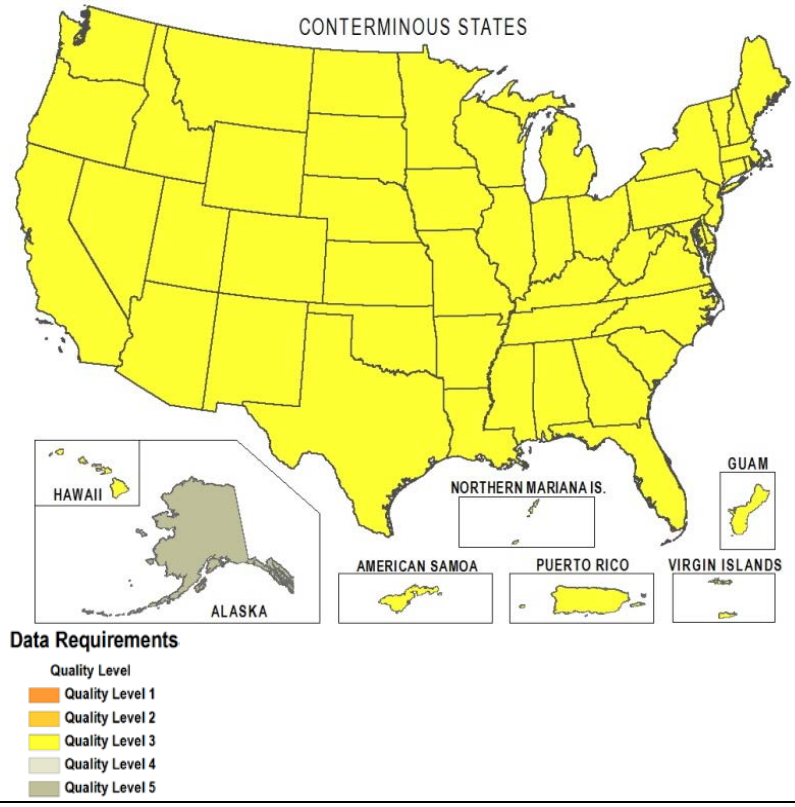
Except for QL5 IFSAR of Alaska, QL3 lidar is required nationwide for health emergency response activities, environmental modeling, vector habitat modeling, and disease prevention planning. For public health and safety, these data are also required to allow workers in many diverse occupations to perform their jobs in a safe office environment rather than under hazardous and unhealthful field conditions.

Update frequency: 6–10 years.

Business Use: Health and Human Services, BU #23.

Estimated program budget supported by elevation data: Unknown.

Quantifiable benefits of enhanced elevation data: Cannot estimate cost savings.



Whereas lidar is technically superior everywhere for mapping the structure of forests, vegetation, and wildlife habitat, it is neither technically nor economically feasible to acquire lidar statewide for Alaska where lidar is limited technically (because of weather conditions) and human populations are sparse. In Alaska, IFSAR is selected because of its all-weather capability and cost efficiencies in mapping broad areas.

Operational benefits (internal) for the CDC of enhanced elevation data for this functional activity

Time/Cost Savings: Moderate	Mission Compliance: Moderate	$ Benefits: Cannot quantify

- Lidar and IFSAR data enable the CDC to respond to public health emergencies with the best available three-dimensional (3D) geospatial data needed to assess conditions that caused the emergency and (or) to respond decisively with corrective actions.
- Vectors are agents that spread disease, for example, ticks, mosquitoes, flies, animals, humans, and birds (West Nile disease). Whereas both lidar and IFSAR have value for mapping of specific habitats, lidar is especially effective in mapping the structure of forests, vegetation, and wildlife habitat; differential lidar, collected in different years, enables the mapping of changes to wildlife habitat including vector habitat.
- Centimeter-level digital terrain model (DTM) data can be derived from lidar data, and they enable the CDC to detect fine-scale sinkholes that can hold standing water. The CDC can determine how long sink-hole water remains stagnant enough to be used as mosquito habitats in a GIS environment, using lidar-derived fine-scale DTM, soil characteristics (for example, water penetration rate), climatic variables, such as wind direction and speed, and other potential datasets.
- Lidar data enable the modeling of cities and rural areas that could be subjected to chemicals from crop dusting, from smog and unclean air conditions, and (or) for modeling of areas affected by accidental chemical spills or terrorist activities that could include the use of chemical, biological, or radiological weapons.
- Lidar provides ancillary information for extracting buildings from remote sensing imagery in a more accurate manner. Extracted buildings can be utilized to estimate population at a local scale, which in turn will be valuable input data for human exposure analysis against environmental pollution.
- Lidar-driven footprints and heights of individual buildings are essential data to use in spatial epidemiology research in urbanized areas, for example, traffic noise research.
- Lidar enables the modeling of dam breaks and plans for mitigating the effects of potential breaks.
- Lidar provides significant benefits for occupational safety and health by enabling many tasks to be performed in an office environment that were previously performed in the field under dangerous or unhealthful conditions. For example, the need for land surveys for highway construction projects (with numerous traffic deaths annually) is largely eliminated by the use of lidar surveys. Similarly, the need for onsite visits and collection of sample data for environment-related activities is often replaced by the use of lidar and other forms of remote sensing, reducing human exposure to field hazards.

Customer service benefits (external) to the public from improved CDC products and services

Performance: Moderate	Timeliness: Moderate	Experience: Moderate	$ Benefits: Cannot quantify

- The CDC partners with State, local, and (or) tribal officials that come to the CDC for help in solving local health issues. These customers are far more satisfied when they recognize that the CDC uses accurate data and advanced geospatial technologies to help solve their problems.

Other benefits from CDC use of enhanced elevation data for this functional activity

Public/Social: Major	Environmental: Major	Strategic/Political: Moderate

- Public and social benefits are major when the CDC uses lidar and modern technology to solve human and animal health problems.
- Environmental benefits are major when the CDC uses lidar and modern technology to solve environmental health problems that impact human and (or) animal health.
- Strategic and political benefits occur when the CDC is able to assist other agencies, including global governments, to solve their problems.

Waterborne Disease Prevention

Mission-Critical Requirements

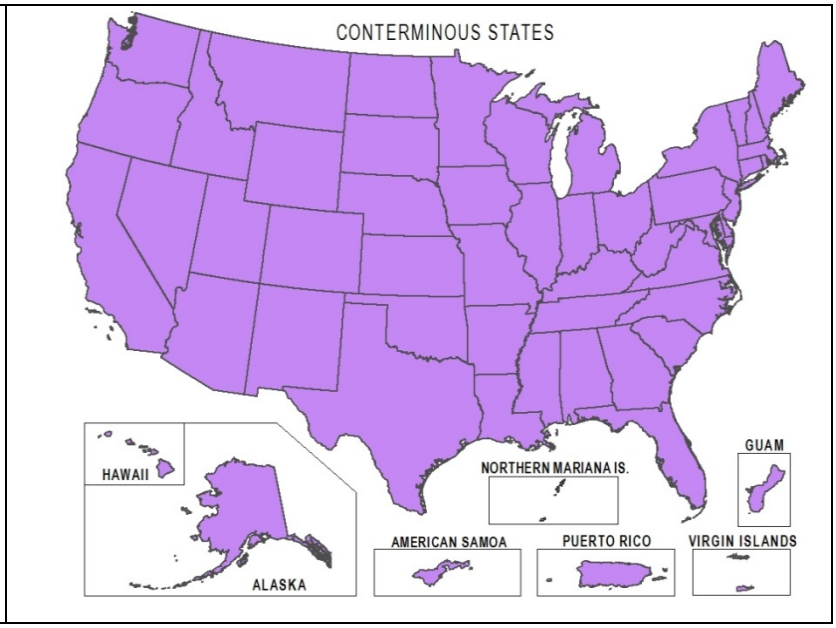
Repeat pass satellite differential IFSAR (DINSAR) is required nationwide for prevention of waterborne diseases, to include health emergency response activities, environmental modeling, and vector habitat modeling.

Update frequency: 6–10 years.

Business Use: Health and Human Services, BU #23.

Estimated program budget supported by elevation data: Unknown.

Quantifiable benefits of enhanced elevation data: Cannot estimate cost savings



Repeat pass satellite differential IFSAR (DINSAR) is required nationwide because of its ability to separate water from land areas and because repeat pass satellite DINSAR enables the accurate mapping of water elevation changes over time. Repeated acquisition of QL5 airborne IFSAR, acquired years apart, would have great difficulty correlating interferograms, whereas satellite DINSAR can more easily correlate interferograms and do so with temporal differences of a few days or weeks as satellites pass over again with precise repeat orbits.

Operational benefits (internal) for the CDC of enhanced elevation data for this functional activity

Time/Cost Savings: Moderate	Mission Compliance: Moderate	$ Benefits: Cannot quantify

- Repeat pass satellite DINSAR data enable the CDC to respond to public health emergencies pertaining to waterborne diseases with the best available 3D geospatial data needed to assess conditions that caused the emergency and (or) to respond decisively with corrective actions.
- Mosquitoes are vectors that thrive in standing water and wetlands that are best mapped with airborne or satellite IFSAR. However, repeat pass satellite DINSAR is the best way to map changes in water surface elevations, especially when the required temporal differences may be a few days or weeks rather than a few years.

Customer service benefits (external) to the public from improved CDC products and services

Performance: Moderate	Timeliness: Moderate	Experience: Moderate	$ Benefits: Cannot quantify

- The CDC partners with State, local, and (or) tribal officials that come to the CDC for help in solving local health issues pertaining to waterborne diseases. These customers are far more satisfied when they recognize that the CDC uses accurate data and advanced geospatial technologies to help solve their problems.

Other benefits from CDC use of enhanced elevation data for this functional activity

Public/Social: Major	Environmental: Major	Strategic/Political: Moderate

- Public and social benefits are major when the CDC uses DINSAR and modern technology to solve human and animal health problems that may pertain to waterborne diseases.
- Environmental benefits are major when the CDC uses DINSAR and modern technology to solve environmental health problems that impact human and (or) animal health.
- Strategic and political benefits occur when the CDC is able to assist other agencies, including global governments, to solve their problems.

Defense Installation Spatial Data Infrastructure

Point of Contact: DISDI Help Desk, *disdi.helpdesk@osd.mil*

The Defense Installation Spatial Data Infrastructure (DISDI) Program provides policy, guidance, and oversight of DOD investments in geospatial information across the installations and environment (I&E) business mission area.

To better manage global installations and bases for the U.S. Army, U.S. Navy, U.S. Air Force and Marine Corps, the DISDI Program, in concert with program managers in each service responsible for installation geospatial information and services (IGI&S), develops standards and policy to enable the sharing and interoperability of high-quality geospatial data at all levels of installation management. The focus of the DISDI initiative is to ensure that the I&E's geospatial information infrastructure is aligned with the DOD's net-centric data sharing strategies and business transformation goals. The DISDI Program focuses on implementing net-centric, geospatial information sharing by integrating geospatial efforts across the DOD. The goal is to reduce redundant information technology (IT) investments and increase the availability of quality geospatial data to any DOD mission in the basing or battle space. The DISDI Program fosters fact-based decisionmaking by centralizing and improving access to strategic visualization capabilities. Implementation of the DISDI's enterprise goals will guarantee the integration of geospatial information within the business decisionmaking process.

With input from its community of interest (Army, Marine Corps, Navy, and Air Force), the DISDI Program team identified a single, consolidated functional activity with mission-critical requirements for elevation data:

- Defense Installation Geospatial Information and Services (IGI&S), under BU#21, Infrastructure and Construction Management, as well as most of the other business uses established for the National Enhanced Elevation Assessment

The DISDI Program team provided the following assessments of elevation data requirements and benefits received from the lidar data that the DISDI community of interest identified as mission-critical. Summarized details are provided in the following pages.

Defense Installation Geospatial Information and Services

Mission-Critical Requirements

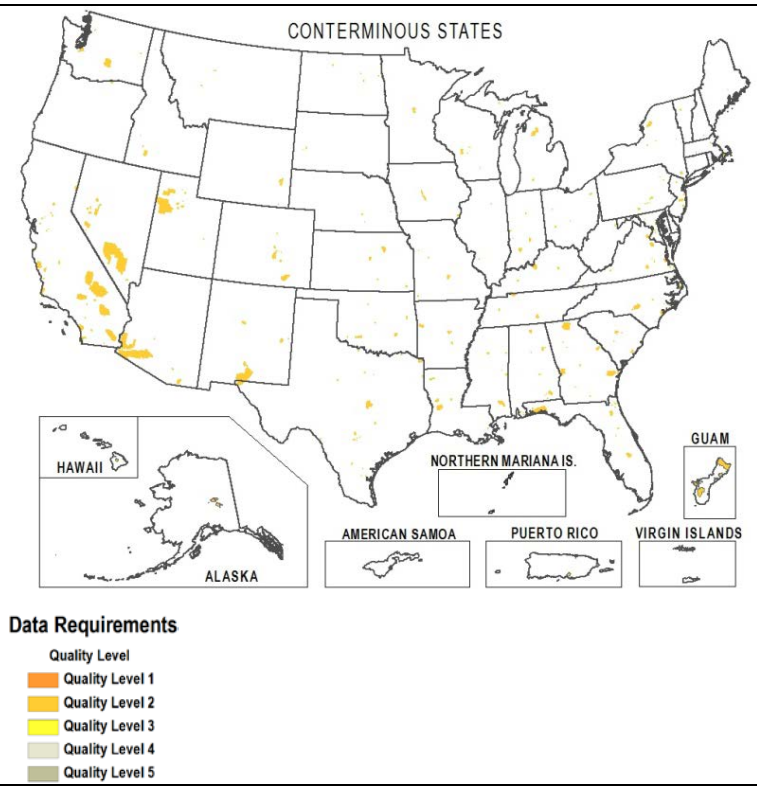
QL2 lidar of cantonment areas, and QL3 lidar of non-cantonment areas, is required for effective and efficient management of installations and the environment for 480 U.S. Department of Defense installations and sites.

Update frequency: 6–10 years.

Business Use: Infrastructure and Construction Management, BU#21.

Estimated program budget supported by elevation data: $54 billion per year.

Quantifiable Benefits of Enhanced Elevation Data: $35 million to $45 million per year



According to DISDI protocols, a mission is "geoenabled" when it leverages geospatial capabilities to help visualize and enhance data, transforming it into actionable information. Lidar data allow the military services to geoenable almost all of the business uses identified for this study:

- BU#1, Natural Resources Conservation, is geoenabled on military installations by lidar data used for minimization of soil erosion and runoff into streams and preservation of wetlands
- BU#2, Water Supply and Quality, is geoenabled on military installations by lidar data used to develop wetlands, reduce causes for water pollution, and ensure the health of aquatic ecosystems
- BU#3, River and Stream Resource Management, is geoenabled on military installations by lidar data used to ensure that rivers and streams sustain their beneficial functions
- BU#4, Coastal Zone Management, is geoenabled on coastal military installations by lidar data used to ensure that coastal zones sustain their beneficial functions
- BU#5, Forest Resources Management, is geoenabled on military installations by lidar data used to determine forest metrics and estimates for tree cutting activities and to ensure forests sustain their beneficial functions
- BU#7, Wildlife and Habitat Management, is geoenabled on military installations by lidar data used to sustain wildlife and habitat
- BU#11, Renewable Energy Resources, is geoenabled on military installations by lidar data used for assessing wind and solar energy potential
- BU#12, Oil and Gas Resources, is geoenabled on military installations by lidar data used for environmental impact assessments, pipeline routing, and construction planning
- BU#13, Cultural Resources Preservation and Management, is geoenabled on military installations by lidar data used for identification of historic human activity, historic or prehistoric artifacts or objects, or earthworks, such as battlefield entrenchments, prehistoric canals, or mounds
- BU#14, Flood Risk Management, is geoenabled on military installations by lidar data used for mitigation of flood risks, including dam, dike, and levee safety
- BU#15, Sea Level Rise and Subsidence, is geoenabled on coastal military installations by lidar data used for mitigating the effects of a projected 1-meter (m) SLR during the current century
- BU#17, Homeland Security, Law Enforcement, and Disaster Response, is geoenabled on military installations by lidar data used to promote security, minimize threats from terrorism and criminal activities, and respond to natural or manmade disasters
- BU#18, Land Navigation and Safety, is geoenabled on military installations by lidar data used to promote safe land navigation, on and off roads
- BU#19, Marine Navigation and Safety, is geoenabled on military installations by topographic and (or) bathymetric lidar used for safe navigation of coastal and riverine waterways
- BU#20, Aviation Navigation and Safety, is geoenabled on (and off) military installations by lidar data used for search, rescue, and recovery of downed aircraft and for identification of terminal procedures (TERPs) airspace obstructions in the vicinity of military airfields
- BU#21, Infrastructure and Construction Management, is geoenabled on military installations by lidar data used to support all forms of infrastructure and construction management, to include cost feasibility studies, environmental impact assessments, estimation of cut and fill requirements, storm water analysis and compliance, or other infrastructure- and construction-related activities
- BU#22, Urban and Regional Planning, is geoenabled on military installations by lidar data used to support master planning activities and environmental studies
- BU#25, Education K–12 and Beyond, is geoenabled on military installations by lidar data used for training of military personnel to understand landforms that impact military operations, line-of-sight for telecommunications and weapon systems, cross-country mobility planning, and so forth, especially when the local topography is similar to that to be encountered in a war zone and when the lidar data for the continental United States (CONUS) used for military education and training are similar to those used in military deployments; lidar and IFSAR are used in dozens of different military training simulators for virtual battlefields
- BU#27, Telecommunications, is geoenabled on military installations by lidar data used to perform viewshed analyses from military and civil telecommunications facilities

Operational benefits (internal) to the DISDI community of interest of lidar data for this functional activity

Time/Cost Savings: Major	**Mission Compliance: Major**	**$ Benefits: $35-$45 million per year**

- Most of the business uses identified for this study have major operational benefits as listed above, with major time and cost savings as well as major mission compliance benefits.

Customer service benefits (external) to the public from improved lidar products and services

Performance: Major	**Timeliness: Major**	**Experience: Major**	**$ Benefits: Unknown**

- Military and civilian personnel and tenant organizations on military installations would receive major benefits from having lidar data for the multiple business uses.

Other benefits from DOD use of lidar data for this functional activity

Public/Social: Major	**Environmental: Major**	**Strategic/Political: Major**

- Intangible benefits include improved public relations. For example, in the case of the siting of a new road, at public forums, this information could be used to demonstrate why a particular plan was selected.
- Lidar is essential for nearly all forms of environmental impact assessments and for compliance with environmental regulations and policies.
- Strategic and political benefits accrue when politicians and their constituents all recognize that DOD makes sound, science-based decisions pertaining to military installations using the best available data.
- Strategic and political benefits accrue when politicians and their constituents all recognize that DOD is cost-conscious by partnering with State and Federal agencies to acquire lidar data of broader areas at economical prices.

Note: For security reasons, DOD exercises great caution when considering public access to lidar data of military installations. For security reasons, DISDI could not separate the cantonment areas from noncantonment areas in the geodatabase used for this assessment.

U.S. Department of Energy

Point of Contact: Mark Tuttle, (865) 241–4150, tuttlema@ornl.gov

It is the overall mission of the U.S. Department of Energy (DOE) to ensure America's security and prosperity by addressing its energy, environmental, and nuclear challenges through transformative science and technology solutions.

Specific goals associated with the DOE's mission include catalyzing the timely, material, and efficient transformation of the Nation's energy system and securing U.S. leadership in clean energy technologies; maintaining a vibrant U.S. effort in science and engineering as a cornerstone of our economic prosperity and providing clear leadership in strategic areas; and enhancing nuclear security through defense, nonproliferation, and environmental efforts.

The Oak Ridge National Laboratory (ORNL), located on the DOE's Oak Ridge Reservation (ORR) in Oak Ridge, Tennessee, is one of the world's leading scientific research centers with historic competencies in energy, life sciences, neutron sciences, and advanced materials and with future research missions in the areas of national security and high-performance computing [for example, the LandScan USA program that supports the U.S. Department of Homeland Security (DHS) Homeland Security Infrastructure Protection (HSIP) database, which has 110,000 users].

Within the DOE Oak Ridge Office (ORO), the Emergency Management Team (EMT) interfaces with DOE headquarters, DOE contractors, members of State and local organizations, and others and provides emergency management planning to support the ORO response to possible emergency events, including (but not limited to) those involving adversaries, those caused by accidents, and those induced by "natural" causes, such as severe weather. The EMT manages the Oak Ridge Operations Center, as well as the Emergency Operations Center, which activates during emergency events. Specifically, the core mission of the EMT is to establish and coordinate ORR emergency management policies, programs, and guidance and implement procedures as required by DOE regulations. In carrying out its mission functions, the EMT maintains interoperational coordination with the ORR's Infrastructure and Construction Management and Site Facility Management groups.

DOE managers identified three major functional activities with mission-critical requirements for enhanced elevation data:

- Population Distributions and Dynamics, under BU#17, Homeland Security, Law Enforcement, and Disaster Response; and BU#23, Health and Human Services
- Site Facility Management, under BU#21, Infrastructure and Construction Management
- Emergency Management Program Oversight, Response, and Recovery, under BU#17, Homeland Security, Law Enforcement, and Disaster Response

DOE managers provided the following assessments of elevation data requirements and benefits received from the enhanced elevation data quality level that they identified as mission-critical or sometimes mission-critical. Summarized details are provided in the following pages.

Population Distributions and Dynamics

Mission-Critical Requirements

In support of the Department of Homeland Security, for the DOE LandScan USA extraction of building footprints, heights, and characteristics to model populations at risk for emergency response and evacuation planning and execution. QL1 lidar is required for the 133 urban areas and QL3 lidar is required for the remainder of the lower 48 States, Hawaii, and U.S. territories.

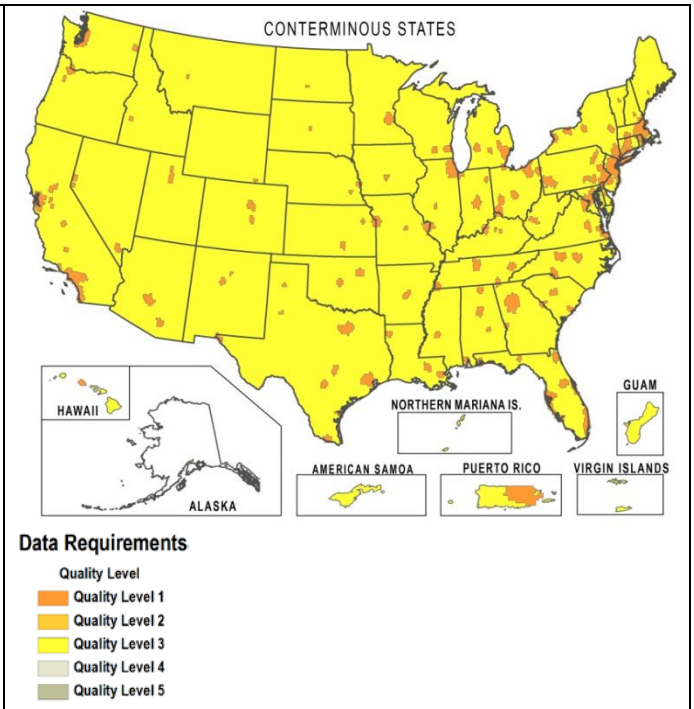
Update frequency: 4–5 years.

Business Use: Homeland Security, Law Enforcement, and Disaster Response, BU#17; and Health and Human Services, BU#23.

Estimated program budgets supported by elevation data: $2 million per year.

Quantifiable Benefits of Enhanced Elevation Data

LandScan USA would realize immediate improvements of between 50 to 70 percent in operational efficiencies at a minimum savings of $1 million per year, plus potential benefits of billions of dollars to the public in an actual national emergency.



Per agreement with the DHS, the ORNL GIS and Technology Computational Sciences and Engineering group requires high accuracy QL1 lidar data of 133 urban areas plus QL3 lidar elsewhere in the United States (except Alaska) to support LandScan USA, a DOE joint research venture with the DHS for population distributions and dynamics. This program involves the study and modeling of buildings, nighttime and daytime population distributions, and seasonal and special events distributions, as well as intercensal population growth areas nationwide—all used for emergency response and evacuation planning and execution. Specifically, high-resolution lidar data are used to extract details of buildings (building sizes, shapes, heights, volumes, and roof types) for building characterization and to model population allocations and temporal occupancies. Higher resolution lidar yields higher accuracy of models used for emergency response plans.

Operational benefits (internal) to the DOE of enhanced elevation data for this functional activity

Time/Cost Savings: Major	Mission Compliance: Major	$ Benefits: $1 million per year minimum

- With lidar, the DOE can model two cities for the price of one, enhancing the value of the HSIP.
- In cities, the DOE also uses QL1 lidar data to support its Visual-Solar Project, which aims to accurately model, catalog, and analyze solar energy resources on the Nation's rooftops. A function of the Visual-Solar Project is its ability to model building integrated photovoltaic (BIPV) resources on a city or county scale. The DOE views the ability to quantify this potential energy source as an important step in increasing the penetration of solar energy into the U.S. electrical generation portfolio. Lidar is used to create high-resolution digital surface models (DSMs), building footprints, and vegetation density products. The use of lidar is especially key in supporting efforts to quantify the impact vegetation has on BIPV potential.
- National Land Cover data are outdated and of poor quality for many areas of the Nation. The enhanced elevation data would greatly improve the spatial modeling processes used by the DOE.

Customer service benefits (external) to the public from improved DOE products and services

Performance: Major	Timeliness: Major	Experience: Major	$ Benefits: Unknown

- The LandScan USA program supports the DHS HSIP database, which has 110,000 users.

- As DOE's customer, the DHS benefits from accurate modeling of buildings and population densities for emergency response plans and actions or evacuations following an actual emergency. This includes natural emergencies from hurricanes, tornados, earthquakes, or wildfires, for example, as well as emergencies from chemical, biological or radiological hazards and (or) airborne diseases, for example, including acts of terrorism.
- Potentially, millions of Americans could benefit when accurate LandScan USA data are used for emergency response plans that are executed efficiently in times of national emergency.

Other benefits from DOE use of enhanced elevation data for this functional activity

Public/Social: Major	Environmental: None	Strategic/Political: Major

- There are major public and social benefits, as well as strategic and political benefits, when the LandScan USA project enables DHS to be fully prepared and poised to respond quickly and effectively to major emergencies that could affect large segments of our population.

Site Facility Management

Mission-Critical Requirements

Accurate and current topographic data and orthoimagery are the two most critical requirements for facilities management throughout the DOE, including multiple DOE sites in Georgia, Idaho, Illinois, Kentucky, New Mexico, Nevada, New York, South Carolina, Tennessee, and Washington. QL3 lidar data are needed for topographic mapping, evaluation of drainage, vegetation, infrastructure, and environmental management, and site cleanup and remediation.

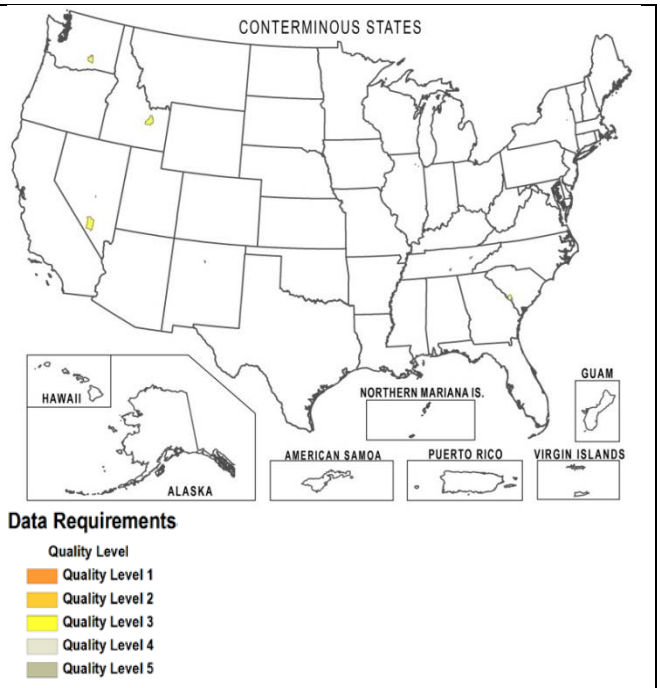
Update frequency: 4–5 years.

Business Use: Infrastructure and Construction Management, BU#21.

Estimated program budgets supported by elevation data at ORNL only: $1.6 million per year.

Quantifiable Benefits of Enhanced Elevation Data

The ORNL alone estimates efficiency improvements of 20 to 75 percent from using lidar for site facilities management at an estimated savings of $560,000 per year



The ORNL requires QL3 lidar data for site facility management and it is assumed that facility management functions at all other DOE sites have similar elevation data requirements.

Operational benefits (internal) to the DOE of enhanced elevation data for this functional activity

Time/Cost Savings: Moderate	Mission Compliance: Moderate	$ Benefits: $560,000 per year

- The ORNL indicated that topographic data are most critical; lidar avoids the need for expensive land surveys and saves considerable time otherwise lost in searching for piecemealed information from multiple sources. With one authoritative source of accurate topographic data for various applications, efficiency improvements are estimated to be between 20 percent and 75 percent.
- Based on the ORNL assessment, savings of at least 20 percent are also assumed for other DOE facilities nationwide, although the aggregated costs for site facility management throughout DOE are unknown.

Customer service benefits (external) to the public from improved DOE products and services

Performance: Unknown	**Timeliness: Unknown**	**Experience: Unknown**	**$ Benefits: Unknown**

- Unknown benefits to the public outside the ORNL.

Other benefits from DOE use of enhanced elevation data for this functional activity

Public/Social: Minor	**Environmental: Moderate**	**Strategic/Political: Minor**

- A significant area of responsibility is environmental cleanup of legacy activities, especially at the ORNL, which processes chemical and nuclear wastes. Having access to uniform and consistent elevation data of this quality and accuracy will greatly enhance the site manager's ability to manage these cleanup and remediation activities.

Emergency Management Program Oversight, Response, and Recovery

Mission-Critical Requirements

QL3 lidar data of oversight, response, and recovery (ORR) are needed for emergency management program oversight for emergency response and recovery planning between State, county, and local jurisdictions.

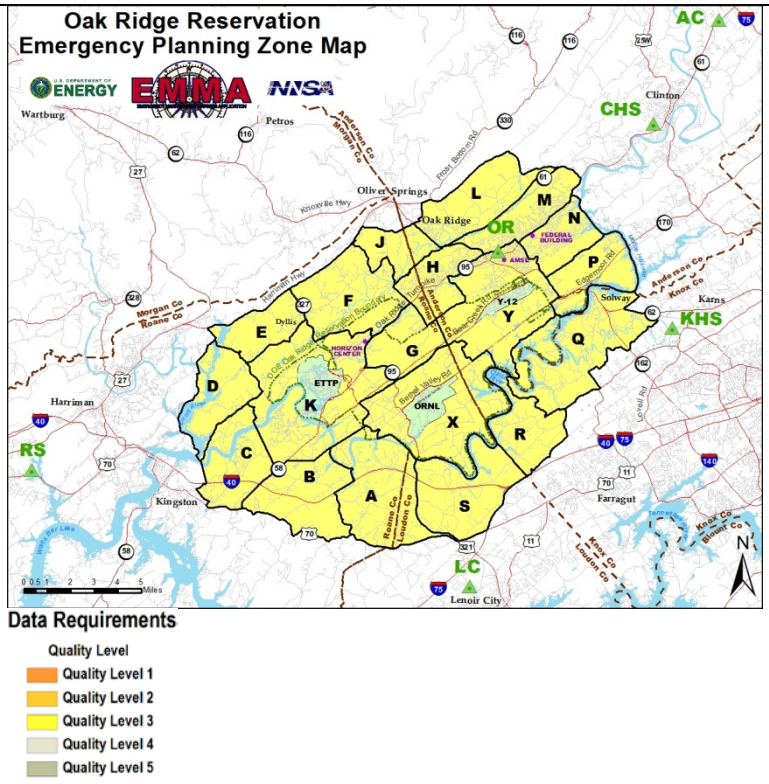
Update frequency: 4–5 years.

Business Use: Homeland Security, Law Enforcement, and Disaster Response, BU#17.

Estimated program budgets supported by elevation data: Estimated to be $5 million per year (reflects the DOE ORO Emergency Management Program).

Quantifiable Benefits of Enhanced Elevation Data

Very limited data are available to determine cost benefits.



The EMT's functional activities associated with GIS and elevation data include the management and maintenance of the ORO Emergency Management Program; coordination of oversight, response, and recovery (ORR)-level activities, such as meetings of the Emergency Management Council, Emergency Response Organization (ERO) Training Working Group, the Drill and Exercise Working Group, and the ORR GIS Working Group and quarterly meetings with the State of Tennessee Emergency Management Agency (TEMA). The EMT also manages and maintains the ORO Emergency Operations Center (EOC), the ORR Joint Information Center, the ERO Notification System, the ORR GIS Emergency Management Mapping System, and the Oak Ridge Operations Center (ORO 24-hour center).

The EMT coordinates with TEMA for administration of the emergency management portion of the Tennessee Oversight Agreement and emergency management activities with ORO and provides coordination with offsite stakeholders that include State and local emergency management officials, the Region 2 Homeland Security Council, and local emergency planning commissions.

The EMT has previously used QL4 elevation data from imagery for dispersion modeling, flood analysis, and mapping to support emergency response and recovery planning activities and to monitor and oversee contractor

activities across the ORR. These functional activities are managed using the Emergency Management Mapping Application (EMMA) program. EMMA is a mapping application that consists of map imagery on which ORR data layers, maintained by the EMT, are overlain. EMMA is used for planning and event response activities on the ORR. EMMA is used for response activities that result from construction or demolition events, malevolent or natural phenomena events, or hazardous material releases. If lidar data were available, the performance of these tasks would be better.

Lidar data are not always mission-critical in supporting the ORO's current operational functions for emergency management oversight of federally owned, contractor-managed events, but are sometimes mission critical, depending on the nature of the emergency.

Operational benefits (internal) for the DOE of enhanced elevation data for this functional activity

Time/Cost Savings: Minor	**Mission Compliance: Moderate**	**$ Benefits: Unknown**

- Additional flood analysis and mapping.
- A somewhat enhanced ability to provide site contractor emergency management program planning, preparedness, and response services using elevation data.
- Enhanced ability to serve the oversight function relative to ensuring safety at federally owned contractor-managed events.

Customer service benefits (external) to the public from improved DOE products and services

Performance: Minor	**Timeliness: Minor**	**Experience: Minor**	**$ Benefits: None**

- Safer surrounding communities.

Other benefits from DOE use of enhanced elevation data for this functional activity

Public/Social: Moderate	**Environmental: Moderate**	**Strategic/Political: Moderate**

- Elevation data in the ORR EMMA program will provide the ERO cadre with an enhanced level of 3D data that would enable a more complete oversight of site and contractor planning, preparedness, and response services, yielding public and social, environmental, and strategic and political benefits for the community.

Department of Homeland Security

Point of Contact: Chris Barnard, (202) 447-3728, robert.barnard@associates.dhs.gov

The Department of Homeland Security (DHS) leverages resources within Federal, State, and local governments, coordinating the transition of multiple agencies and programs into a single, integrated agency focused on protecting the American people and their homeland. More than 87,000 different governmental jurisdictions at the Federal, State, and local level have homeland security responsibilities. The comprehensive national strategy seeks to develop a complementary system connecting all levels of government without duplicating effort.

The following DHS agencies and offices have mission-critical requirements for enhanced elevation data:

- The DHS Office of Infrastructure Protection (IP) leads the coordinated national program to reduce and mitigate risk within the 18 national critical infrastructure sectors from acts of terrorism and natural disasters and to strengthen the ability of the sectors to respond and quickly recover from an attack or other emergency. IP serves as the sector-specific agency (SSA) for 6 of the 18 critical infrastructure sectors—chemical, commercial facilities, critical manufacturing, dams, emergency services, and nuclear reactors, materials, and waste. Other DHS offices serve as SSAs for information technology, communications, government facilities, transportation systems, and postal and shipping sectors. Additional non-DHS sectors coordinated by DHS include agriculture and food (U.S. Department of Agriculture), banking and finance (Treasury), defense industrial base (DOD), energy (DOE), national monuments and icons (U.S. Department of the Interior (DOI)), healthcare and public health (Department of Health and Human Services), and water (U.S. Environmental Protection Agency (EPA)).
- U.S. Customs and Border Protection (CBP) has a priority mission of keeping terrorists and their weapons out of the United States.
- The U.S. Coast Guard (USCG) protects the maritime economy and the environment, defends our maritime borders, and saves those in peril.
- The U.S. Secret Service (USSS) safeguards the Nation's financial infrastructure and payment systems to preserve the integrity of the economy and protects national leaders, visiting heads of state and government, designated sites, and national special security events.
- FEMA builds and supports the Nation's emergency management system. FEMA's enhanced elevation data requirements and benefits are documented separately.

In addition to FEMA requirements, the DHS managers identified four major functional activities with mission-critical requirements for elevation data:

- Infrastructure Protection, under BU#17, Homeland Security, Law Enforcement, and Disaster Response
- Border Protection, under BU#17, Homeland Security, Law Enforcement, and Disaster Response
- Coastal Search and Rescue, under BU#17, Homeland Security, Law Enforcement, and Disaster Response, and BU#19, Marine Navigation and Safety
- Special Security Events, under BU#17, Homeland Security, Law Enforcement, and Disaster Response

DHS managers provided the following assessments of elevation data requirements and benefits received from the enhanced elevation data quality level that they identified as mission-critical. Summarized details are provided in the following pages.

Infrastructure Protection

Mission-Critical Requirements

The DHS Office of IP requires QL3 lidar for 49 States and U.S. territories and small areas of Alaska and QL1 lidar for the Atlantic, Pacific, and Gulf coasts for maritime awareness and security as well as infrastructure 3D modeling, simulation, and analyses.

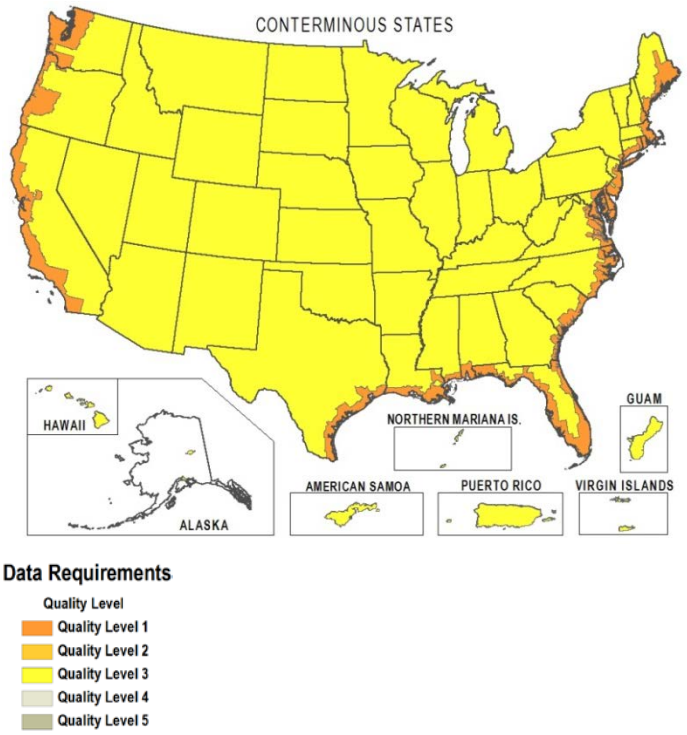
Update frequency: 6–10 years.

Business Use: Homeland Security, Law Enforcement, and Disaster Response, BU#17.

Estimated program budget: Not available.

Quantifiable Benefits of Enhanced Elevation Data

No credible cost savings can be placed on the dollar value of infrastructure protected from acts of terrorism or natural disasters.



The DHS Office of IP has divisions responsible for infrastructure information collection; infrastructure analysis and strategy; protective security coordination; contingency planning and incident management; infrastructure security compliance; and partnerships and outreach. To execute their missions, these divisions rely on enhanced elevation data for 3D modeling, simulation, and analyses, both before and after events.

Operational benefits (internal) to the DHS of enhanced elevation data for this functional activity

Time/Cost Savings: Major	Mission Compliance: Major	$ Benefits: Cannot determine

- Enhanced elevation data provide rapid and improved vulnerability assessments for critical infrastructure, including models for vulnerabilities based on tsunami and hurricane tidal surges, explosive blasts, aerosol spread, chemical spills, and viewshed as well as identification of surveillance points.
- Higher accuracy and resolution digital elevation data make all vulnerability models more accurate and effective in fulfilling their design purposes and allows automated analyses of thousands of "what-if" scenarios for critical infrastructure protection. This is necessary for DHS mission compliance.
- Having authoritative 3D data immediately available saves considerable time in searching for the best available data, which may otherwise be missing, inconsistent, or of questionable quality.

Customer service benefits (external) to private and public partners from improved DHS products and services

Performance: Major	Timeliness: Major	Experience: Major	$ Benefits: Unknown

- DHS 3D models, used for simulation and analysis of risks to critical infrastructure, depend upon accurate and current elevation data. The performance of two-dimensional (2D) models is not nearly as effective as that of 3D models that include the DTM of the bare Earth terrain and the DSM of top surfaces of trees and buildings. DSMs are needed for viewshed and line-of-sight analyses and aerosol spread models, whereas DTMs are needed for analysis of chemical spills, floods, and hurricane tidal surges.

- Immediately following an actual event, the availability of accurate pre-event 3D models is invaluable for rapid damage analysis, response, and recovery, when compared with post-event data. Whenever time is of the essence, the availability of accurate 3D models saves lives and property.

Other benefits from DHS use of enhanced elevation data for this functional activity

Public/Social: Major	Environmental: Minor	Strategic/Political: Major

- National enhanced elevation data give the DHS the ability to be proactive in using 3D models to assess vulnerabilities of critical infrastructure, to mitigate risks from terrorism or natural disasters, and to respond rapidly in times of emergency. Although dollar benefits cannot be quantified, this has tremendous public and social value as well as strategic and political value.
- Americans consistently list homeland security as their highest priority goal. Dollars spent on mitigation of risks from terrorism or natural disasters have a high return on investment, but this return cannot be quantified (pre-event) in terms of damages avoided.

Border Protection

Mission-Critical Requirements

The CBP requires QL3 lidar for a 40-mile-wide buffer along the U.S. borders with Canada and Mexico for siting and placement of towers and sensors and to support human patrols and drones.

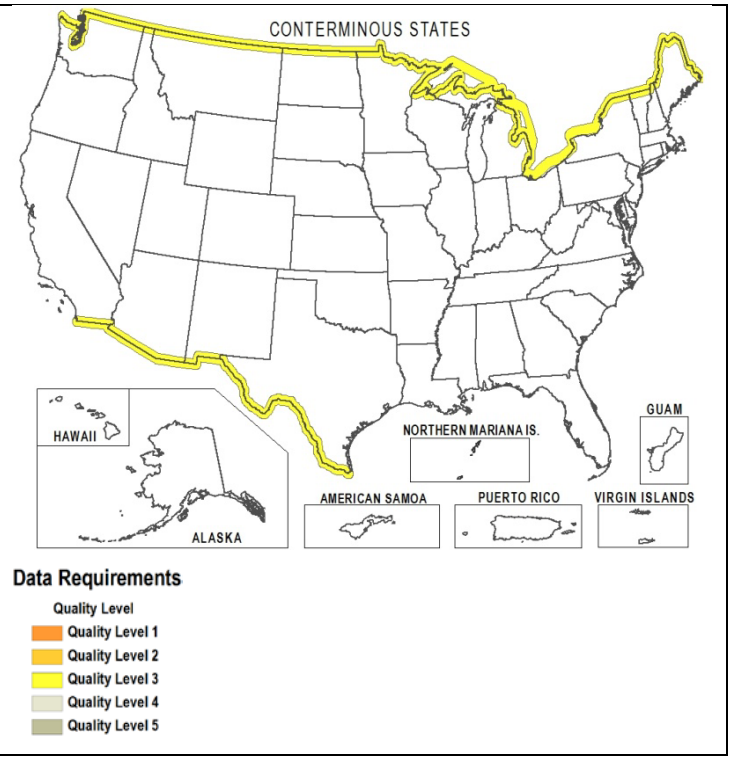
Update frequency: >10 years.

Business Use: Homeland Security, Law Enforcement, and Disaster Response, BU#17.

Estimated program budget: Unknown.

Quantifiable Benefits of Enhanced Elevation Data

Cost savings due to improved siting and placement of sensors cannot be estimated



The CBP previously had the Secure Border Initiative (SBInet) virtual fence designed to detect, track, and apprehend illegal aliens. After spending $1 billion on the SBInet for 53 miles in Arizona, the project was cancelled in favor of human patrols and drones, stating that the project cost too much and was not achieving enough. The CBP would have been able to avoid duplicative procurements, which would have resulted in considerable cost avoidance, if they had had access to lidar data for improved siting and placement of SBInet towers and sensors. Today, savings from lidar would support human patrols and drones, but cost savings cannot be estimated.

Operational benefits (internal) to the CBP of enhanced elevation data for this functional activity

Time/Cost Savings: Moderate	Mission Compliance: Moderate	$ Benefits: Unknown

- With QL3 lidar, the CBP would be able to determine where sensors should be placed for optimum effect and where human patrols could physically observe border intrusions with infrared sensors and night-vision goggles, for example. The safety of border patrol agents would also be improved.

- Better understanding of vulnerabilities leads to better deployment of field agents, and better understanding of terrain helps to locate sensor systems; these combined efforts lead to increased interdictions and seizures.
- Search and rescue operations would also benefit from enhanced terrain data, allowing rescue teams to better understand the terrain before and during missions and potentially saving lives.

Customer service benefits (external) to the public from improved CBP products and services

Performance: Moderate	**Timeliness: Minor**	**Experience: Moderate**	**$ Benefits: Unknown**

- Enhanced elevation data would improve border security for border area residents and the American public at large.

Other benefits from CBP use of enhanced elevation data for this functional activity

Public/Social: Moderate	**Environmental: None**	**Strategic/Political: Moderate**

- Socially and politically, the public will be better served when enhanced elevation data are available to provide a cost-effective way to use terrain knowledge to maximum effect in border security.
- Enhanced elevation data would improve public perception of government actions to address the issues of illegal immigration and smuggling.

Coastal Search and Rescue

Mission-Critical Requirements

QL3 lidar is required by the USCG for the *Rescue 21* advanced command, control, and communications system to triangulate the position of vessels in distress and determine their location and to better model radio reception for the *Rescue 21* program.

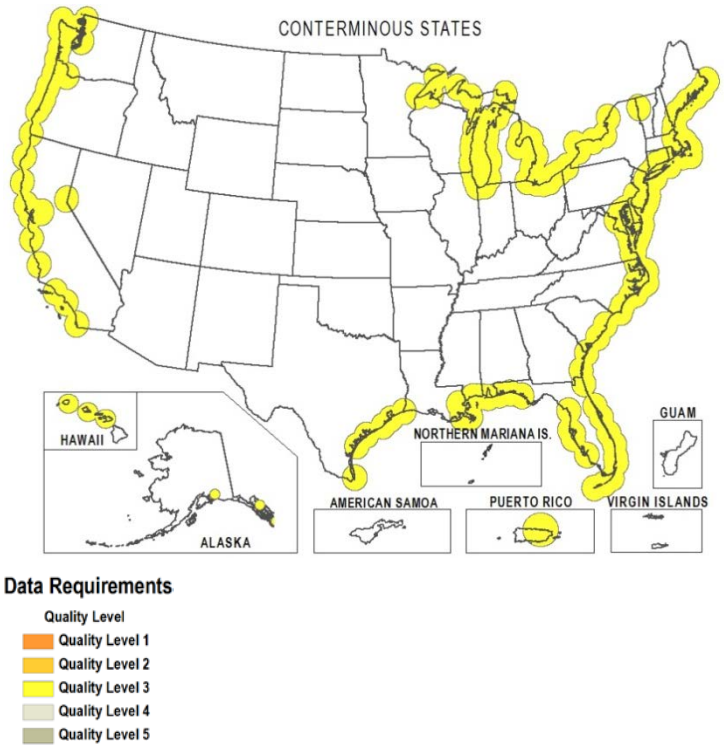
Update frequency: >10 years.

Business Use: Homeland Security, Law Enforcement, and Disaster Response, BU#17.

Estimated Program Budget: Not available.

Quantifiable Benefits of Enhanced Elevation Data

Cannot estimate dollar benefits of an improved Search and Rescue system, or *Rescue 21's* improved benefits from lidar data



Using its National Distress and Response System (NDRS), the USCG saves nearly 5,000 lives annually, but the NDRS has many limitations. The new NDRS Modernization Project (*Rescue 21*) has improved the ability to assist mariners in distress. *Rescue 21* uses digital elevation data of near shore topography and direction-finding radios and communication towers along coastal areas to triangulate the position of a vessel in distress and determine its location with accurate range and bearing from communication towers.

Operational benefits (internal) to the USCG of enhanced elevation data for this functional activity

Time/Cost Savings: Major	Mission Compliance: Moderate	$ Benefits: Cannot determine

- By rapidly determining the location of mariners in distress, the USCG will experience significant (and often critical) time savings in deploying rescue vessels or aircraft to distress locations.

Customer service benefits (external) from improved USCG products and services

Performance: Moderate	Timeliness: Major	Experience: Moderate	$ Benefits: Unknown

- *Rescue 21* will save additional lives and property at sea by taking the "search" out of search and rescue; but cost savings due to elevation data cannot be determined.

Other benefits from USCG use of enhanced elevation data for this functional activity

Public/Social: Major	Environmental: None	Strategic/Political: Major

- *Rescue 21* will provide the Nation with a 21st century maritime command, control, and communications (C3) system that encompasses the United States. By replacing outdated technology with a fully integrated C3 system that improves interoperability, *Rescue 21* will protect mariners while helping defend the Nation's coasts.

Special Security Events

Mission-Critical Requirements

QL2 lidar of the primary 133 urban areas of the United Sates is required by the USSS for 3D modeling, viewshed analyses, and placement of surveillance equipment and (or) agents.

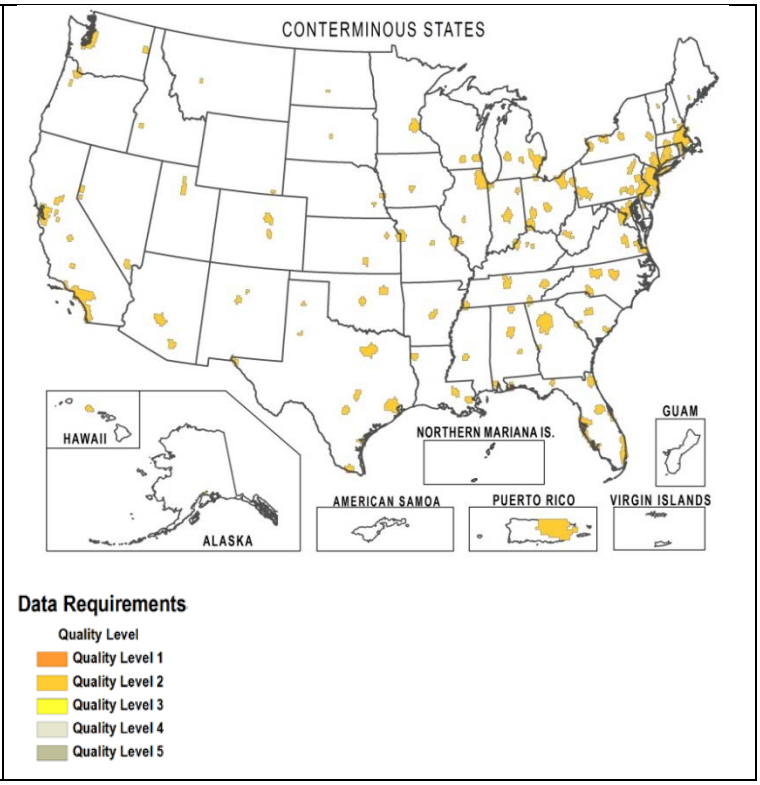
Update frequency: Annually.

Business Use: Homeland Security, Law Enforcement, and Disaster Response, BU#17.

Estimated Program Budget: Not available.

Quantifiable Benefits of Enhanced Elevation Data

Cannot estimate dollar benefits of successful USSS operations, or the increased benefits of elevation data



The U.S. Secret Service (USSS) protects national leaders, visiting heads of state and government, designated sites, and at national special security events. Whether performing investigative operations or protective operations, the USSS needs rapid access to accurate, current, and consistent elevation data of the physical environment. Elevation data are used for 3D modeling, viewshed analyses, and placement of surveillance equipment and (or) agents without revealing unpublicized, sensitive areas by deploying agents on the ground before the arrival of national leaders or visiting heads of state and government.

Operational benefits (internal) to the USSS of enhanced elevation data for this functional activity

Time/Cost Savings: Major	Mission Compliance: Major	$ Benefits: Cannot determine

- Accurate and current elevation data are required to determine, from an office environment, where to place surveillance devices that will not be blocked by unexpected berms, buildings or trees, and (or) where to place USSS agents. The USSS can perform its mission most effectively when it is not surprised by an actual physical environment that is changed from the expected physical environment.
- Nationwide, consistent datasets would reduce the time spent finding, validating, and manipulating data from disparate sources.

Customer service benefits (external) from improved USSS products and services

Performance: Major	Timeliness: Major	Experience: Major	$ Benefits: Unknown

- The American public is best served when the USSS succeeds 100 percent of the time in its mission.

Other benefits from USSS use of enhanced elevation data for this functional activity

Public/Social: Major	Environmental: None	Strategic/Political: Major

- Public and political benefits are high when the USSS consistently protects national leaders, visiting heads of state and government, designated sites, and national special security events.

Environmental Protection Agency

Point of Contact: Jerry Johnston, jerry_johnston@ios.doi.gov

The mission of EPA is to protect human life and the environment.

The EPA's purpose is to ensure that:

- All Americans are protected from significant risks to human health and the environment where they live, learn, and work.
- National efforts to reduce environmental risk are based on the best available scientific information.
- Federal laws protecting human health and the environment are enforced fairly and effectively.
- Environmental protection is an integral consideration in U.S. policies concerning natural resources, human health, economic growth, energy, transportation, agriculture, industry, and international trade and these factors are similarly considered in establishing environmental policy.
- All parts of society—communities, individuals, businesses, and State, local, and tribal governments—have access to accurate information sufficient to effectively participate in managing human health and environmental risks.
- Making our communities and ecosystems diverse, sustainable, and economically productive.
- Lead in working with other Nations to protect the global environment.

The EPA's annual plan for fiscal year 2012 identifies five major goals and budget requirements.

No.	Goal description [mission-critical requirements for enhanced elevation data]
1	Take action on climate change, improve air quality, and develop adaptation strategies to address climate change. [For this goal, accurate elevation data are mission-critical for assessing potential impacts of sea level rise.]
2	Protect and restore our waters to ensure that drinking water is safe and that aquatic ecosystems sustain fish, plants, wildlife, and economic, recreational, and subsistence activities. [For this goal, accurate elevation data are mission-critical for land cover characterization, hydrologic modeling, and runoff modeling used in decision support tools for diverse EPA activities, including protection of the Nation's critical water infrastructure from terrorist threats.]
3	Clean up communities, advance sustainable development, and protect disproportionately impacted low-income, minority, and tribal communities; prevent releases of harmful substances and clean up and restore contaminated areas. [For this goal, accurate elevation data are mission-critical for decision support tools for assessment and cleanup of Brownfields and other contaminated lands and for emergency preparedness and response activities.]
4	Ensure the safety of chemicals, prevent pollution, reduce the risk and increase the safety of chemicals, and prevent pollution at the source. [Accurate elevation data are mission-critical for modeling the spread of point-source and non-point-source pollution.]
5	Enforce environmental laws; protect human health and the environment through vigorous and targeted civil and criminal enforcement. [Accurate elevation data are mission-critical for targeted sites.]

The EPA managers identified three major functional activities with mission-critical requirements for elevation data:

- Sea Level Rise (SLR) Vulnerability Assessments, under BU#15, Sea Level Rise and Subsidence
- Environmental Protection, Land Cover Characterization, and Runoff Modeling, under both BU#1, Natural Resources Conservation, and BU#2, Water Supply and Quality
- Broad Area Air and Water Quality Research, under BU#2, Water Supply and Quality, and BU#23, Health and Human Services

EPA managers provided the following assessments of elevation data requirements and benefits received from the enhanced elevation data quality level that they identified as mission-critical. Summarized details are provided in the following pages.

Sea Level Rise Vulnerability Assessments

Mission-Critical Requirements

High accuracy QL2 lidar datasets are mission-critical for spatially explicit vulnerability maps and estimates of populations, land cover types, infrastructure and economic activity affected by sea level rise (SLR), and steps taken to mitigate these vulnerabilities.

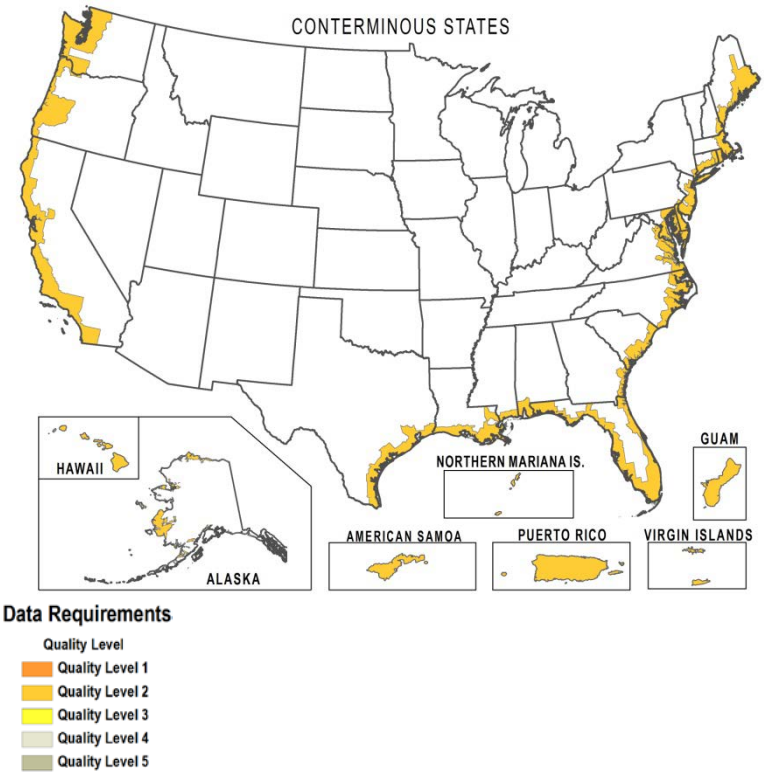
Update frequency: 6–10 years.

Business Use: Sea Level Rise and Subsidence, BU#15.

Estimated program budget supported by elevation data: $280 million per year.

Quantifiable Benefits of Enhanced Elevation Data

Estimated financial benefits to EPA, $5.6 million per year; coastal communities stand to save millions to billions of dollars per year by taking proactive steps to mitigate SLR and by informed siting of drinking water, waste water, and other infrastructure facilities



In an articles entitled "lidar is essential for determining which lands are currently at elevations that would be inundated by rising tide levels due to SLR and for determining what populations, economic activities, infrastructure, and total property values will be subject to inundation without additional shoreline protection (Gesch, 2009)."In regions that will have a simple inundation response to rising seas, elevation is the most important factor in assessing potential impacts—especially if the potential inundation area is used as a mask to generate estimates of affected populations, land cover types, infrastructure, or economic activity." lidar QL2 data are accurate to 0.6 foot [ft; 18.2 centimeters (cm)] at the 95 percent confidence level. Less-accurate elevation data in the NED estimated 457,799 people would be impacted in a defined study area in North Carolina compared with 102,503 people impacted when accurate lidar data were used. Environmental impact assessments (EIAs) that affect entire populations should not be based on inaccurate elevation data with high levels of uncertainty that cause undue alarm and overreaction.

Operational benefits (internal) to the EPA of enhanced elevation data for this functional activity

Time/Cost Savings: Major	Mission Compliance: Major	$ Benefits: $5.6 million per year

- The EPA's EIAs depend upon accurate elevation data for vulnerability mapping and estimates of SLR threats to human populations, infrastructure, and the natural environment, including coastal wetlands, marshes, and subaquatic vegetation that affect the fish and shellfish industries. Credible EIAs cannot be performed without accurate lidar data.
- In support of EPA goal no. 1, if the EPA's science and technology programs were funded at the $280 million per year level, a 2 percent improvement in efficiency and (or) effectiveness by using lidar QL2 data identified as mission-critical, the annual cost benefit to EPA would be $5.6 million.

Customer service benefits (external) to the public from improved EPA products and services

Performance: Major	Timeliness: Major	Experience: Major	$ Benefits: Billions

- High-accuracy and redistributable elevation data are mission-critical to other Federal, State, and local governments responsible for climate change policy, planning, and response to predicted SLR.

- The populations, economic activities, infrastructure, and total property values subject to inundation are at the local level where steps will need to be taken to protect shorelines and infrastructure subject to future inundation from SLR. Certainly, future construction of drinking water, stormwater, sewer, and sanitary facilities, and other public infrastructure projects must be based on accurate estimates of SLR.
- In 2009, the governor of California asked for lidar mapping of all California coastlines so that the State could analyze risks from SLR and develop plans to mitigate SLR losses assumed to be in the billions of dollars for California alone.
- Cost benefits are imprecise but estimates are that billions of dollars would be saved by State and local communities and citizens from having accurate elevation data on which to base their SLR mitigation activities.

Other benefits from EPA use of enhanced elevation data for this functional activity

Public/Social: Major	Environmental: Major	Strategic/Political: Moderate

- The public will benefit socially, environmentally, and strategically from increased public safety and planned infrastructure development that avoids risks of floods or inundation from the future, predictable effects of SLR.

Reference Cited.

Gesch, D.B., 2009, Analysis of lidar elevation data for improved identification of lands vulnerable to sea-level rise: Journal of Coastal Research special issue no. 53, p. 48–58.

Environmental Protection, Land Cover Characterization, and Runoff Modeling

Mission-Critical Requirements

High accuracy QL2 lidar datasets are mission-critical for the EPA to understand urban area modeling, to understand characteristics and hydrodynamics of streams and estuaries, and to make decisions on how to protect and (or) restore the air we breathe, the water we drink, and (or) the environment that sustains us. QL5 IFSAR data are required for Alaska.

Update frequency: 4–5 years.

Business Use: Natural Resources Conservation, BU#1 and Water Supply and Quality, BU#2.

Estimated program budget supported by elevation data: $544 million per year.

Quantifiable Benefits of Enhanced Elevation Data

Estimated financial benefits to the EPA, $10.9 million per year; benefits to States and local communities difficult to quantify, but likely to be millions of dollars per year (assumed to be $2 million per year).

Combined with multispectral imagery, high-accuracy lidar, slope, and aspect data are mission-critical for urban area modeling (relevant to Clean Water Act and Clean Air Act activities), land use and land cover (LULC) mapping, land cover characterization, and runoff modeling.

Hydrologic modeling relies heavily upon lidar data for: definition of watersheds, catchment areas, wetlands, and swamps; nutrient loading from farm runoff and industrial point source and nonpoint source pollution; and wellhead protection (proactive management of land to assess and mitigate potential risks posed to well water quality).

Is water safe for drinking and swimming? Are fish and shellfish safe to eat? High-accuracy elevation datasets are mission-critical for improving water quality on a watershed basis, for managing the benefits of wetlands, and for improving the health of the Great Lakes, the Chesapeake Bay ecosystem, the Gulf of Mexico, Long Island Sound, and Puget Sound—all considered to be high priority by the EPA.

Operational benefits (internal) to the EPA of enhanced elevation data for this functional activity

Time/Cost Savings: Major	Mission Compliance: Major	$ Benefits: $10.9 million per year

- In support of EPA Goals No. 2, 3, 4 and 5, if EPA science and technology programs, budgeted at $544 million per year, experienced a 2 percent improvement in efficiency and (or) effectiveness for EPA by using lidar QL2 data identified as mission-critical, the annual cost benefit to EPA would be $10.9M.
- For environmental assessments, EPA needs high-accuracy, high-resolution topographic data to characterize the landscape for both environmental protection and assessment of ecosystem services. Currently, the data are available piecemeal in patches around the country. Nationwide QL2 lidar is mission-critical to provide an accurate and consistent approach across States for definition and mapping of designated use zones for application of water quality criteria and more-cost effective derivation of nutrient criteria, for example. EPA would not need to perform extensive research to identify the best available datasets, but would know where to go to obtain the most accurate and credible source of elevation data used in diverse environmental models.

Customer service benefits (external) to the public from improved EPA products and services

Performance: Minor	Timeliness: Major	Experience: Major	$ Benefits: $2 million per year

- Nationwide QL2 lidar is also mission-critical for providing States and local communities with an accurate and consistent approach across States for definition and mapping of designated use zones for application of water quality criteria and more cost effective derivation of nutrient criteria, for example.
- States receive grants from the EPA and receive credit for best management practices (BMPs). States and local partners currently perform sampling of small areas only; each sample survey entails expensive surveys of vegetation locations and conditions, for example, recording data on field sheets. Then, actions are taken to extrapolate sampled data to pertain to broad areas.
- High-accuracy lidar data would enable science-based assessments to be made much more efficiently and credibly over broad areas, benefiting from decision support tools and data periodically updated.
- The EPA estimates that financial benefits to the States and local communities will be on the order of millions of dollars per year (assumed $2 million per year for the benefit and cost analysis).

Other benefits from EPA use of enhanced elevation data for this functional activity

Public/Social: Major	Environmental: Major	Strategic/Political: Major

- Lidar significantly reduces uncertainty in all environmental assessments, improves public confidence in EPA's assessments, and enables appropriate steps to be taken to protect and (or) restore the environment.
- National coverage of QL2 lidar will permit greatly expanded geographic coverage of EPA science, generating new public, social, environmental, and political benefits.

Broad Area Air and Water Quality Research

Mission-Critical Requirements

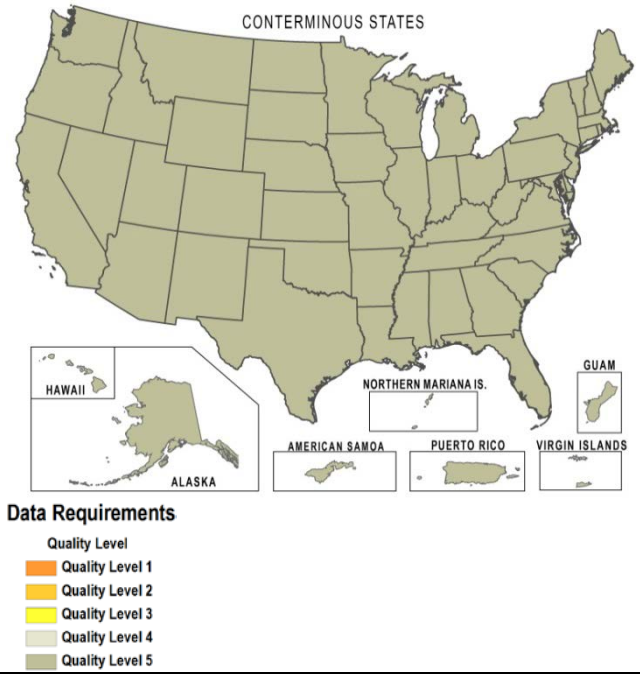
Mid-accuracy QL5 IFSAR DEMs are mission-critical for the EPA's broad area research projects pertaining to air and water quality, health, and human services.

Update frequency: 6–10 years.

Business Use: Water Supply and Quality, BU#2 and Health and Human Services, BU#23.

Estimated Program Budget supported by elevation data: $2.8 million per year (President's budget for FY12).

Quantifiable Benefits of Enhanced Elevation Data: $280,000 per year.



In addition to environmental assessments that require high-accuracy and high-resolution lidar data, the EPA also performs research and environmental assessments of broad areas that require consistent, nationwide coverage of mid-accuracy elevation data that can be generated from platforms such as airborne IFSAR.

Operational benefits (internal) to the EPA of enhanced elevation data for this functional activity

Time/Cost Savings: Minor	**Mission Compliance: Moderate**	**$ Benefits: $280,000 per year**

- Airborne IFSAR data for DTMs and DSMs improve the accuracy of EPA models for air and water quality research, without requirements to store and process large lidar datasets.
- Because the elevation data are mission critical, the value of the IFSAR data was estimated to be 10 percent of the annual budget for air and water quality research.

Customer service benefits (external) from improved EPA products and services

Performance: Moderate	**Timeliness: Minor**	**Experience: Moderate**	**$ Benefits: Unknown**

- With nationwide IFSAR data, the National Geospatial Program (NGP) will be able to better meet the diverse mission needs of EPA customers across the agency.

Other benefits from EPA use of enhanced elevation data for this functional activity

Public/Social: Minor	**Environmental: Major**	**Strategic/Political: Minor**

- Improved air and water quality research for environmental protection.

Federal Aviation Administration

Point of Contact: Joseph (Jay) Jackson, (301) 427-512, Joseph.A.Jackson@faa.gov

The mission of the Federal Aviation Administration (FAA) is to provide the safest, most efficient airspace system in the world. The FAA provides a safe, secure, and efficient global airspace system that contributes to the promotion of U.S. airspace safety and national security. As the leading authority in the international airspace community, FAA is responsive to the dynamic nature of stakeholder needs, economic conditions, and environmental concerns.

The "FAA Flight Plan" is the strategic plan for the agency, including goals and objectives. The plan states that the" goal is to ensure the success of the FAA's mission through stronger leadership, better-trained and safer workforce, enhanced cost-control measures, and improved decisionmaking based on reliable data." Among many different types of data, reliable data include accurate and reliable real-time geopositioning of aircraft, accurate mapping of terrain features to maintain minimum safe altitudes, and high-accuracy, high-density mapping of terrain, buildings, towers, trees, and other potential obstacles for terminal instrument procedures, especially when flying under instrument flight rules during adverse weather conditions.

Two major safety objectives are to reduce commercial air carrier fatalities and to reduce general aviation fatalities. Reductions of general aviation accidents in Alaska are specifically mentioned in the plan to minimize controlled flight into terrain (CFIT) accidents when failures occur and backup safeguards are inadequate, resulting in pilots flying their aircraft into situations where they are not aware of their surroundings. Accurate onboard digital terrain information is seen as vital for avoidance of CFIT accidents.

The "FAA Flight Plan" describes the Next Generation Air Transportation System (NextGen) as an overhaul of America's air traffic control system. FAA managers identified two major functional activities with mission-critical requirements for enhanced elevation data:

- Terminal Instrument Procedure Development, under BU#20, Aviation Navigation and Safety
- Enroute Instrument Procedure Development, under BU#20, Aviation Navigation and Safety

FAA managers provided the following assessments of elevation data requirements and benefits received from the enhanced elevation data quality level that they identified as mission-critical. Summarized details are provided in the following pages.

Terminal Instrument Procedure Development

Mission-Critical Requirements

QL1 lidar data are required of airfield terminal areas for development of aviation instrument approach and departure procedures, including hardcopy and digital visual flight rule (VFR) and instrument flight rule (IFR) charts, for safe navigation around or above obstacles near airfields.

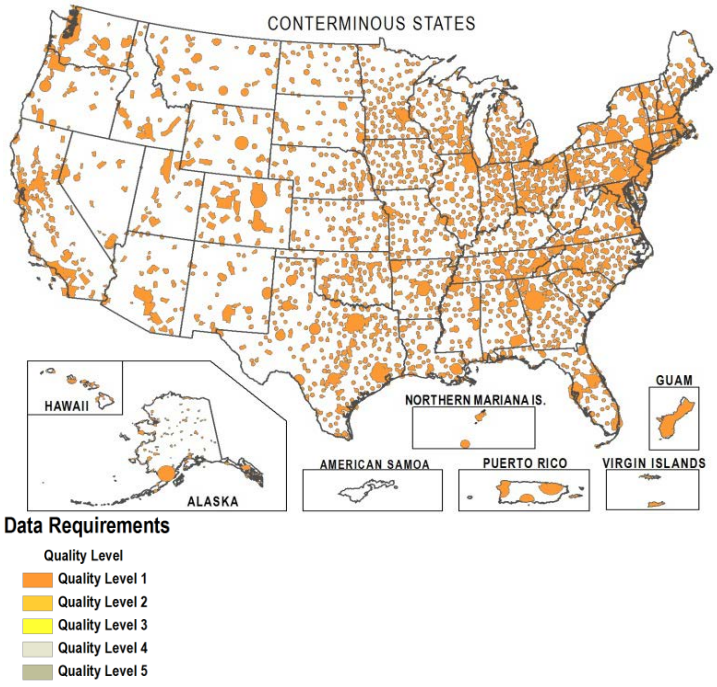
Update frequency: 4–5 years.

Business Use: Aviation Navigation and Safety, BU#20.

Estimated program budgets supported by elevation data: $729 million per year for mission support services.

Quantifiable Benefits of Enhanced Elevation Data.

The FAA and the aviation community would save an estimated $22 million per year by using lidar for this purpose. Commercial and general aviation would have superior TERPs and would presumably fly safer routes.



The FAA develops and maintains approach and departure procedures for more than 4,100 airfields in the United States and its territories. It is most important for the FAA to know the elevations of the bare Earth terrain and secondarily to know the elevations of any features above the bare Earth in defined areas of terminal air space. The FAA maintains an interagency agreement with the National Geodetic Survey (NGS) to survey and validate third party surveys of potential obstacles along sloped parallelograms extending outward from the ends of runways, with lesser accuracy required beyond 5 miles of the runways. The FAA strives to ensure that growing trees and new manmade structures (for example, buildings, towers) do not encroach upon flight paths within specified tolerance levels. The FAA needs high-accuracy, high-density elevation data to reduce requirements for expensive ground surveys for assessing obstacle clearance around airfields and designing aviation instrument approach and departure procedures which allow aircraft to safely navigate around or above obstacles. The FAA uses such elevation data for production of analog and digital visual flight rule (VFR), enroute, and instrument flight rule (IFR) aviation charts.

Operational benefits (internal) to the FAA of enhanced elevation data for this functional activity

Time/Cost Savings: Major	Mission Compliance: Major	$ Benefits: $12 million per year

- With QL1 lidar, the FAA would experience major database improvements. Such data would allow the obstacle database to become Electronic Terrain and Obstacle Database (eTOD)-compliant.
- A lot of time is currently spent verifying locations and vertical accuracies of obstacles, airport environments, and minimum safe altitude warning (MSAW) sites; having a single, complete, and standardized DEM would greatly reduce the time spent verifying discrepancies or lack of data. For each airfield, with a single accurate and authoritative source of elevation data, FAA aeronautical information specialists would save a majority of their time now spent researching multiple data sources to identify and update information for aeronautical charts and digital datasets listed above. One manager stated that "the efficiency gains from time spent looking for sources of data coverage would be major." An estimate could be translated into annual cost savings of $4 million per year.
- If QL1 lidar, with 8 data points per square meter, can be demonstrated to consistently identify and map vertical obstacles currently identified and mapped by NGS land surveyors with theodolites and Global Positioning System (GPS) receivers, then an estimated $5 million per year could be saved from costs currently spent for land surveys of potential obstacles.

- A national lidar elevation dataset will help minimize potential impacts of the current four-dimensional (4D) site elevations on IFR arrival and departure procedures during obstruction evaluation (OE) aeronautical studies. The OE aeronautical study processes and the severity of any IFR effects may be eliminated or reduced with more accurate site elevations (estimated savings of $3 million per year).

Customer service benefits (external) to the public from improved FAA products and services

Performance: Major	Timeliness: Major	Experience: Major	$ Benefits: $10 million per year

- Stakeholders of FAA products and services include: air carriers; airport authorities; shippers; foreign, State, and local governments; aerospace manufacturers; military aviation; commercial space launch companies; and others such as the national Transportation Safety Board (NTSB), the Office of Management and Budget, and Congress.
- The FAA's eCommerce representative determined that the number of downloads from an FAA Web site where pilots or others download aviation products that rely on elevation data to be 60,000 per week.
- When available, QL1 lidar data for terminal air space will provide major benefits for all stakeholders, especially air traffic controllers and airport operators who serve these stakeholders (estimated benefit $3 million per year).
- Increased vertical and horizontal accuracy of aeronautical products results in improved IFR instrument approach procedures, lower minimum vectoring altitudes in both the terminal and low enroute environments, and increases the number of GPS-derived terminal approach procedures, improving operational efficiencies and reducing aviation fuel consumption by commercial and military aviation (estimated benefit $4 million per year).
- Savings for airport owners who currently procure elevation data from consulting contractors; major time and cost savings for airport design and obstruction analysis (estimated benefit $3 million per year).

Other benefits from FAA use of enhanced elevation data for this functional activity

Public/Social: Major	Environmental: Major	Strategic/Political: Major

- Safer flights improve public safety and promote strategic and political goals.
- Continuous descent profiles increase fuel efficiency and lower aircraft noise footprints.

Enroute Instrument Procedure Development

Mission-Critical Requirements

Nationwide QL5 IFSAR is required to meet DEM accuracy requirements called for in International Civil Aviation Organization (ICAO) annex 15 for area 2.

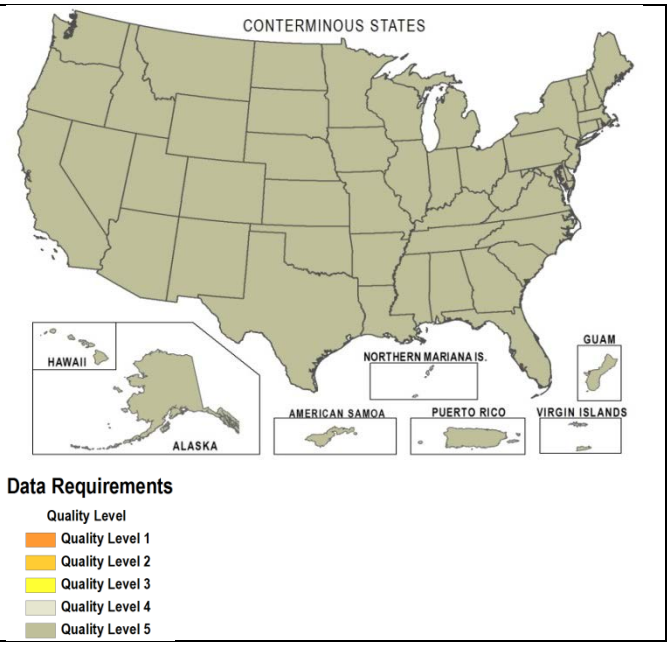
Update frequency: 4–5 years.

Business Use: Aviation Navigation and Safety, BU#20.

Estimated program budgets supported by elevation data: $3 million per year [creation and maintenance of MSAW and General Terrain Monitor (GTM) maps].

Quantifiable Benefits of Enhanced Elevation Data

The FAA would realize improved accuracies compared with lower levels of DEMs currently used. The value of safer enroute navigation cannot be estimated.



Standard and recommended practices for eTOD are documented in annex 15 of the in International Civil Aviation Organization (ICAO). Area 1 of the eTOD covers the whole country, and DEM requirements for area 1 are the least demanding [90-meter (m) DEM post spacing and 60-m (200-ft)-equivalent contour accuracy]. Area 2 of the eTOD

covers established terminal control areas [out to a maximum of a 45-kilometer (km) radius from the aerodrome reference point (ARP) if no terminal control area is established] and requires mid-accuracy DEMs (30-m DEM post spacing and 6-m (20-ft)-equivalent contour interval]. Because of the density of thousands of airfields with 45-km buffers, the gaps between the thousands of 45-km buffers are so small that it is more economical to specify that mid-accuracy DEMs are required nationwide. Because airborne IFSAR delivers DEMs with 5-m post spacing and 20-ft-equivalent contour accuracy, these data are ideal for enroute navigation and approaches before entering that part of terminal air space with a 5-nautical mile buffer around the ARP where lidar data are needed to satisfy accuracy requirements.

The Sector Design and Analysis Tool (SDAT) provides airspace specialists with an FAA-owned tool that has application throughout the lifecycle of an airspace project. The SDAT is used in more than 50 facilities throughout the national airspace (NAS) for problems ranging from airspace visualization and documentation to sector analysis and data translation for a full-scale airspace redesign project.

Operational benefits (internal) to the FAA of enhanced elevation data for this functional activity

Time/Cost Savings: Moderate	**Mission Compliance: Moderate**	**$ Benefits: Cannot quantify**

- Faster production of more accurate FAA MSAW and GTM products.
- More reliable standardized DEM dataset for terrain verification.

Stakeholder service benefits (external) to the public from improved FAA products and services

Performance: Major	**Timeliness: Moderate**	**Experience: Major**	**$ Benefits: Cannot quantify**

- An improved MSAW system, enabled by accurate elevation data, benefits the airlines and the flying public.

Other benefits from FAA use of enhanced elevation data for this functional activity

Public/Social: Moderate	**Environmental: Major**	**Strategic/Political: Major**

- Products that are more precise will economize flights while improving public safety.

Federal Bureau of Investigation

Point of Contact: Patrick Hall, (202) 324-7579

The overall mission of the FBI is to uphold the law through the investigation of violations of Federal criminal statutes; to protect the United States from hostile intelligence efforts; to provide assistance to other Federal, State, and local law enforcement agencies; and to perform these responsibilities in a manner that is faithful to the Constitution and laws of the United States.

FBI managers identified the following major functional activity with mission-critical requirements for elevation data:

- 3D Modeling and Analysis, under BU#17, Homeland Security, Law Enforcement, and Disaster Response

FBI managers provided the following assessments of elevation data requirements and benefits received from the enhanced elevation data quality level that they identified as mission-critical. Summarized details are provided in the following pages.

3D Modeling and Analysis

Mission-Critical Requirements

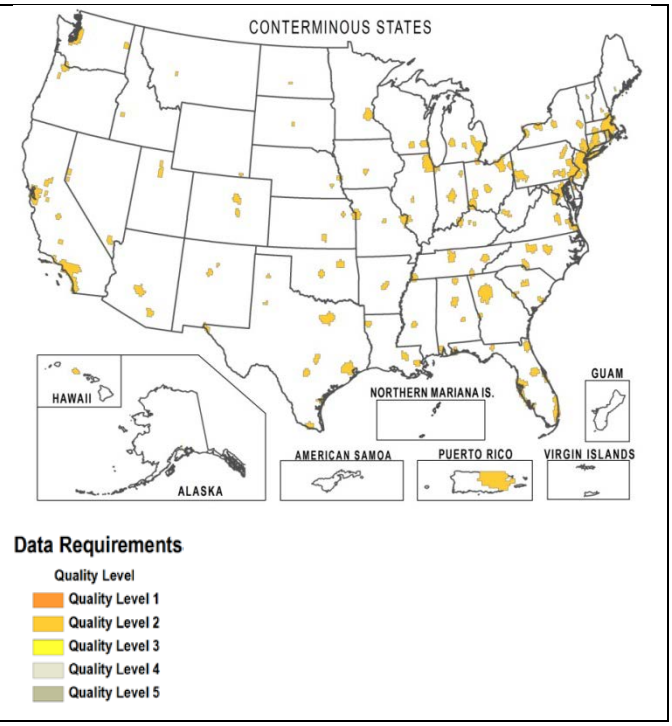
FBI requirements are satisfied by QL2 lidar provided by the National Geospatial-Intelligence Agency over the 133 urban areas. NGA provides these data to multiple agencies for disaster response, law enforcement, homeland security, and 3D modeling and analyses.

Update frequency: 4–5 years.

Business Use: Homeland Security, Law Enforcement, and Disaster Response, BU#17.

Estimated program budget: Cannot provide.

Quantifiable Benefits of Enhanced Elevation Data: Cannot determine.



The National Geospatial-Intelligence Agency (NGA) provides QL2 lidar to the FBI and others as required.

Operational benefits (internal) to the FBI of enhanced elevation data for this functional activity

Time/Cost Savings: Moderate	Mission Compliance: Moderate	$ Benefits: Cannot determine

- Lidar data enable the FBI to perform topographic mapping, area familiarization, and 3D modeling and analysis of sites as incidents occur.
- Knowing exactly where to go for accurate and consistent elevation data saves time for the FBI in not having to research to determine the best available data from potentially dozens of diverse sources of questionable quality and currency.

Customer service benefits (external) to private and public partners from improved FBI products and services

Performance: Major	Timeliness: Major	Experience: Major	$ Benefits: Cannot determine

- Lidar data enable the FBI to provide better 3D modeling and analysis to tactical teams and better quality courtroom presentations.

Other benefits from FBI use of enhanced elevation data for this functional activity

Public/Social: None	Environmental: None	Strategic/Political: None

- None Specified.

Federal Communications Commission

Point of Contact: Don Campbell, (202) 418-2405, Donald.Campbell@fcc.gov

It is the mission of the Federal Communications Commission (FCC) to make available so far as possible, to all the people of the United States, without discrimination on the basis of race, color, religion, national origin, or sex, rapid, efficient, nationwide and worldwide wire and radio communication services with adequate facilities at reasonable charges.

An FCC statement of principles says, "Broadband service can be an indispensable engine for unleashing innovation and investment, spurring job creation and economic growth, and ensuring our country's global competitiveness. Working to make sure that America has world-leading high-speed broadband networks—both wired and wireless—lies at the very core of the FCC's mission in the 21st century.".

During the past two decades, the FCC raised more than $52 billion through spectrum auctions and worked through tectonic industry developments that changed America from a hardwired voice-oriented Nation to a hybrid voice-data, wireless world power.

Improved spectrum management and frequency coordination impact the following FCC goals:

- Develop and implement a national broadband plan
- reform universal services
- Ensure spectrum availability and efficiency for future economic growth and U.S. competitiveness
- spur broadband deployment
- Protect and empower consumers
- Poster public safety efforts

FCC managers identified a single functional activity with mission-critical requirements for elevation data:

- Spectrum Management and Frequency Coordination, under BU#27, Telecommunications

FCC managers provided the following assessments of elevation data requirements and benefits received from the QL5 IFSAR data that they identified as mission-critical. Summarized details are provided in the following pages.

Spectrum Management and Frequency Coordination

Mission-Critical Requirements

QL5 IFSAR data are needed to determine line-of-sight conditions between transmit and receive locations and as inputs to automated propagation prediction software. Consistent, nationwide coverage of DTMs (and potentially DSMs) from airborne IFSAR are superior to NED data which is inconsistent and obsolete.

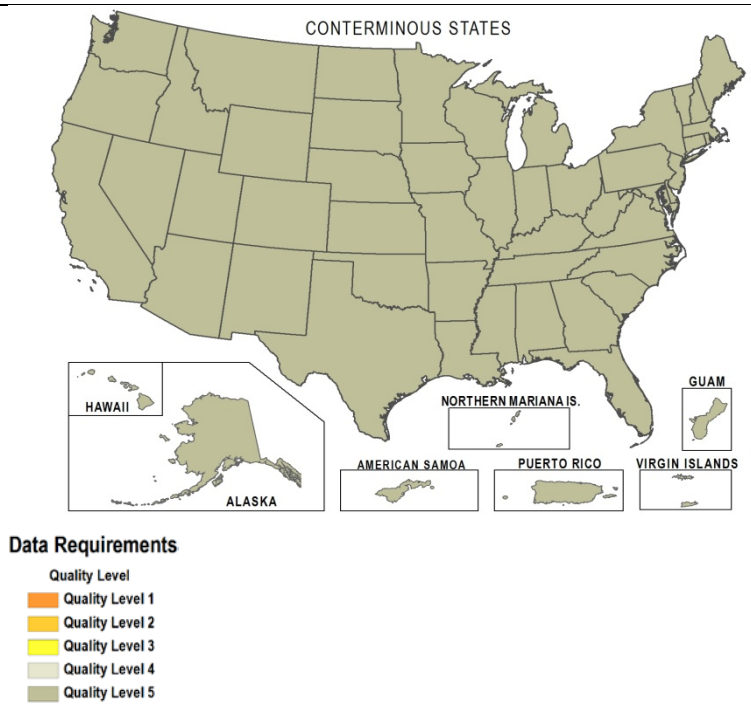
Update frequency: >10 years.

Business Use: Telecommunications, BU#27.

Estimated program budget supported by elevation data: $92 million per year.

Quantifiable Benefits of Enhanced Elevation Data

Benefits to FCC and applicants include simplified, consistent, and reliable processes for frequency interference analyses, but cost benefits to FCC and its customers cannot be estimated.



Operational benefits (internal) to the FCC of enhanced elevation data for this functional activity

Time/Cost Savings: Minor	Mission Compliance: Major	$ Benefits: None

- Better spectrum management, frequency coordination, and licensing of non-Federal radio communications facilities will be possible when using accurate and consistent elevation data nationwide.

Customer service benefits (external) to the public from improved FCC products and services

Performance: Major	Timeliness: Major	Experience: Major	$ Benefits: Unknown

- More accurate propagation studies by can be performed by applicants for radio licenses.
- Simpler and quicker approvals will be possible when the FCC and applicants all use the same, nationwide coverage of IFSAR data for frequency interference analyses.
- Better use will be made of the spectrum, benefitting all who use broadband services for improved productivity and competitiveness.

Other benefits from FCC use of enhanced elevation data for this functional activity

Public/Social: Major	Environmental: Major	Strategic/Political: Moderate

- The public benefits when elevation data helps to harness communications technologies to spur economic growth, job creation, U.S. competitiveness, and public safety.

Federal Emergency Management Agency

Point of Contact: Paul Rooney, (617) 832-4719, paul.rooney@dhs.gov

The mission of FEMA is to support our citizens and first responders to ensure that as a Nation we work together to build, sustain, and improve our capability to prepare for, protect against, respond to, recover from, and mitigate all hazards.

FEMA is the Federal agency charged with building and supporting the Nation's emergency management system. The range of FEMA's activities is broad and spans the life cycle of disasters. The disaster life cycle describes the process through which emergency managers prepare for emergencies and disasters, respond to them when they occur, help people and institutions recover from them, mitigate their effects, reduce the risk of loss, and prevent disasters from occurring.

The National Flood Insurance Program (NFIP) was established in 1968 to reduce future flood damage through hazard identification and mapping, effective community floodplain management, and insurance protection for property owners. FEMA's management of the NFIP has evolved to best manage mounting flood losses and escalating costs of disaster relief. As originally conceived, the NFIP was the means to get communities and citizens to understand their risk from flooding and to mitigate against future flood damage. Congress provided the incentives to do this by encouraging community participation, discounting premiums for structures built prior to the publication of a flood insurance rate map (FIRM) for their community, mandating the purchase of flood insurance, and authorizing grant programs to mitigate repetitively damaged structures. The NFIP flood risk identification and floodplain management land use and building standards reduced the costs and consequences of flooding by an estimated $14 billion from 2000 through 2010. It would be difficult to comprehend what the costs of flooding would be for all levels of government if these standards were not in place.

FEMA also manages multiple programs for disaster preparedness, response and recovery operations, including the Hazard Mitigation Assistance Program, the Individual Assistance Program, and the Public Assistance Program.

FEMA managers identified one major functional activity with mission-critical requirements for elevation data:

- Flood Risk Analysis, under BU#14, Flood Risk Management

FEMA managers provided the following assessments of elevation data requirements and benefits received from the enhanced elevation data quality level for flood risk analysis. Time limitations and significant disaster response activities during the development of this report prevented a detailed analysis of the benefits for disaster preparedness, response, and recovery. Summarized details are provided in the following pages.

Flood Risk Analysis

Mission-Critical Requirements

QL3 data are needed for highest and high risk areas, QL4 data are needed for areas of moderate risk, and QL5 data are needed for areas of low risk for input into the floodplain modeling and mapping process that results in FIRMs, which are used an estimated 15 million times per year for floodplain management and insurance rating.

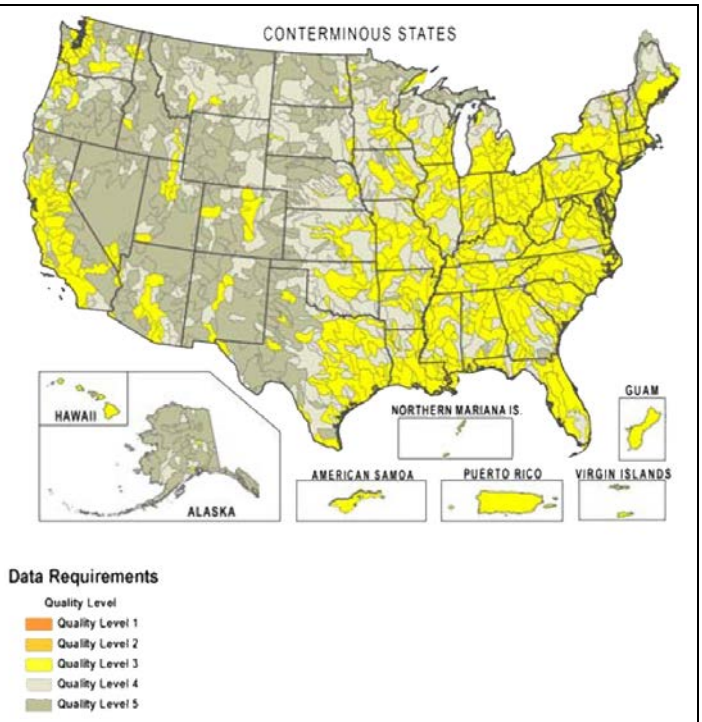
Update frequency: 6–10 years.

Business Use: Flood Risk Management, BU#14.

Estimated program budget supported by elevation data: $220 million per year.

Quantifiable Benefits of Enhanced Elevation Data

FEMA would save $13.5 million per year in internal costs.



Accurate elevation data are vital for FEMA floodplain modeling and mapping processes that result in FIRMs. As a result, FEMA has committed to using only high-quality elevation data for new flood map projects. Elevation data are used to plot the location of the special flood hazard area (SFHA) boundaries shown on the FIRMs. Prior to the availability of lidar data, photogrammetrically derived contour maps along stream corridors and detailed field surveys were used to develop these boundaries. The availability of lidar data reduces (but does not eliminate) the need for field surveys, and high accuracy data over larger areas increase the accuracy of the flood hazard boundaries. The availability of lidar data facilitates the automated plotting of flood hazard boundaries, making the FIRMs more efficient to create and update. For most of the past decade, FEMA set the standards for lidar data nationwide. Lidar data play a crucial role in hydrologic modeling of watersheds, hydraulic modeling of floodplains, and delineation of SFHA boundaries; lidar provides accurate and credible data for proactive floodplain management.

Operational benefits (internal) to FEMA of enhanced elevation data for this functional activity

Time/Cost Savings: Major	Mission Compliance: Major	$ Benefits: $13.5 million per year

- FEMA spent approximately $20 million each year for lidar data in fiscal years 2010 and 2011 and in fiscal year 2012 expected to spend approximately $13 million per year in future years to obtain the high-quality elevation data needed. A national program would eliminate the need for FEMA to spend these funds.
- Use of high accuracy digital elevation data has already made FEMA flood risk products much more accurate and efficient to produce. Flood hazard boundary delineation can be automated, and cross-sections can be cut from the digital elevation data models, thereby reducing the need for field surveys. More accurate floodplain boundaries result in reduced requests from property owners for letters of map change to better reflect ground conditions.
- Management, preservation, and distribution of digital elevation data is a significant effort and expense. While FEMA has archive responsibilities related to the statutory identification of flood hazards, a national enhanced elevation program with a robust data management capability would allow FEMA to reduce its operational costs for elevation data management This might allow FEMA to realize an initial investment of $2 million in data management system infrastructure and annual savings of $0.5 million.

- Having the data available immediately would cut nearly a year off the production time for a flood map update. Shortening the time it takes from the beginning of a flood map update to its completion would have a variety of benefits for the currency of flood data and the management of the mapping program (fig. 1–4).

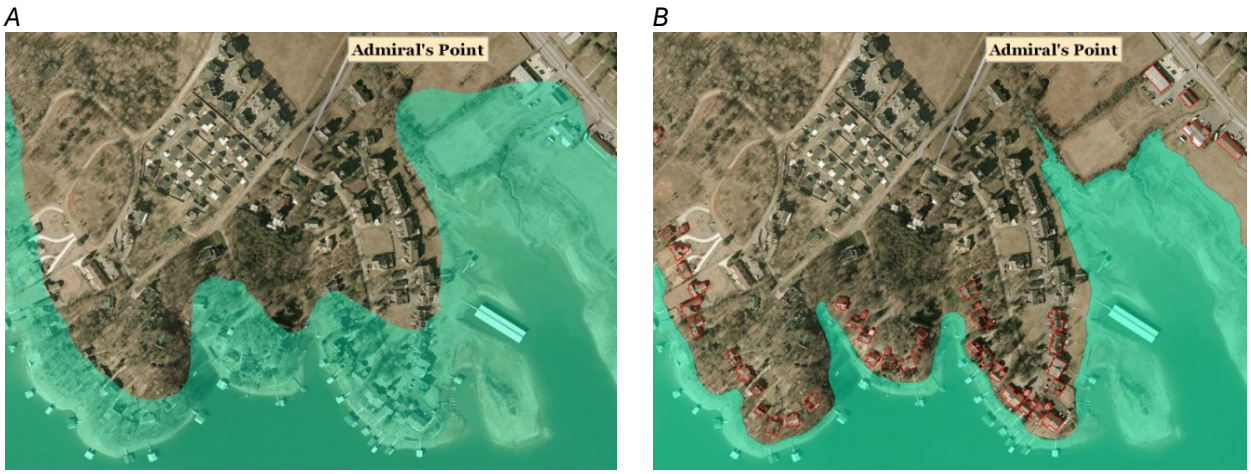


Figure 1–4. Satellite images showing the difference in the special flood hazard area (SFHA; shaded in green) at Admirals Point in Towns County, Georgia, between *A*, inundation areas developed without lidar, and *B*, inundation areas developed with lidar. More than 300 structures (outlined in red in *B*) were removed from the SFHA using higher accuracy lidar data. In other locations, additional structures are added to SFHAs as a result of more accurate modeling.

Customer service benefits (external) to the public from improved FEMA products and services

Performance: Major	Timeliness: Major	Experience: Major	$ Benefits: Cannot be determined

- FEMA flood hazard maps are used an estimated 15 million times per year for State and community floodplain management regulations, for calculating flood insurance premiums, and for determining whether property owners are required by law to obtain flood insurance as a condition of obtaining mortgage loans or other Federal or federally related financial assistance. People purchase needed flood insurance when they trust the accuracy and currency of the FIRMs.
- Property owners can request that FEMA remove a structure or parcel from a designated SFHA. Currently, requests must be accompanied by building elevations certified by a licensed surveyor (average cost to requesters is more than $500), which verifies the elevation of the lowest elevation of the ground around the structure or the lot. This information is compared to the water surface elevation of the 1 percent annual chance flood (base flood elevation, BFE) to determine if the structure or parcel can be removed from the SFHA. In some cases, FEMA may be able to accept ground elevation information from accurate lidar data rather than from a survey. This would result in a significant time and cost savings for the requestor. FEMA typically processes more than 15,000 requests of this type each year. While this approach might only apply to a fraction of that number, the benefit would be significant.
- Lidar data allow FEMA to produce products (flood depth grids) that were not possible with older technologies. These new products will allow homeowners and communities to understand and manage their flood risk more effectively.
- Availability of enhanced elevation data nationally, not just where FEMA acquires the data to support a specific map update need, are likely to lead to innovative tools that build on FEMA flood risk data, making the data more powerful, effective, and easier to use. For example, commercial Web sites might allow users to visualize a variety of flood levels in 3D or compare the lifetime risk of flooding between various locations.
- A national enhanced elevation program would reduce the length of a flood map update. This would have significant benefits for the communities and citizens who are customers of the NFIP. The community officials will be better engaged with the map update process if it is completed more quickly and affected communities and homeowners will receive updated information sooner.

Other benefits from FEMA use of enhanced elevation data for this functional activity

Public/Social: Moderate	Environmental: Moderate	Strategic/Political: Major

- FEMA expects that elevation data will have many other applications for public safety, risk communication, environmental protection, and other applications.
- FEMA also expects that the increased flood map accuracy resulting from the use of high-quality elevation data has significant strategic and political benefits when there are questions about the scientific and technical basis of FEMA flood maps.
- FEMA also expects that using a standard public dataset will have strategic benefits in the perception of the data as unbiased and scientifically based. Relying on data from a national enhanced elevation program led by the USGS would likely improve the perception of FEMA flood risk products.

Federal Energy Regulatory Commission

Points of Contact: Justin Smith (hydropower), Justin.smith@ferc.gov, *(202) 502-6426; Howard Wheeler (gas), howard.wheeler@ferc.gov (202) 502-8688*

The Federal Energy Regulatory Commission (FERC) is an independent agency that regulates the interstate transmission of electricity, natural gas, and oil. FERC also reviews proposals to build liquefied natural gas (LNG) terminals and interstate natural gas pipelines as well as licensing hydropower projects.

FERC's mission is to assist consumers in obtaining reliable, efficient, and sustainable energy services at a reasonable cost through appropriate regulatory and market means. The agency's two primary goals are to ensure that consumer rates, terms, and conditions are just, reasonable, and not unduly discriminatory or preferential and to promote the development of safe, reliable, and efficient energy infrastructure that serves the public interest.

FERC's scope of regulatory oversight includes the regulation of transmission and wholesale sales of electricity and sales of natural gas for resale and the transportation of oil by pipeline in interstate commerce. FERC also reviews certain mergers and acquisitions and corporate transactions by electricity companies that may include, under limited circumstances, the siting applications for electric transmission projects.

Additional regulatory functions of FERC include approving the siting and abandonment of natural gas pipelines and storage facilities and ensuring the safe operation and reliability of operating LNG terminals. FERC licenses and inspects private, municipal, and State hydroelectric projects; protects the reliability of the high-voltage interstate transmission system through mandatory reliability standards; and oversees environmental matters related to natural gas and hydroelectricity projects.

FERC monitors and investigates energy markets, administers accounting and financial reporting regulations and conduct of regulated companies, and enforces FERC regulatory requirements through imposition of civil penalties and other means as required.

FERC managers identified two major functional activities with mission-critical requirements that could use enhanced elevation data:

- Pipeline Routing and Facility Siting, under BU#12, Oil and Gas Resources
- Flood Risk Mapping for Hydroelectric Dam Break Failures and Analysis, primarily under BU#17, Homeland Security, Law Enforcement, and Disaster Response

FERC managers provided the following assessments of elevation data requirements and benefits received from the enhanced elevation data quality level that they identified as mission-critical. Summarized details are provided in the following pages.

Pipeline Routing and Facility Siting

Mission-Critical Requirements

QL1 lidar for 48 conterminous States plus QL5 IFSAR for Alaska are required for geological hazards and topographic features analysis for gas pipeline routing, facility siting, and National Environmental Policy Act (NEPA) compliance.

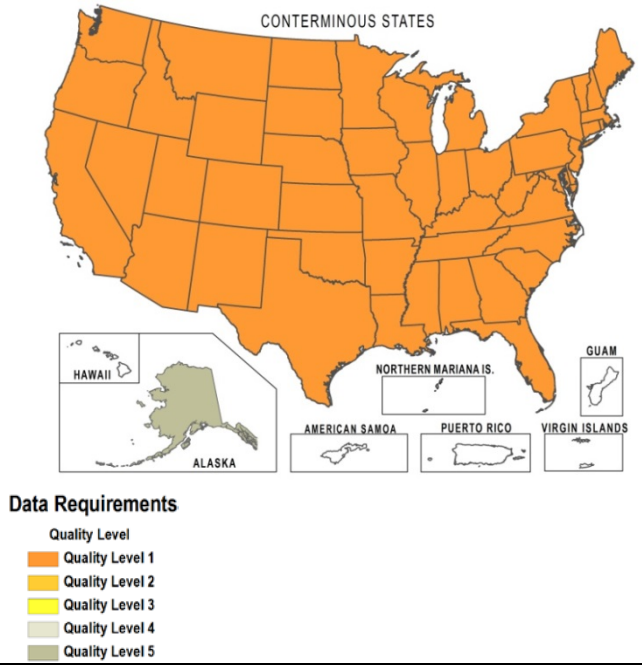
Update frequency: >10 years.

Business Use: Oil and Gas Resources, BU#12.

Estimated program budgets that utilize elevation data to support a portion of this work: $500,000 per year (geohazards analysis), $3.5 million per year (NEPA compliance), $35 million per year (Gas Certificate Program).

Quantifiable Benefits of Enhanced Elevation Data

As a regulatory agency, FERC is unable to estimate annual dollar savings by using nationwide lidar data as the single, validated source of accurate elevation data to evaluate pipeline routes and alternatives.



NEPA has established the requirement that all Federal agencies that fund or permit projects make those decisions in full consideration of their effects on the natural and human environments. NEPA further requires agencies to make these effects known to interested parties and the public. The central element in the environmental review process is a rigorous evaluation of alternatives including the "no action" alternative.

FERC reviews and approves the siting and abandonment of natural gas pipelines and storage facilities and ensures the safe operation and reliability of operating LNG terminals.

FERC could use high-quality QL1 lidar data to identify and analyze geological hazards (for example, landslide and fault locations, geologic formations) and their potential public safety impact on the routing or design of pipelines and storage facilities. FERC could also use these data to evaluate and compare existing geological features with newly proposed or modified pipeline route or facility siting plans; identify and evaluate potential conflicts, environmental impact, and NEPA compliance assessments; provide preferred or alternative routing and facility siting options; and select application options.

For Alaska, lidar data are required by the oil and gas industry for pipeline routing, but companies acquire their own lidar data without normally sharing it with others. For Alaska, QL5 IFSAR would satisfy FERC's requirements. Additionally, FERC could also benefit from bathymetric data of navigable waters and selected lakes.

FERC is purely a regulatory agency and therefore does not make any elevation-based products available for public or private use.

Operational benefits (internal) to FERC of enhanced elevation data for this functional activity

Time/Cost Savings: Moderate	Mission Compliance: Moderate	$ Benefits: Unknown

- FERC performs reviews of pipeline routes and facility locations as applications are received. Having QL1 lidar data already available would help FERC and applicants in numerous ways. Accurate and consistent hazard analysis by the applicant and FERC accelerates the application and review process and avoids the much higher costs of acquiring elevation data of proposed corridors.
- QL1 lidar aids the applicants and FERC in hazards analysis and route selection by enabling geologic fault and landslide analysis for linear facilities routing.

Customer service benefits (external) to the public from improved FERC products and services

Performance Moderate	**Timeliness: Moderate**	**Experience: Moderate**	**$ Benefits: Unknown**

- Commercial applicants would benefit by having public access to the best, validated source of accurate elevation data for their evaluation of pipeline routes and alternatives.
- Rapid access to the best elevation data, also used by FERC, avoids conflicting information and enables quicker reviews by FERC without delays for expensive, data acquisition for pipeline corridors.

Other benefits from FERC use of enhanced elevation data for this functional activity

Public/Social: Moderate	**Environmental: Moderate**	**Strategic/Political: Moderate**

- The public is best served if applicants for route permits and FERC use the best topographic data to make their recommendations and decisions for pipeline routes.
- EIAs and NEPA compliance are enhanced by the use of the best elevation data.
- Strategically and politically, the Nation is best served when accurate elevation data are used to make pipeline routing decisions that affect public safety and to protect the environment.

Flood Risk Mapping for Hydroelectric Dam Break Failures and Analysis

Mission-Critical Requirements

QL3 lidar for 48 conterminous States plus QL5 IFSAR for two watersheds in Alaska is required for performing flood risk mapping for hydroelectric dam break failures and analysis to mitigate impact to public safety and natural and built environments.

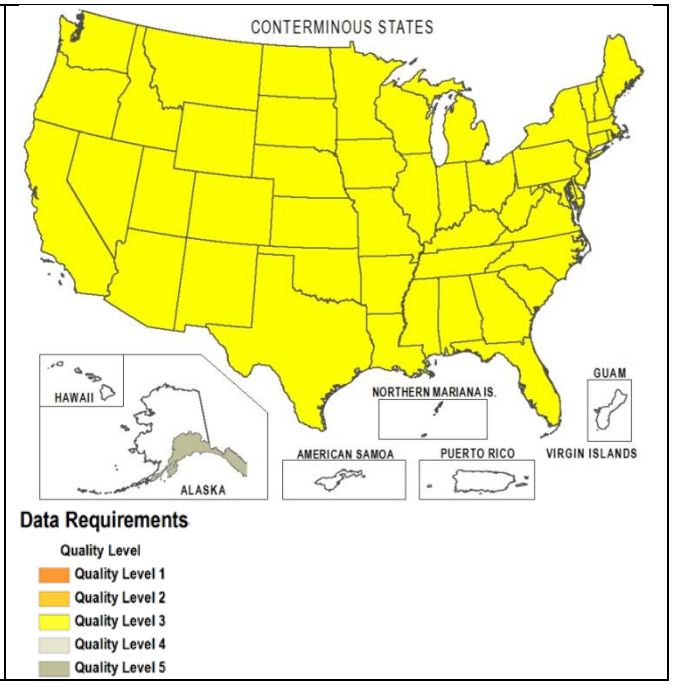
Update frequency: 6–10 years.

Business Use: Primarily under Homeland Security, Law Enforcement, and Disaster Response, BU#17.

Estimated budgets for programs that use elevation data to support a portion of this work: $15 million per year (dam safety).

Quantifiable Benefits of Enhanced Elevation Data

As a regulatory agency, FERC is unable to estimate annual dollar savings by using lidar and IFSAR in performing periodic dam breach analyses.



FERC could use lidar and IFSAR data to support flood risk mapping for dam break failures, specifically nonfederally owned hydroelectric dams, and modeling and analysis of failures and their potential impact to public safety and natural and built environments. FERC currently uses elevation data to confirm inventory land features such as lakes, streams, rivers, and wetlands, including forests, farms, and residential areas. For dam break analysis, FERC could use lidar and IFSAR to better analyze the effects of floods, landslides, and earthquakes on dam retention and structural capacities.

FERC is purely a regulatory agency and therefore does not make any elevation-based products available for public or private use.

Operational benefits (internal) to FERC of enhanced elevation data for this functional activity

Time/Cost Savings: Moderate	Mission Compliance: Major	$ Benefits: Unknown

- Lidar and IFSAR data would not increase the speed of FERC's analysis, but would make hazard analyses and estimations more accurate.

Customer service benefits (external) to the public from improved FERC products and services

Performance: Major	Timeliness: Moderate	Experience: Major	$ Benefits: Unknown

- Lidar and IFSAR data are widely used by others [for example, the BIA, the BLM, FERC, the Tennessee Valley Authority (TVA), the U.S. Army Corps of Engineers (USACE), and the U.S. Bureau of Reclamation (Reclamation)] for dam break analyses of federally owned dams. FERC procedures are consistent with those of other Federal dam safety partners.

Other benefits from FERC use of enhanced elevation data for this functional activity

Public/Social: Major	Environmental: None	Strategic/Political: Minor

- FERC is able to perform dam safety analysis better and faster which benefits public safety.
- Some strategic and political benefit from performing accurate dam breach analyses and planning.

U.S. Fish and Wildlife Service

Point of Contact: Chris Lett, (703) 358-2404, chris_lett@fws.gov

The mission of the FWS is, working with others, to conserve, protect, and enhance fish, wildlife, and plants and their habitats for the continuing benefit of the American people.

The FWS is divided into regions (fig. 1–5). Central to the mission of the FWS, along with State and tribal natural resource agencies, private land partners, and other stakeholders, is providing and protecting a healthy environment for fish, wildlife, and people. Long-term goals include stewardship of the National Wildlife Refuge System (NWRS) and the National Fish Hatchery System (NFHS); recovery of threatened and endangered species; protection and conservation of trust species; and support for international conservation, habitat conservation, and migratory birds.

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Figure 1–5. Map of the United States showing the delineation of U.S. Fish and Wildlife Service regions.

Surface, subsurface (bathymetric), and base elevation datasets are critical for understanding the habitats in which the Nation's fisheries and wildlife resources exist. A better geospatial understanding of how fisheries and wildlife habitats are distributed leads to more accurate resource management and, therefore, to reduced management costs through improved performance and productivity.

Although most responsibilities are distributed, the FWS has several national level programs including Endangered Species, Fisheries and Habitat Conservation, Migratory Birds, and Landscape Conservation Cooperatives.

The FWS provided the following assessments of elevation data requirements and benefits received from the enhanced elevation data quality level that they identified as mission-critical. Topographic lidar-derived and bathymetric elevation data-derived datasets are needed to better understand and manage the landscape and waterscape for fish and wildlife resources. Summarized details are provided in the following pages. Most FWS work is done at the project level; therefore, it is extremely difficult to determine overall national needs for elevation data. FWS identified five general functional activities with mission-critical requirements for enhanced elevation data:

- National Wildlife Refuge System, under BU#7, Wildlife and Habitat Management
- Endangered Species and Fisheries and Habitat Conservation, primarily under BU#7, Wildlife and Habitat Management
- Wetlands Inventory and Mapping, under BU#1, Natural Resources Conservation
- Migratory Birds, under BU#7, Wildlife and Habitat Management
- Landscape Conservation Cooperatives, largely under BU#15, Sea Level Rise and Subsidence

National Wildlife Refuge System

Mission-Critical Requirements

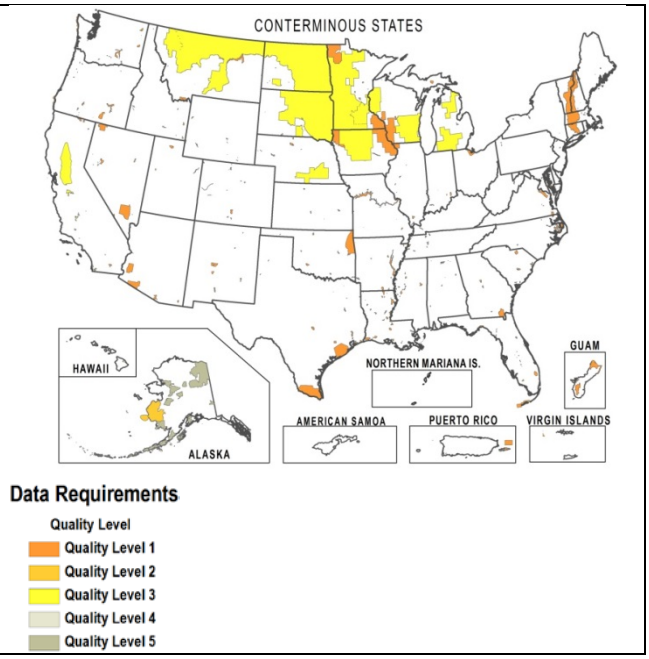
For management of NWRS lands: QL1 lidar for refuges in the lower 48 States, Hawaii, Guam, American Samoa, Northern Mariana Islands, and Puerto Rico; QL2 lidar for refuges in the Yukon Delta, Alaska; QL3 lidar for wetland management districts in the lower 48 States; and QL5 IFSAR for other refuges in Alaska.

Update frequency: 6–10 years.

Business Use: Wildlife and Habitat Management, BU#7.

Estimated program budget for the NWRS of which a portion is supported by elevation data: $502.8 million per year.

Quantifiable benefits of enhanced elevation data: Cannot estimate cost savings.



The National Wildlife Refuge System includes 553 national wildlife refuges and other units of the NWRS, plus 38 wetland management districts. Elevation data requirements differ because each refuge has separate congressionally defined legislation, mission, and sometimes funding, resulting in varying responsibilities and associated needs. Operation and management of national wildlife refuges are also influenced by a wide array of other laws, treaties, and executive orders pertaining to the conservation and protection of natural and cultural resources.

Critical decisionmaking processes that use the current NED are inaccurate, incomplete, or unreliable. Questions, strategies, and decisions concerning resources, human safety, habitat assessments, mean high tide, watershed delineations, tree-line elevation ascent, the spread of invasive species, wildfire behavior, sea level change, and coastal inundation and erosion, based on the NED are severely hampered.

Current and accurate elevation data are required by refuge managers, researchers, and planners for multiple FWS applications. DEMs, derivative products (slope maps, aspect maps, contours, and relief maps), and lidar point cloud data are used to model vegetation, potential restorable wetlands, hydrologic drainage patterns, carbon storage potential, and wildlife habitat. DEMs can also be used to model carbon dioxide (CO_2) contributions from peat-related wildfire events before- and after-fire event. DEMs can be used to quantify the volume of peat burned in the fire event and the volume of CO_2 gas released. DEMs are needed for mapping surfaces, computing volumetric changes of glaciers, delineating floodplains and coastal wetlands, determining stream locations and flow patterns, and identifying cultural resources and landforms. DEMs are used for habitat vulnerability assessments and

simulating storm surge, glacial outburst floods, tsunami, and climate change scenarios, all necessary for protection of natural resources and habitat conservation.

Operational benefits (internal) for the FWS of enhanced elevation data for this functional activity

Time/Cost Savings: Major	Mission Compliance: Major	$ Benefits: Cannot quantify

- Developing alternatives for comprehensive conservation plans and supporting refuge operational activities, including asset management and restoration of watersheds, stream banks, wetlands, forests, dams, and habitat, can be achieved far more efficiently with lidar and IFSAR. Many important restoration projects are in fact impossible to execute without lidar and IFSAR; derived elevation data and elevation data periodic updates improve the ability of the FWS ability to determine how well restoration efforts are proceeding.
- Existing comprehensive conservation plans set target goals for habitat requirements to meet the needs of a variety of wildlife species groups (for example, waterfowl, shorebirds, and wading birds). The FWS refuge system currently has very limited data to evaluate whether it is providing optimal habitat conditions for wildlife species; thus, the FWS must use more labor-intensive methods to evaluate habitat conditions.
- Lidar and IFSAR enable the FWS to implement efficient sampling practices for biological surveys, including inventory and monitoring, invasive species control, and habitat management plans.
- Lidar and IFSAR are mission-critical for all forms of hydrologic and hydraulic modeling and analyses for preservation and protection of water resources on FWS lands, as well as the evaluation of the potential impact of sea level rise on FWS coastal assets.
- Automation of hydrologic modeling and the inherently lower cost and time requirements of aerial surveys rather than field survey provide significant cost savings.

Customer service benefits (external) to the public from improved FWS products and services

Performance: Moderate	Timeliness: Moderate	Experience: Moderate	$ Benefits: Cannot quantify

- FWS customers are the American public, Refuge visitors, and communities that surround FWS lands. Additional customers are threatened and endangered species (ES), trust species, and all wildlife and plants that make the NWRS their habitat. All customers benefit when lidar and (or) IFSAR data enable natural resources and habitat to be preserved and protected for present and future generations.
- Lidar data provide much better evaluation of resource inventories and conditions, maps and visitor center displays that are more engaging, and better education of refuge visitors on habitat conservation and restoration actions.

Other benefits from FWS use of enhanced elevation data for this functional activity

Public/Social: Moderate	Environmental: Major	Strategic/Political: Major

- Major environmental, strategic, and political benefits are achieved by the use of lidar and IFSAR data for the conservation, protection, and enhancement of national wildlife refuges.
- Increased data availability would support necessary work at more refuges.

Endangered Species and Fisheries and Habitat Conservation

Mission-Critical Requirements

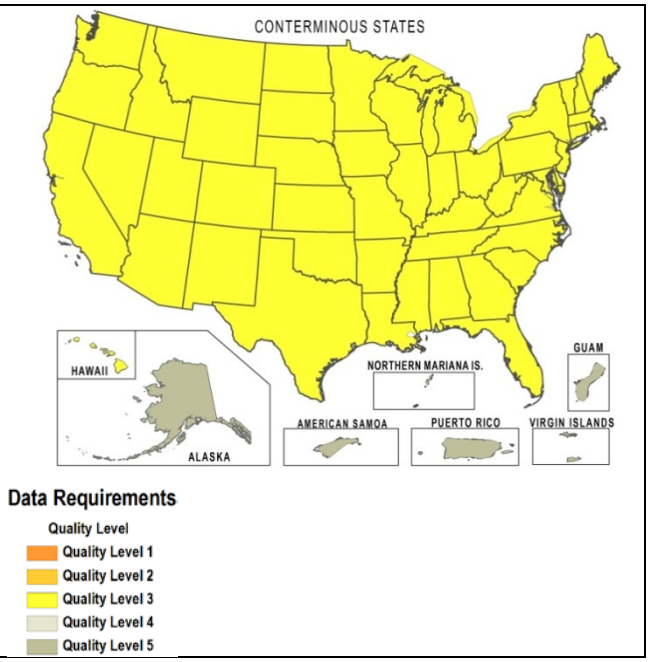
For management of ES and fisheries habitat conservation (FHC), QL3 lidar for the lower 48 States and Hawaii and QL5 IFSAR for Alaska, Guam, American Samoa, Northern Mariana Islands, and Puerto Rico. The FWS prefers lidar acquisition during both leaf-on and leaf-off conditions.

Update frequency: 6–10 years.

Business Use: Primarily under Wildlife and Habitat Management, BU#7.

Estimated program budget for ES and FHC of which a portion is supported by elevation data: $437.1 million per year.

Quantifiable benefits of enhanced elevation data: Cannot estimate cost savings.



As the principal Federal partner responsible for administering the Endangered Species Act (ESA), the FWS takes the lead in recovering and conserving our Nation's imperiled species by employing scientific tools to increase populations and to develop a workforce of conservation leaders to implement these tools to protect and recover species, such as our national symbol, the Bald Eagle.

Accurate elevation data are required for natural resources damage assessments, including evaluating exposure of trust species to toxic spills; proposing, designating, and informing the public about critical habitat for threatened and endangered (T&E) species; and delivering official species lists and section 7 consultations. Lidar and (or) IFSAR data would also greatly benefit the conduct of large-scale, multidisciplinary, multispecies analyses for habitat conservation and for landscape conservation planning and restoration.

Operational benefits (internal) for the FWS of enhanced elevation data for this functional activity

Time/Cost Savings: Major	Mission Compliance: Major	$ Benefits: Cannot quantify

- Time and cost savings are achieved for vegetation mapping. Improved mission compliance is achieved for habitat management and identification of priority areas for conservation and restoration.
- The effect of elevation and elevation derivatives (for example, slope, and aspect) on the processing times of models has not been measured but has a role in machine learning. It is not so much the cost savings resulting from improved processing times that is important but the accuracies of the model results. Without elevation data and derivatives, models will be much less accurate. When habitat modeling is planned over areas that do not have elevation data and derivatives, considerable time and money need to be expended to acquire these data to support the project. Lidar and IFSAR data also provide time savings in avoiding issues with private property access and having to coordinate with landowners.

Customer service benefits (external) to the public from improved FWS products and services

Performance: Major	Timeliness: Moderate	Experience: Moderate	$ Benefits: Cannot quantify

- FWS customers are the American public, such as fishermen, who benefit from more accurate habitat datasets. Accurate bathymetry maps help not only the FWS understand where fish live but also are a benefit to boating and shipping communities. Knowing where underwater structure exists is a part of the infrastructure that has never been adequately mapped. Additionally, the plants and wildlife benefit from conservation and preservation

efforts. All customers benefit when lidar data enable natural resources to be preserved and protected for present and future generations.

- Lidar data provide much better evaluation of resource inventories and conditions, maps that are more engaging, and better models for conservation and habitat preservation.

Other benefits from FWS use of enhanced elevation data for this functional activity

Public/Social: Moderate	Environmental: Moderate	Strategic/Political: Moderate

- FHC relies on collaboration with the public, international partners, state agencies, tribes, private landowners, industry, and other Federal agencies to achieve the conservation goals and objectives. The program conserves and restores habitat to ensure that fish and wildlife populations are sustained for the benefit of current and future generations of Americans, and enhanced elevation data are mission critical for this effort to succeed.

Wetlands Inventory and Mapping

Mission-Critical Requirements

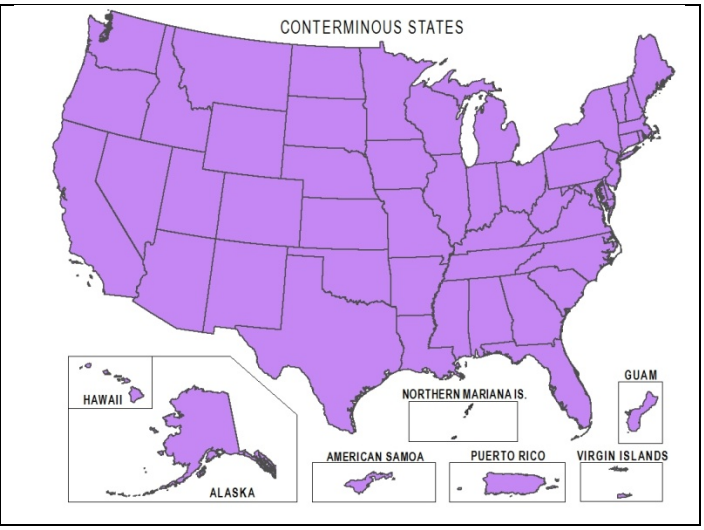
DINSAR is required for monitoring the extent and status of wetlands for management, research, policy development, education, and planning through the National Wetlands Inventory (NWI).

Update frequency: 6–10 years.

Business Use: Natural Resources Conservation, BU#1.

Estimated program budget for NWI of which a portion is supported by elevation data: $5 million per year.

Quantifiable benefits of enhanced elevation data: Cannot estimate cost savings.



The FWS Division of Fisheries and Habitat Conservation works with partners to promote healthy fish and wildlife, healthy habitats, healthy people, and a healthy economy. A key program in the division is monitoring the extent, status, and trends of wetlands for management, research, policy development, education, and planning through the National Wetlands Inventory (NWI).

In addition to surface and subsurface (bathymetry) lidar required for ES and FHC, the FWS also requires IFSAR data. It is now possible to map water level changes in wetlands using IFSAR techniques down to a couple of inches, affecting fisheries and wildlife management as well as flood forecasting, water supplies, and other applications where water quantity changes can be mapped instead of relying on stream point gages. Using surface, subsurface, and base elevation data from lidar and IFSAR systems improves mapping and modeling efficiencies and accuracies for generating NWI geospatial maps, analysis, and reports. Repeat pass satellite DINSAR (multiple data takes) can be used to map water elevation changes down to a couple of inches as has already been demonstrated in the Florida Everglades; IFSAR has the potential to revolutionize flood extent mapping as well as improving waterfowl population estimates, which are driven by changing water levels in the Plains and Prairie Pothole region of the continent. The Everglades project, though, was performed with repeat pass satellite DINSAR and not airborne IFSAR. Repeat pass satellite DINSAR is required nationwide because of its ability to separate water from land areas and because repeat pass satellite DINSAR enables the accurate mapping of water elevation changes over time. Repeated acquisition of QL5 airborne IFSAR, acquired years apart, would have great difficulty correlating interferograms, whereas satellite DINSAR can more easily correlate interferograms and do so with temporal differences of a few days or weeks as satellites pass over again with precise repeat orbits.

Operational benefits (internal) for the FWS of enhanced elevation data for this functional activity

Time/Cost Savings: Major	Mission Compliance: Major	$ Benefits: Cannot quantify

- Quality surface and subsurface elevation datasets will enable the FWS to more reliably deliver natural resource enhancement benefits thereby focusing more funding on nonstructural hydrologic restoration rather than water treatment and flood control. The FWS will be more efficient to the extent that it targets these benefits.
- Current NWI mapping programs in Minnesota have already proven the cost savings for more efficient and accurate delineation of restorable and existing wetlands. This new approach saves millions of dollars that would have been used in more traditional mapping approaches.
- Time and cost savings are achieved for hydrologic studies and hydrologic coding of wetland types; improved mission compliance is achieved for habitat management and identification of priority areas for conservation and restoration.

Customer service benefits (external) to the public from improved FWS products and services

Performance: Major	Timeliness: Moderate	Experience: Moderate	$ Benefits: Cannot quantify

- FWS customers are the American public who benefit from more accurate NWI datasets. Restorable wetlands as well as existing wetlands and deep-water habitats are better defined using IFSAR surface and elevation mapping techniques.
- With both lidar and radar systems it is now possible to measure carbon credits through carbon stored in wetlands through changes in sediment (carbon) over time; especially with restored farmed wetlands.
- Lidar- and radar-based IFSAR data provide much better evaluation of wetland inventories and conditions, maps that are more engaging, and better models for wetland preservation.

Other benefits from FWS use of enhanced elevation data for this functional activity

Public/Social: Moderate	Environmental: Moderate	Strategic/Political: Moderate

- The Nation's fish and aquatic resources are among the world's richest, and provide substantial social, economic, and ecological benefits**.** Mapping of subsurface structure is needed to better manage these benefits.

Migratory Birds

Mission-Critical Requirements

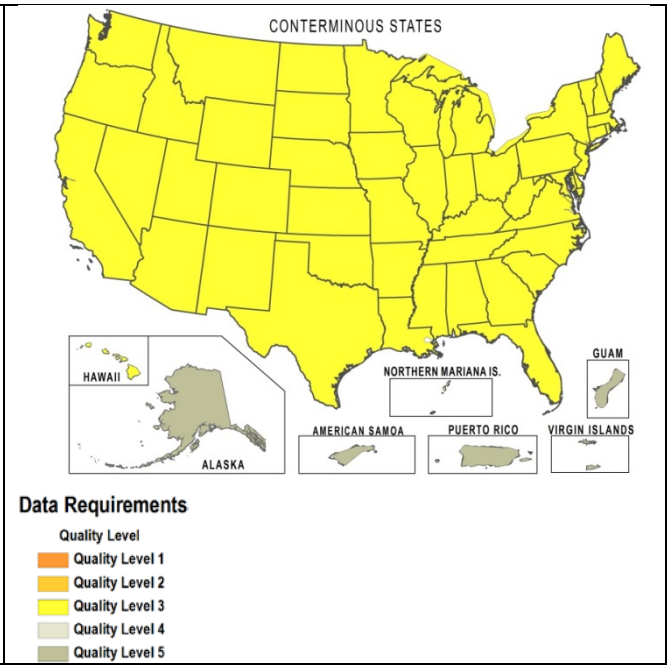
For management of migratory birds: QL3 lidar for the lower 48 States and Hawaii, and QL5 IFSAR for Alaska, Guam, American Samoa, Northern Mariana Islands, and Puerto Rico. The FWS prefers lidar acquisition during both leaf-on and leaf-off conditions.

Update frequency: 6–10 years.

Business Use: Wildlife and Habitat Management, BU#7.

Estimated program budget for migratory birds of which a portion is supported by elevation data: $54.4 million per year.

Quantifiable benefits of enhanced elevation data: Cannot estimate cost savings.



Migratory birds have a significant role in the health of the environment, economy, and culture in the Nation and internationally. The mission of the FWS Migratory Bird Program is to conserve migratory bird populations and their habitats for future generations, through careful monitoring and effective management and by supporting national and international partnerships that conserve habitat for migratory birds and other wildlife.

As the lead Federal agency for managing and conserving migratory birds in the United States, many FWS programs are actively involved in migratory bird conservation activities. Although these activities are generally developed within a specific FWS program, the success of these activities is also dependent upon close intra-agency coordination in addition to building and sustaining vital partnerships with other Federal and State agencies, tribes, and private entities.

Bird surveys, survey design, navigation for pilots, and spatially referenced survey data are reliant on accurate surface and elevation data. Assessing habitat conditions and monitoring habitat improvement projects in joint ventures and conducting research on relationships between bird abundance, productivity, habitat quality and quantity, and migration movement patterns require accurate surface and elevation data. For example, waterfowl surveys are conducted yearly with low flying aircraft. These surveys need to know where new structures such as wind-power farms, cell phone towers, and buildings are erected which may pose an obstacle along a flight survey route if they go unmapped.

Operational benefits (internal) for the FWS of enhanced elevation data for this functional activity

Time/Cost Savings: Moderate	**Mission Compliance: Major**	**$ Benefits: Cannot quantify**

- Targeting of wetland and grassland restoration will be enabled to enhance wetland restoration for migratory birds, water quality of lakes and rivers, with the collateral benefit of flood abatement.
- Enhanced elevation data will help the FWS better manage coastal impounded and natural wetlands in the face of sea level rise and climate change, in order to meet its wildlife conservation mission.
- The FWS may shift its management strategies in response to elevation data analysis, in conjunction with other factors, to better meet its wildlife conservation mission.

Customer service benefits (external) to the public from improved FWS products and services

Performance: Major	**Timeliness: Moderate**	**Experience: Moderate**	**$ Benefits: Cannot quantify**

- FWS customers are the American public and anyone who benefits from improved migratory bird data and models. Additional customers include migratory birds that utilize habitat and benefit from conservation and preservation efforts. All customers benefit when lidar and IFSAR data enable natural resources to be preserved and protected for present and future generations.
- Lidar and IFSAR datasets provide a more accurate resource inventory and condition, maps that are more engaging, and better models for conservation and habitat preservation.

Other benefits from FWS use of enhanced elevation data for this functional activity

Public/Social: Moderate	**Environmental: Moderate**	**Strategic/Political: Moderate**

- Migratory birds are some of nature's most magnificent resources. When bird populations and habitat are preserved, the public benefits, the environment benefits, and the political will of the American public is satisfied.

Landscape Conservation Cooperatives

Mission-Critical Requirements

For management of Landscape Conservation Cooperatives: QL1 lidar for the areas affected by sea level rise for all 50 States including Alaska, plus Puerto Rico, Guam, American Samoa, and the Northern Mariana Islands.

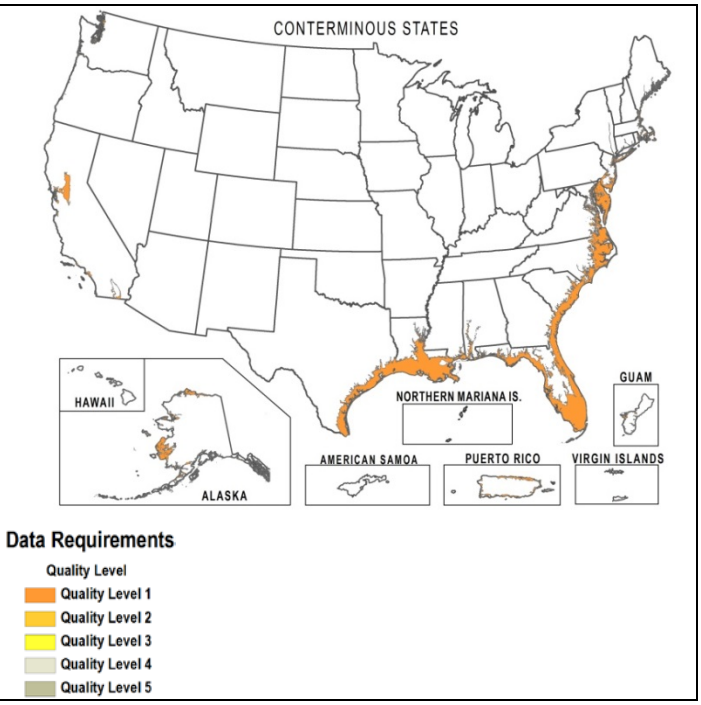
Update frequency: 6–10 years.

Business Use: Largely under Sea Level Rise and Subsidence, BU#15.

Estimated program budget for the LCCs of which a portion is supported by elevation data: $37.4 million per year.

Quantifiable benefits of enhanced elevation data: Cannot estimate cost savings.

Benefits accrue to LCC partners, including other DOI agencies, other Federal agencies, States, tribes, nongovernmental organizations, universities, and others.



Landscape Conservation Cooperatives (LCCs) are applied conservation science partnerships focused on a defined geographic area that inform on-the-ground strategic conservation efforts at landscape scales.

LCCs enable resource management agencies and organizations to collaborate in an integrated fashion within and across landscapes. LCCs provide scientific and technical support to inform landscape-scale conservation using adaptive management principles. LCCs engage in biological planning, conservation design, inventory and monitoring program design, and other types of conservation-based scientific research, planning, and coordination. LCCs play an important role in helping partners establish common goals and priorities, so they can be more efficient and effective in targeting the right science in the right places. Products developed by LCCs inform the actions of partners and other interested parties in their delivery of on-the-ground conservation. LCCs include modeling climate change factors and sea-level rise, urban growth, and other factors affecting habitat conservation.

When it relies on the current NED, the Sea Level Affecting Marshes Model (SLAMM) can be inaccurate and incomplete. Questions, strategies, and decisions based on the NED concerning climate change, strategic habitat conservation, sea level change, coastal inundation and erosion, and isostatic rebound are severely hampered.

Operational benefits (internal) for the FWS of enhanced elevation data for this functional activity

Time/Cost Savings: Moderate	Mission Compliance: Major	$ Benefits: Cannot quantify

- Current DEMs are inadequate to fully assess effects of climate change due to sea-level rise and changes in the amount of precipitation across FWS administrative boundaries. Additionally, there is the potential of assessing with lidar and RADAR the structure of forests and vegetation that could significantly improve the ability ogf the FWS ability to map and model the response of species to future habitat change. With enhanced elevation data, the FWS expects significant reduction in variance estimates around predictions of habitat use, and the FWS will be able to provide better guidance to its conservation partners on how much and where they need to conserve natural habitats to maintain bird species into the future. This has the potential to reduce the total cost of conservation efforts of the FWS and partners due to reduction in the variance associated with FWS predictions.
- Quantifying these estimates is inherently difficult outside the context of the conservation questions being addressed. Directly, increased precision would be obtained in many biological modeling efforts, potentially reducing the duration of time required to acquire field validation measurements. This action is often the most

time consuming and costly of biological inventory and monitoring efforts. The amount of saving incurred is specific to individual project metrics. The FWS estimated an average saving of 20 percent in field validation costs. In addition, cost savings associated with statistical validation of modeling results should also be expected. This may reduce overall project cost by 5 to 10 percent.

- Lidar-derived products provide an opportunity to map habitat structure at a scale and resolution economically infeasible with traditional cruise-based methods. These same data sets have applications for hydrologic and hydraulic predictions and allow integrated modeling and mapping of multiple landscape features. As the FWS does basic-scale strategic analysis and planning, being limited by the spatial extent of lidar products is a constant concern. The FWS approaches some products in a regression relationship with existing remotely sensed data (for example, it can derive indices of sufficient reliability to quantify habitat based on correlation of lidar-derived and imagery-based data).
- The delivery of lidar-derived large-scale elevation models, in conjunction with ground control point data and clear language on the utilized vertical datum, would be a powerful tool to help ensure that practitioners are interpreting local benchmark data correctly.

Customer service benefits (external) to the public from improved FWS products and services

Performance: Major	**Timeliness: Major**	**Experience: Moderate**	**$ Benefits: Cannot quantify**

- FWS customers are the American public and anyone who benefits from improved strategic habitat conservation. In particular, the LCCs function with partners that include government and nongovernmental organizations. Additional customers include wildlife and plants that utilize habitat and benefit from conservation and preservation efforts. All customers benefit when lidar and RADAR derived elevation datasets enable natural resources to be preserved and protected for present and future generations.
- Lidar and IFSAR datasets provide much better evaluation of resource inventories and conditions, maps that are more engaging, and better models for conservation and habitat preservation.

Other benefits from FWS use of enhanced elevation data for this functional activity

Public/Social: Moderate	**Environmental: Major**	**Strategic/Political: Major**

- The American public supports the preservation of critical landscapes and preserving the natural environment for future generations.

International Boundary and Water Commission

Point of Contact: Gilbert Anaya, (915) 832-4702, Gilbert.Anaya@ibwc.gov

The mission of the IBWC is to "provide bi-national solutions to issues that arise during the application of United States-Mexico treaties regarding boundary demarcation, national ownership of waters, sanitation, water quality, and flood control in the border region". It is further defined in the strategic plan to "provide flood protection to U.S. residents and ensure the efficient conveyance, utilization, and accurate accounting of boundary and transboundary river waters through the operation and maintenance of flood control structures, dams, reservoirs, power plants, and gaging stations in accordance with domestic law and international agreements."

Established in 1889, the International Boundary and Water Commission (IBWC) has responsibility for applying the boundary and water treaties between the United States and Mexico and settling differences that may arise in their application. The IBWC is an international body comprising the United States and Mexican Sections, each headed by an engineer-commissioner appointed by the respective president. Each Section is administered independently of the other. The United States Section of the IBWC is a Federal government agency that operates under the foreign policy guidance of the U.S. Department of State. The Mexican Section is under the administrative supervision of the Mexican Ministry of Foreign Affairs.

Under its mission, the IBWC operates flood control levee systems; diversion dams, which provide and regulate irrigation waters; storage dams, which hold water for conservation, distribution, and power generation; gaging stations; and wastewater treatment plants. Additionally, the IBWC is responsible for collecting water quality data throughout the Texas portion of the Rio Grande Basin. The IBWC also uses its Emergency Management Program to keep the public informed of emergency operations that may be undertaken in case of an emergency or during emergency management exercises.

The IBWC currently uses lidar data to evaluate its levees and flood control projects to ensure they meet FEMA certification requirements; the IBWC works with FEMA and USACE in this regard. Lidar data are also used for hydraulic modeling and dam break and levee failure analyses. The IBWC uses bathymetric data to evaluate reservoir silting on a 5-year cycle. The IBWC works closely with Reclamation since both have similar missions. The IBWC also shares surface water and groundwater data with USGS.

IBWC managers identified the following major functional activity with mission-critical requirements for elevation data:

- Flood Risk Mapping, under BU#14, Flood Risk Management

IBWC managers provided the following assessments of elevation data requirements and benefits received from the enhanced elevation data QL2 lidar that they identified as mission-critical. Summarized details are provided in the following pages.

Flood Risk Mapping

Mission-Critical Requirements

QL2 lidar of the IBWC area of interest along the United States-Mexico border is required for hydraulic modeling, dam break, and levee failure analyses.

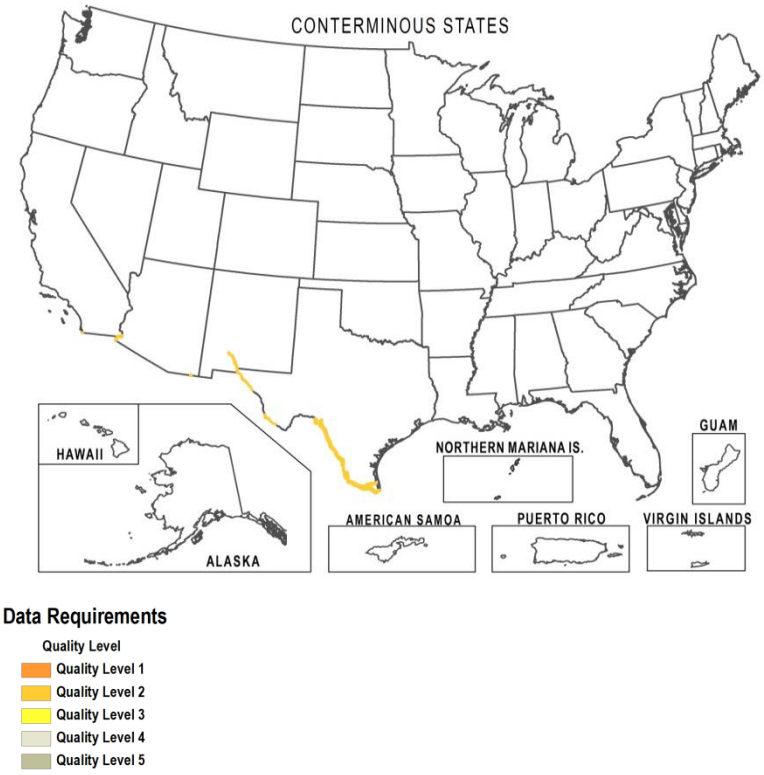
Update frequency: 4–5 years.

Business Use: Flood Risk Management, BU#14.

Estimated program budget: $0.6 million per year.

Quantifiable Benefits of Enhanced Elevation Data

The IBWC has estimated that $14.3 million per year in benefits, on average, can be attributed to the availability of lidar for evaluation, levee design, flood modeling, and flood operations management.



The IBWC has determined that QL2 data that cover their areas of interest along the United States-Mexico border would meet their needs for modeling purposes. Other reaches of the Rio Grande Basin are sparsely populated and (or) in areas with high relief (for example, canyons) where lidar data are not a priority; a lower level of elevation data would be sufficient. However, for project design and construction, data and field surveys of higher than QL2 accuracy would be needed for specific project areas. Additionally, the IBWC requires bathymetric data for reservoir silt determinations.

The IBWC prepares inundation maps and risk analyses for its 7 dams based on 12 different release bands that are used to help to alert communities to rising water surface elevations. The IBWC flood risk mapping standards and guidelines are based on international agreements established jointly with Mexico to convey a certain flow volume.

Operational benefits (internal) to the IBWC of enhanced elevation data for this functional activity

Time/Cost Savings: Major	Mission Compliance: Major	$ Benefits: $1.3 million per year

- High quality elevation data provide improved ability to analyze and identify dam and levee height deficiencies quickly.
- Hydraulic models can be more readily updated to provide more accurate water surface elevations.
- The assessment of flood risks due to dam failure is facilitated. Inundation maps using this type of analysis benefit communities downstream of these facilities that are potentially in harm's way. This increased understanding could reduce or eliminate potential future loss of life or catastrophic economic impact.
- The IBWC estimates that internal benefits of $1.3 million per year (10 percent of the stakeholder benefits listed below) can be attributed to the availability of lidar data.

Customer service benefits (external) to private and public partners from improved IBWC products and services

Performance: Major	Timeliness: Major	Experience: Moderate	$ Benefits: $13 million per year

- The IBWC has estimated that its flood control projects along the Rio Grande provide $323 million in flood control protection benefits (for the U.S. side) over a 25 year period, based on the occurrence of a levee failure that would damage agriculture and business and flood events that carry close to 100-year flows through the system that could have caused damage if the levees failed. This estimate is based on a 2004 study that estimated flood damages to property that are avoided by the existence of the IBWC flood control measures. High-quality elevation data are critical to the design and maintenance of the flood control inventory and to the protection of properties and lives within the communities served by these projects.
- The IBWC estimates that stakeholder benefits of $13 million per year, based on expended costs for levee rehabilitation (design, construction, and modeling, conducted this past year) can be attributed to the availability of lidar for evaluation, levee design, flood modeling, and flood operations management.
- High-quality elevation data result in improved facility maintenance and flood risk modeling. The IBWC has many stakeholders, including the United States-Mexican border residents, municipal water users, and irrigation and agricultural districts. The communities rely on the IBWC for flood protection through the operation of its dams and maintenance of flood control levees and structures. The United States-Mexican border has experienced incredible growth in population over the last few decades and more people live within the flood control projects. The impact of levee failure due to flooding would damage many businesses and homes.
- The analyses being conducted by the IBWC are benefiting communities by ensuring that the flood control projects are adequate to convey flood flows and by providing mapping products that help them visualize potential impacts (especially in nonlevee areas, such as Del Rio, Eagle Pass, Laredo, and Rio Grande City).

Other benefits from IBWC use of enhanced elevation data for this functional activity

Public/Social: Minor	Environmental: Major	Strategic/Political: Major

- Improved partnering for data collection with local communities and FEMA. For example, local communities working with FEMA on map modernization used IBWC lidar data for their new maps. Additionally, local leaders have expressed interest in partnering on other projects. For example, the Texas Natural Resource Information System (TNRIS) partnered with the IBWC on its 2010 lidar imagery collection and was able to collect additional areas by engaging the communities.

National Aeronautics and Space Administration

Point of Contact: David Harding, (301) 614-6503, David.J.Harding@nasa.gov

The mission of the National Aeronautics and Space Administration (NASA) mission is to pioneer the future in space exploration, scientific discovery, and aeronautics research. Its lidar activities include development of advanced instrumentation and measurement approaches, testing and use of prototype instruments on airborne platforms, and the conduct of Earth and planetary remote sensing missions. Its Earth-based lidar science objectives focus on the solid Earth (topography and natural hazards), the biosphere (vegetation structure, carbon storage, and habitat quality), the cryosphere (ice sheets, glaciers, and sea ice), and the hydrosphere (water cycle and storage).

NASA spaceflight missions that acquired Earth topography data in the past were the shuttle radar topography mission (SRTM) that mapped the Earth's land surface between ±60° at a spatial sampling of 30 m by SAR interferometry, the ice cloud and land elevation satellite (ICESat) that conducted global sampling using a single-beam profiling lidar, and the advanced spaceborne thermal emission and reflection radiometer (ASTER) global mapping project that employed stereophotogrammetric methods. NASA's future Earth science spaceflight missions are based on the recommendations of the National Research Council (2007). The most relevant of those for lidar mapping objectives are the ICESat-2 mission, which will conduct global sampling using a multiple-beam instrument, and the lidar surface topography (LIST) mission, which will conduct global mapping using a swath imaging instrument. The LIST program's mission is to "develop a scientific understanding of Earth's system and its response to natural and human induced changes." The LIST project (fig. 1–6) will pioneer new global environmental observations and improve the operational services they provide to the Nation. These services include weather forecasting; climate prediction; natural hazard assessment, prediction, and response; and environmental management.

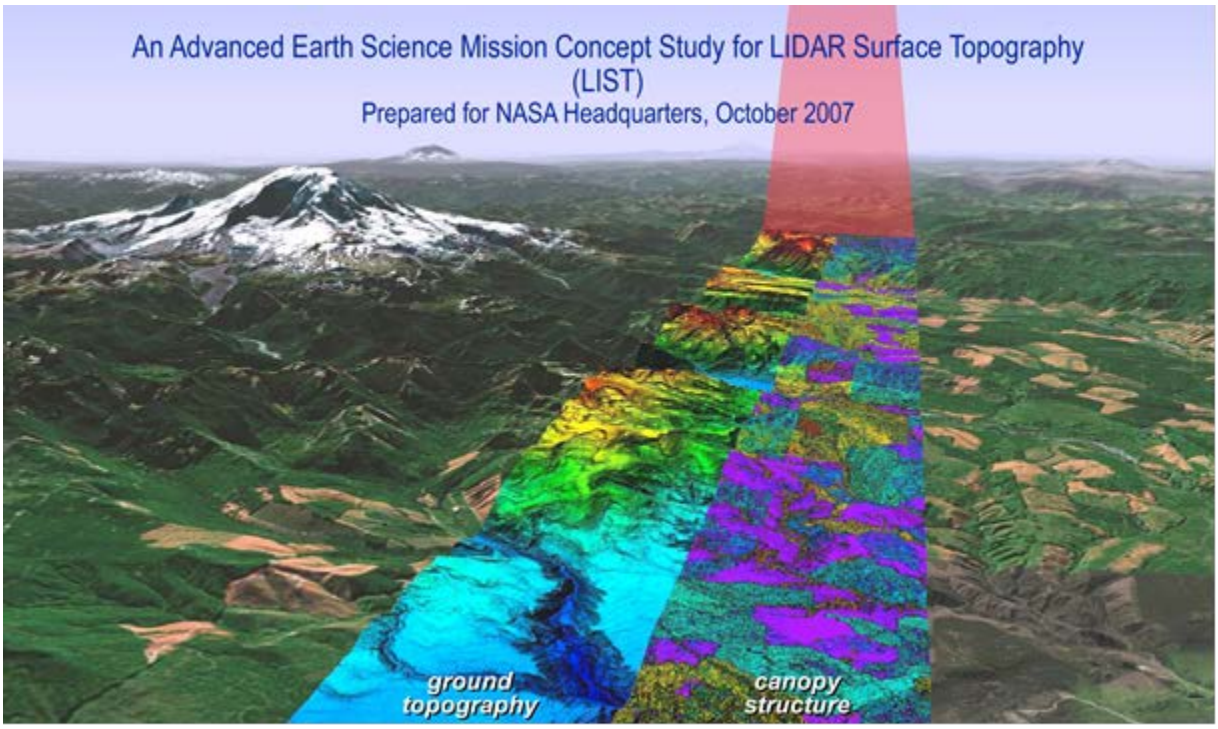


Figure 1–6. Satellite image illustrating the light detection and ranging (lidar) surface topography (LIST) concept, which will include mapping of vegetation structure and the topography of the ground surface. From Blair and others, 2007.

NASA identified one functional activity with requirements for enhanced elevation data:

- Advanced Earth Science Mission Support, under BU#25, Education K–12 and Beyond (including basic research).

NASA managers provided the following assessments of elevation data requirements and benefits received from the enhanced elevation data quality level that they identified as mission-critical. Summarized details are provided in the following pages.

References Cited

Blair, J.B., Hofton, Michelle, and Rabine, David, 2007, Mapping using NASA's full-waveform medium/high-altitude, LVIS lidar system: National Aeronautics and Space Administration, 23 p., accessed March 16, 2012, at http://www.espo.nasa.gov/oib/docs/OIB_LVIS.pdf.

National Research Council, 2007, Earth science and applications from space—National imperatives for the next decade and beyond: National Research Council, 456 p. (Accessed March 16, 2012, at http://www.nap.edu/catalog/11820.html.)

Advanced Earth Science Mission Support

Mission-Critical Requirements

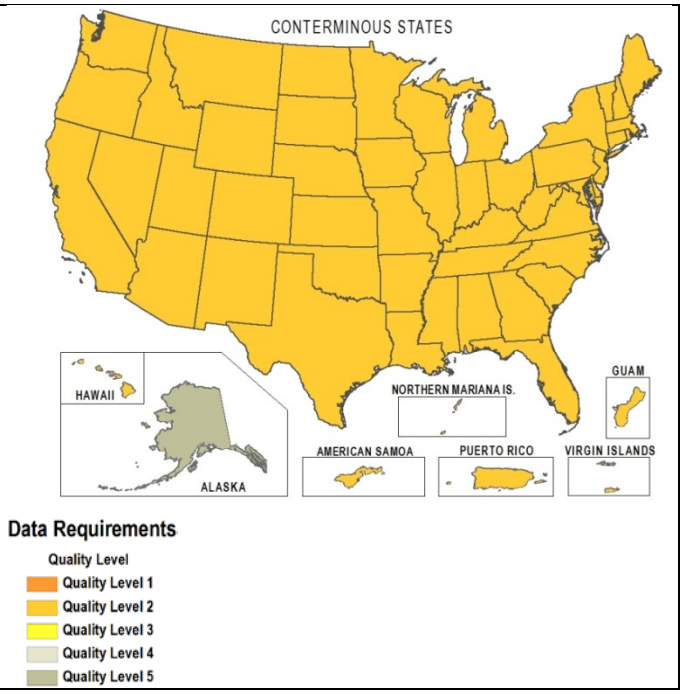
QL2 lidar is required nationwide (except Alaska) for calibration and validation of NASA sensor systems and existing datasets and to serve as the ground topography base for comparison with reobserved canopy structure from the LIST sensors for 4D mapping of changing land cover. QL5 IFSAR is required of Alaska to map through clouds and fog and then combine with LIST data to provide the most accuracy mapping of Alaska regardless of clouds and fog.

Update frequency: 4–5 years.

Business Use: Education K–12 and Beyond (including Basic Research), BU#25.

Estimated program budget supported by elevation data: In the range of $500 million to $1 billion.

Quantifiable benefits of enhanced elevation data: Unable to estimate.



LIST is responsive to a diverse array of science and applied measurement needs articulated by a broad spectrum of Earth science disciplines. The mission will provide compelling foundation data needed to make high priority scientific advances and to serve important societal needs:

- Solid Earth—landscape evolution; interactions between climate, tectonics, and erosion; earthquake, volcano, landslide, and coastal hazards
- Vegetation structure—carbon storage; disturbance and response; habitat and biodiversity; wild-fire fuel loads; slope stabilization
- Cryosphere—ice sheet, ice cap, and glacier elevation change; ice flow and dynamics; sea ice cover and thickness
- Water cycle—water storage; snow depth; river discharge

Key science requirements of the LIST are to create lidar surface topography with:

- 5-m spatial resolution
- ≤10-cm [root mean square error of Zipf-Law deviation (RMSEz)] relative vertical accuracy per footprint for flat surfaces
- ≤20 cm (RMSEz) absolute vertical accuracy per footprint for flat surfaces
- 1 m vegetation vertical structure resolution per 25-m × 25-m area

- Complete one-time global mapping in 3 years or less, accounting for land-area annual mean cloud cover of 50 percent
- Natural hazards monitoring, target 10-km × 10-km areas within a month after event occurs
- Ecosystem monitoring, reobserve selected locations annually in same season
- Cryosphere monitoring, reobserve selected locations seasonally
- Water storage monitoring, reobserve selected locations monthly

Applicability of national lidar Products to NASA programs:

- Airborne QL2 lidar has a vertical root mean square error (RMSE) of 9.25-cm and spatial resolution of 0.7 m, yielding 2 points per square meter on average. Lidar is the best technology for penetrating vegetation to map the bare-Earth terrain beneath the trees. Lidar also maps the canopy, but does so better under leaf-on conditions than leaf-off conditions.
- Except for small project areas, low-altitude, airborne lidar is not practical for mapping all of Alaska because of perpetual cloud and fog conditions and the high costs involved in overcoming these conditions in remote environments where it sometimes takes years to obtain acceptable conditions for optical data acquisition; this is why airborne QL5 IFSAR (day and night, all-weather) is widely considered to be the most feasible technology for statewide mapping in Alaska. Airborne IFSAR normally has 185 cm or less (RMSEz) absolute vertical accuracy with 5-m spatial resolution and achieves higher accuracy than the SRTM or any current commercial radar satellite that also maps through clouds and fog.
- Whereas the QL5 IFSAR of Alaska may have lesser vertical accuracy than the design accuracy of the LIST, airborne IFSAR has the same 5-m spatial resolution and is processed to provide both the bare-Earth DTM and the top DSM. IFSAR data also includes orthorectified radar images (ORIs) that can be used for comparison with data from the LIST, which may also encounter difficulties with clouds and fog.

Operational benefits (internal) for NASA of enhanced elevation data for this functional activity

Time/Cost Savings: Moderate	Mission Compliance: Major	$ Benefits: Cannot quantify

- QL2 lidar of 49 States and U.S. territories will enable NASA to calibrate and validate data from prior topography missions and the ICESat-2 and LIST sensors to ensure that the data satisfy mission measurement requirements.
- QL2 lidar data will also serve as the most accurate ground topography base map for determination of vegetation height and derived estimates of aboveground biomass from the ICESat-2 and LIST vegetation structure observations (fig. 1–6). This lidar ground topography base map will then be used repeatedly for change-detection purposes as LIST periodically reobserves the Earth for natural hazards, ecosystem monitoring, cryosphere monitoring, and (or) water storage monitoring.
- The combination of QL5 IFSAR with LIST data should provide an ideal means to reevaluate changing conditions anywhere in Alaska. Where the LIST data are able to image without clouds or fog, the LIST data can be used to update or improve the IFSAR DTM; where the LIST data cannot image because of perpetual clouds or fog, the IFSAR data will remain the best available data for mapping the DTM and DSM surfaces in Alaska.

Customer service benefits (external) to the public from improved NASA products and services

Performance: Major	Timeliness: Moderate	Experience: Moderate	$ Benefits: Cannot quantify

- The combination of LIST data with lidar and IFSAR (in Alaska) will enable NASA's customers to receive data of highest accuracy anywhere in the U.S. and its territories.

Other benefits from NASA use of enhanced elevation data for this functional activity

Public/Social: Major	Environmental: Major	Strategic/Political: Major

- The LIST mission implementation will likely cost in the range $500 million to $1 billion. That investment will yield major benefits through data of higher accuracy when coupled with the use of QL2 lidar for system calibration and validation and when the lidar and IFSAR data provide the most accurate ground topographic surfaces with which canopy structure from the LIST is periodically updated and compared to determine changes.

- Environmental benefits are major when the LIST succeeds in meeting its Earth-based science objectives that pertain to the solid earth (topography and natural hazards), the biosphere (vegetation structure), the cryosphere (ice sheets, glaciers, and sea ice), and the hydrosphere (water cycle and storage).
- Strategic and political benefits are major when NASA addresses these objectives worldwide, and not just for U.S. territory alone. Calibration and validation of LIST using QL2 and QL5 data for the United States will provide an important foundation enabling understanding of LIST data quality that will be applicable on a global basis.

National Geospatial-Intelligence Agency.

Point of Contact: Sandra.L.Mitchell@nga.mil

The National Geospatial-Intelligence Agency (NGA) is a member of the military and intelligence communities. The agency provides timely, relevant, and accurate geospatial intelligence support for global world events, disasters, and military actions. The NGA's mission is to aggressively capture, integrate, and provide the homeland security, homeland defense, and emergency preparedness, response, and recovery communities with a common operational picture; analyze threat support and critical infrastructure protection; and expedite readiness, response, and recovery in the event of manmade or natural disasters.

Under its mission, the NGA provides geospatial intelligence support for global world events, disasters, and military actions. The NGA provides other Federal agencies with data, including elevation data, and mapping products that are used for disaster response, law enforcement, and research.

NGA managers identified the following major functional activity with mission-critical requirements for elevation data:

- Homeland Security and Disaster Preparedness, under BU#17, Homeland Security, Law Enforcement, and Disaster Response

NGA managers provided the following assessments of elevation data requirements and benefits received from the enhanced elevation data quality level that they identified as mission-critical. Summarized details are provided in the following pages.

Homeland Security and Disaster Preparedness

Mission-Critical Requirements

QL2 lidar of the 133 urban areas is required for disaster response, law enforcement, homeland security, research, and 3D modeling, simulation, and analyses.

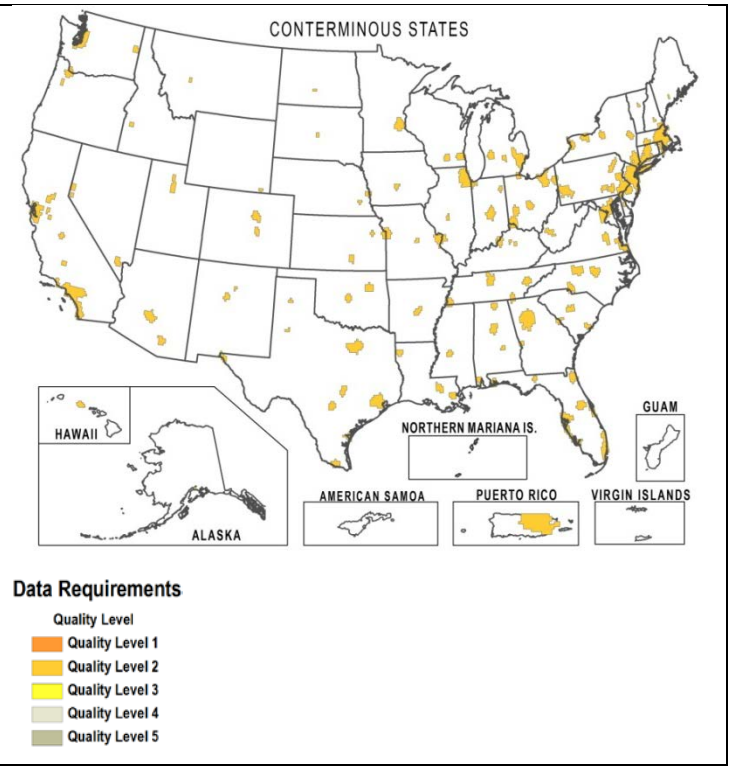
Update frequency: 4–5 years.

Business Use: Homeland Security, Law Enforcement, and Disaster Response, BU#17.

Estimated program budget: Cannot provide.

Quantifiable Benefits of Enhanced Elevation Data

No credible cost savings can be placed on the dollar value of infrastructure or lives protected from acts of terrorism or natural disasters.



The NGA currently acquires all the elevation data it needs to support its mission. However, QL2 lidar data that cover the 133 urban areas could meet many of the NGA's needs and could reduce data acquisition turnaround time and costs.

Operational benefits (internal) to the NGA of enhanced elevation data for this functional activity

Time/Cost Savings: Major	Mission Compliance: Moderate	$ Benefits: Cannot determine

- Use of common elevation data standards and delivery of commonly used elevation data products could result in cost savings to NGA from not having to acquire and process the data if the deliverables met their needs for timeliness, content, and format.
- High-quality elevation data would provide a better 3D landscape across the Nation and better public information that could be used by all for the myriad of modeling and analysis activities supported by the data.

Customer service benefits (external) to private and public partners from improved NGA products and services

Performance: Major	Timeliness: Major	Experience: Major	$ Benefits: Cannot determine

- The NGA's customers are other Federal agencies that have a homeland security mission. The benefits to these customers would come from having high quality elevation data readily available, at no cost to them, and in the public domain with no distribution restrictions.

Other benefits from NGA use of enhanced elevation data for this functional activity

Public/Social: Major	Environmental: Major	Strategic/Political: Major

- Political benefits would be realized by a national elevation program that would maximize the benefits from taxpayer dollars and make more effective use of Federal budgets.
- National enhanced elevation data would provide the ability to be proactive in using 3D models to assess vulnerabilities of baseline infrastructure, to mitigate risks from terrorism or natural disasters, and to respond rapidly in times of emergency. Although dollar benefits cannot be quantified, this has tremendous public and social value as well as strategic and political value.
- Americans consistently list homeland security as their highest priority goal. Dollars spent on mitigation of risks from disasters has a high return on investment, but this return cannot be quantified (pre-event) in terms of damages avoided.
- Public safety is benefited when safeguarding national special security events.

National Oceanic and Atmospheric Administration

Point of Contact: Kirk Waters, (843) 740-1227, Kirk.Waters@noaa.gov

The mission of the National Oceanic and Atmospheric Administration (NOAA) is to understand and predict changes in Earth's environment and conserve and manage coastal and marine resources to meet our Nation's economic, social, and environmental needs.

NOAA was formed in 1970, but the agencies that came together at that time date back to 1807, when the United States Coast and Geodetic Survey was formed, followed by the Weather Bureau in 1870, and the Bureau of Commercial Fisheries in 1871. NOAA products and services affect more than one-third of America's gross domestic product. NOAA scientists provide citizens, planners, emergency managers, and other decisionmakers with reliable information including accurate weather forecasts and the data needed to protect and manage the Nation's coastal and ocean resources and to enable society to plan and respond to climate change.

NOAA requires high quality elevation and bathymetric data to support the following programs:

- the National Marine Fisheries Service, which is responsible for the stewardship of the Nation's living marine resources and their habitat
- the National Ocean Service, which provides science-based solutions to address threats, such as climate change, population growth, port congestion, and contaminants in the environment, to coastal areas
- NOAA National Data Centers, which provide data and information services including Earth system monitoring, perform official assessments of the environment, and conduct related research
- Oceanic and Atmospheric Research, which conducts environmental research, provides scientific information and research leadership, and transfers research into products and services to help NOAA meet the evolving economic, social, and environmental needs of the Nation
- the National Weather Service (NWS), which provides weather, hydrologic, and climate forecasts and warnings for the United States, its territories, adjacent waters and ocean areas, for the protection of life and property and the enhancement of the national economy

NOAA managers identified the following major functional activities with mission-critical requirements for elevation data:

- Coastal Mapping and Modeling, under BU#4, Coastal Zone Management, and BU#19, Marine Navigation and Safety
- Coastal and Marine Resources Conservation, under BU#1, Natural Resources Conservation
- Advanced Hydrologic Prediction Service Static Inundation Mapping, under BU#14, Flood Risk Management

NOAA managers provided the following assessments of elevation data requirements and benefits received from the enhanced elevation data quality level that they identified as mission-critical. Summarized details are provided in the following pages.

Coastal Mapping and Modeling

Mission-Critical Requirements

NOAA requires QL2 topographic lidar plus bathymetric lidar of coastal counties (except the bulk of Alaska) and QL5 IFSAR of coastal States for modeling, mapping, and forecasting coastal hazards; tsunami modeling and warnings; and support of NOAA initiatives, including the integrated ocean and coastal mapping initiative. Alaska coastal areas will require evaluation of lidar requirements after receipt and analysis of IFSAR data.

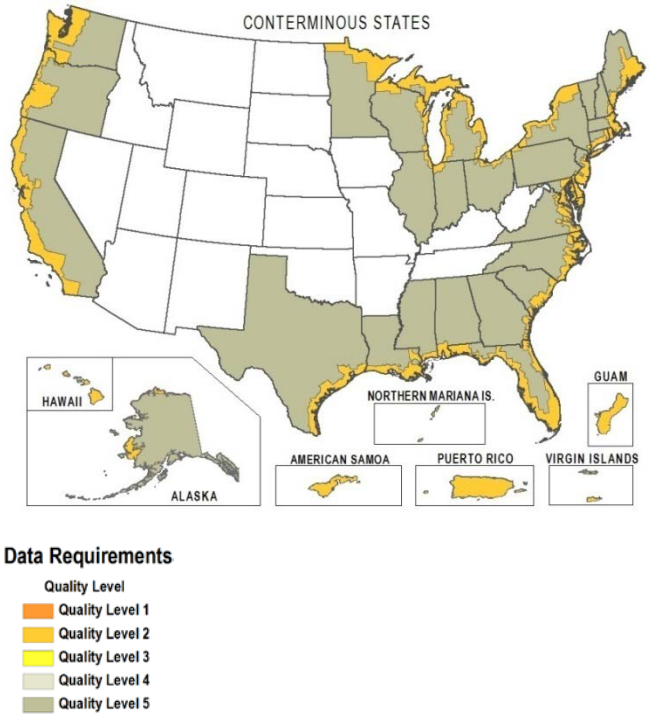
Update frequency: 4–5 years.

Business Use: Coastal Zone Management, BU#4, and Marine Navigation and Safety, BU#19.

Estimated program budget: $10 million per year, with less than half spent on elevation data and largely client-funded.

Quantifiable Benefits of Enhanced Elevation Data

Potential benefits of $9.8 million per year, of which $300,000 per year would come from improved in-house operational efficiencies, $8 million per year, from coastal communities through avoided losses, and $1.5 million per year, as savings to DEM users from having downloadable, integrated topographic and bathymetric datasets.



NOAA has determined that QL2 data that cover the coastal counties of the United States are needed for coastal mapping and modeling activities. With respect to tide coordinated lidar versus bathymetric lidar, NOAA has indicated that its requirement is to have seamless coverage of high-accuracy data across the intertidal zone (that is, no data gaps, areas of sparse, or noisy coverage) to enable extraction of tidally referenced shorelines. This requirement can be met in multiple ways, but the ideal case for seamless coverage is to have a combination of bathymetric lidar collected at (or above) mean high water (MHW) and topographic lidar collected at (or below) MLLW for areas with sufficient water clarity. However, the bathymetric requirements extend beyond the area that can be covered by lidar and generally the lidar-suitable area is only a small fraction of what is needed. In addition, bathymetric lidar is not considered by NOAA to meet the target detection requirements specified by the International Hydrographic Office for nautical charting but can serve as an effective preliminary survey tool.

NOAA coastal mapping and modeling activities include:

- Developing adaptation strategies for dealing with climate change and natural hazards such as hurricanes and tsunamis
- Producing and delivering nautical charts, hydrographic surveys, and other navigational products and services
- Providing surveying, positioning, and geodetic data and services for the construction, transportation, mapping, and other industries

Operational benefits (internal) to NOAA of enhanced elevation data for this functional activity

Time/Cost Savings: Moderate	Mission Compliance: Moderate	$ Benefits: $300,000 per year

- High-accuracy elevation data provide the ability to model, map, and forecast coastal hazards, including coastal flooding and storm surge heights from hurricanes. These models and maps are saving lives and property. Better data will allow coastal managers to make better management decisions. The benefits from this quality data can be difficult to quantify without first having the improved data. Studies of the opportunity costs for unnecessary evacuation have used $1 million per mile of coast, though some studies put the number much lower. Higher

accuracy and more current data are expected to change the predictions of impacted areas, reducing unnecessary evacuations.

- Completion of seamless coastal bathymetric and topographic maps for all inhabited coastal areas of the United States would enhance NOAA tsunami modeling and warning efforts and increase navigational safety.
- The availability of nationwide high-quality elevation data would provide some improvement to NOAA in operational efficiency (although not yet precisely quantified) by providing data that simultaneously support a wide range of coastal mapping, science, and management applications. The data would support NOAA's integrated ocean and coastal mapping (IOCM) initiative and provide approximately $300,000 annual benefits in reduced backlog.

Customer service benefits (external) to private and public partners from improved NOAA products and services

Performance: Moderate	Timeliness: Moderate	Experience: Moderate	$ Benefits: $9.5 million per year

- Customers will have better data to use for management decisions, which can be better informed by issues such as the effects of shoreline change, beach and shoreline management, flood risk assessment, and potential areas of inundation from future sea level rise. Avoiding siting municipal infrastructure or housing developments in areas likely to see losses due to sea level change could easily equate to $1 million avoided loss per coastal county. With approximately 200 of these counties facing the ocean in the continental United States, this equates to a $200 million benefit spread over 25 years (that is, an estimated customer service benefit of $8 million per year).
- Customers are benefiting from new coastal geospatial data products (for example, lidar point clouds) that are being distributed in addition to standard shoreline products.
- The availability of high-quality, tide-coordinated topographic or topographic-bathymetric data for larger portions of the coastal United States would result in NOAA being able to increase production of coastal mapping products for certain types of project areas.
- High-resolution coastal DEMs are currently used by NOAA's Tsunami Warning Centers to improve tsunami warnings. The DEMs provide significantly more accurate real-time tsunami forecasts and more effective, targeted, and less costly emergency response for at-risk U.S. coastal communities. Prior to the advent of digital elevation data and computer modeling, coastal communities could only be warned of when a tsunami wave might arrive, but not its expected height, inundation, or duration. The building of new or improved high-resolution, integrated bathymetric and topographic DEMs of U.S. coastal communities at risk of tsunamis would expand the coverage of coastal areas with DEMs to support NOAA's Tsunami Warning System. Such expanded coverage would further enhance and improve tsunami forecast and warning efforts and lead to more effective, targeted, and less costly emergency response in affected coastal communities. Alaska, especially, has a high known tsunami hazard and poor data coverage where these new data would be particularly valuable.
- Public dissemination of existing, unrestricted, high-resolution DEMs of select U.S. coastal communities from NOAA's National Geophysical Data Center (NGDC) has greatly benefited scientists, Federal and State agencies, private companies, journalists, and the public. The coastal DEMs save the users the intensive effort required to seamlessly integrate bathymetric and topographic data at the coast. To date, the NGDC thoroughly documented coastal DEMs have been downloaded more than 30,000 times in the past 4 years. The direct benefits realized from the improved tsunami models are difficult to quantify in terms of lives saved, but a rough estimate of the dollar savings to users downloading the data can be made. While the careful assembly of each coastal DEM requires an average of 3 months, it is assumed a typical individual user would only spend 1 day to make an inferior product that still meets their needs. This equates to 120 man-years saved (that is, 30 man-years annually or about $1.5 million per year) and does not include the additional savings for the subset users that require the high-quality DEM. The development and dissemination of additional unrestricted, accurate, high-resolution (about 10-m cell size), 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.

Other benefits from NOAA use of enhanced elevation data for this functional activity

Public/Social: Moderate	Environmental: Major	Strategic/Political: Moderate

- Better data mean managers and the public will have higher confidence in the results on which they are making their decisions. Higher confidence in the data means higher confidence in the products, which means more responsive management actions and reductions in risk from coastal inundation.
- Increased academic use of the data (for example, using lidar data in research and teaching at the University of New Hampshire Center for Coastal and Ocean Mapping Joint Hydrologic Center). The benefits of academic research are unpredictable by their very nature, but the general trend is that the overall benefits of research outweigh the costs.
- Increased use of the data in coastal resource mapping and monitoring, restoration, and other related areas.
- Increased interagency collaboration, cooperation, and support of cross-agency goals, standards, and specifications.

Coastal and Marine Resources Conservation

Mission-Critical Requirements

NOAA requires QL2 topographic lidar plus bathymetric lidar data for habitat delineation, assessment, and analysis; location of sample sites; and management of protected areas.

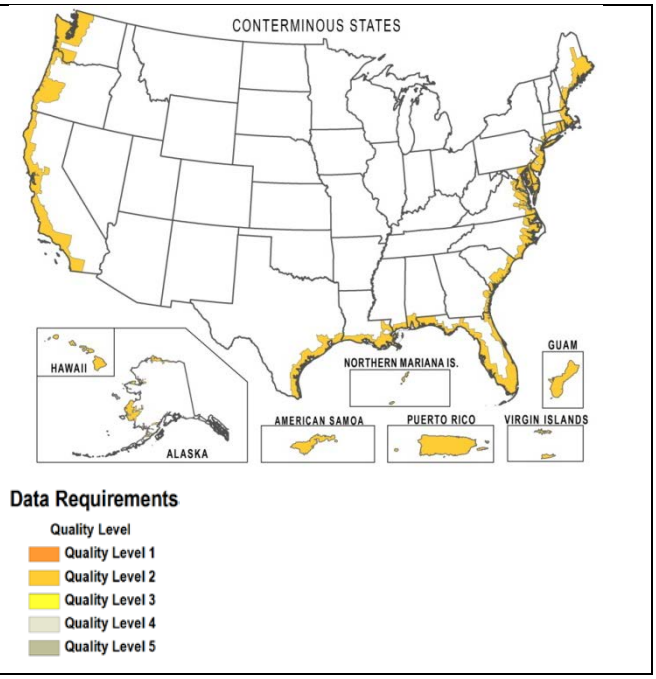
Update frequency: 4–5 years.

Business Use: Natural Resources Conservation, BU#1.

Estimated program budget: Budget estimate not available.

Quantifiable Benefits of Enhanced Elevation Data

NOAA estimated that it would benefit from high quality elevation data by $1.4 million per year. These benefits would be realized by the Coral Reef Conservation Program as well as through time and cost savings on field surveys and site visits, especially in remote coastal areas. Customer service cost benefits cannot be estimated.



NOAA manages marine resources within several offices, including the following:

- the National Marine Fisheries Service, which is responsible for the management, conservation and protection of living marine resources within the U.S. EEZ (water 3 to 200 miles offshore)
- the Office of National Marine Sanctuaries, which manages 13 sanctuaries and 1 marine national monument, encompassing more than 150,000 square miles of U.S. ocean and Great Lakes waters
- the Coral Reef Conservation Program, which coordinates all NOAA activities related to coral reefs

Most of the elevation data requirements for marine resources conservation activities are for bathymetric data. However, there is a need for either tide coordinated QL2 topographic lidar data in the near shore areas and (or) bathymetric data in areas between 0 and 20 m as well as for QL2 lidar data of wetland areas. Bathymetric lidar is an integral part of filling the needs in the shallow waters with sufficient clarity, though generally the lidar-suitable area is only a fraction of the required bathymetry. Bathymetric and topographic data are used to support the sampling design for fish surveys, delineate marine habitats, provide fish habitat consultations, assess impacts of oil spills, assess coastal injuries and restoration, locate sample sites, manage protected areas, identify coral reef resources, and characterize coral reef health.

Operational benefits (internal) to NOAA of enhanced elevation data for this functional activity

Time/Cost Savings: Moderate	Mission Compliance: Moderate	$ Benefits: >$1.4 million per year

- High-quality elevation data would save costs and time by reducing the time and equipment required for field visits to survey areas of interest. Additionally, site evaluations could be done in remote areas that are currently not accessible or too costly to evaluate.
- High-quality elevation data provide improved ability to consistently analyze habitats across broader coastal areas, including coastal areas in Alaska that have not previously been assessed due to lack of data.
- Completion of seamless coastal bathymetric and topographic maps would enhance the ability to conserve coral reefs as mandated by the Coral Reef Conservation Act. Benefits of elevation data are estimated to be approximately $1.4 million per year (5 percent of $300 million over 11 years).
- Coastal topographic and bathymetric lidar data would allow NOAA and partner agencies to better meet their conservation and management requirements for National Marine Sanctuaries and Marine National Monuments.
- Improved critical habitat evaluations and more focused critical habitat designations under the Endangered Species Act.
- Improved analysis of potential impacts to marine resources, including sea level rise among others.

Customer service benefits (external) to private and public partners from improved NOAA products and services

Performance: Major	Timeliness: Moderate	Experience: Moderate	$ Benefits: Cannot accurately estimate

- Improved quality of mapping provides value to NOAA's customers.
- Better communication with the public regarding local wetland issues that might affect their livelihoods and when new rules or regulations are being considered for specific species that rely on land or water interface areas during their life cycles.
- Better technical assistance to other Federal agencies regarding impacts of proposed projects to critical habitats, resulting in projects and activities with lower impacts to endangered species.
- Improved ability of communities to develop mitigation plans.

Other benefits from NOAA use of enhanced elevation data for this functional activity

Public/Social: Moderate	Environmental: Moderate	Strategic/Political: Moderate

- Improved collaboration with partner agencies and non-profit organizations, including the USCG, other Federal agencies, State and local partners, regional citizens groups, and environmental or public safety groups.
- Better data will result in projects and activities with lower impacts to endangered species and improved conservation of marine resources.
- Improved recreation and fishing opportunities resulting from improved marine habitats. Ecosystems, such as coral reefs, estuaries, and beaches, generate billions of dollars in tourism, recreation, and food revenues each year. Though accurate elevation data are important for the management of these areas and to maintain their economic values, the contribution of elevation alone cannot be estimated.

Advanced Hydrologic Prediction Service Static Inundation Mapping

Mission-Critical Requirements

NOAA requires QL3 lidar for FEMA's high priority areas, QL4 DEMs from imagery for FEMA's mid-priority areas, and QL5 IFSAR for FEMA's low priority areas. These data are required for hydrologic modeling, flood forecasting and warning, and flood inundation mapping of riverine areas nationwide for which NOAA provides advanced hydrologic prediction services.

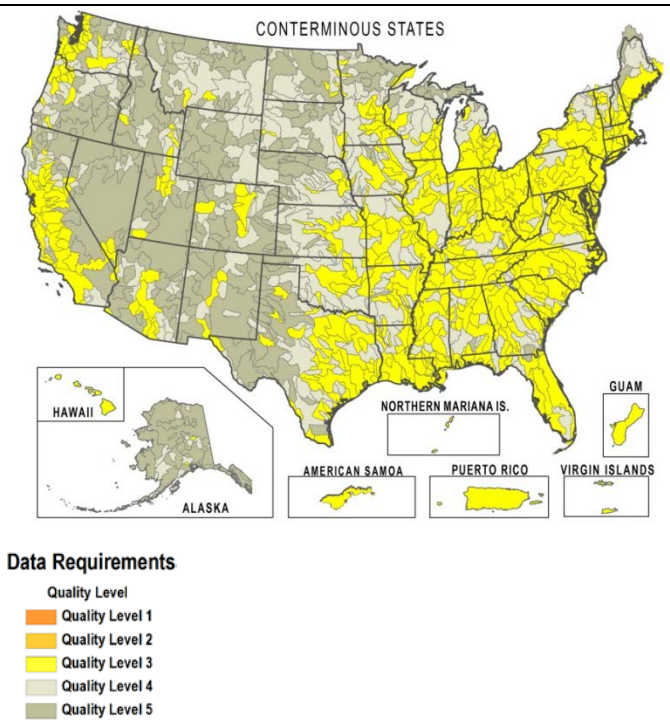
Update frequency: 4–5 years.

Business Use: Flood Risk Management, BU#14.

Estimated program budget: $400,000 per year.

Quantifiable Benefits of Enhanced Elevation Data

NOAA has estimated that the flood loss reduction benefits of the AHPS program can be estimated at $243 million per year and 10 percent ($24.3 million per year) can be directly attributed to lidar data.



Under NOAA, the NWS provides river and flood forecasts at approximately 4,000 locations nationwide and issues watches and warnings to protect life and property. As a part of this program, the NWS developed the Advanced Hydrologic Prediction Service (AHPS), which is designed to provide enhanced flood forecast information in graphical formats that are easier to understand and use. In 2007, the AHPS provided its first set of flood forecast inundation maps for North Carolina, in response to NWS stakeholder surveys indicating the need to better understand its hydrologic forecasts and the impacts of flooding at the local community level. Currently, the AHPS offers flood inundation maps for about 60 locations nationwide.

The maps are disseminated as a map library that allows the user to view the extent of the inundation and the depth of flooding. Using the digital elevation and hydraulic models, flood inundation maps are generated for various flood categories and at stage intervals normally from minor flooding to flood of record or major flooding, whichever is higher. The maps are generated slightly differently than FEMA FIRMs, which are regulatory maps based on flood frequencies. In particular, NOAA maps are based on hydraulic simulations of steady flow as the upstream boundary condition and the gage as the downstream or intermediate boundary condition. The simulations are repeated to target various elevations at the river gage until a collection of flood depth grids and inundation polygons is assembled. High-quality elevation data are needed for the AHPS flood mapping products. NOAA elevation data requirements for riverine flood forecast inundation mapping are similar to FEMA requirements for flood risk analysis.

If flood forecast inundation maps were available at all AHPS river forecast locations, the potential annual benefit of this service is estimated to be worth about $24 million per year or about 10 percent of the reported benefits in a study prepared for the National Hydrologic Warning Council (EASPI, Inc., 2002). The study concluded that the flood loss reduction benefits of the AHPS program would be $243 million per year. Additional benefits could be derived based on more effective risk mitigation planning and floodplain management. The flood inundation mapping service is dependent on the availability of elevation data of the appropriate quality for hydraulic modeling and flood inundation mapping. Detailed lidar data is essential to the success of the flood inundation mapping.

Operational benefits (internal) to NOAA of enhanced elevation data for this functional activity

Time/Cost Savings: Major	Mission Compliance: Major	$ Benefits: $24 million per year

- High-quality elevation data are critical to the hydraulic modeling and mapping of flood risk areas.

- Enhanced flash flood guidance and warnings for poorly drained soils, roadways, burned areas, and slot canyons are now possible.
- NWS inundation maps for river forecast locations are saving lives and property by showing the impact of forecast flood events using elevation data and models from FEMA flood insurance studies. NOAA has estimated that river and flood forecasts provided through the AHPS Program provide $243 million per year in flood loss reduction benefits. While it is difficult to estimate what fraction of the program's benefits can be attributed to accurate elevation data, about 10 percent or $24 million per year would be reasonable.

Customer service benefits (external) to private and public partners from improved NOAA products and services

Performance: Major	**Timeliness: Moderate**	**Experience: Major**	**$ Benefits: Cannot accurately estimate**

- High-quality elevation data result in enhanced decision support to the emergency management community, law enforcement officials, and disaster officials who ensure public safety in flood-prone areas. Local communities can better position resources using more refined geographic information about the extents of forecasted flood inundation areas.
- High-quality elevation data that cover more of the Nation's flood-prone areas would result in the ability of the NWS to provide AHPS flood inundation maps for currently unmapped areas that are at risk.

Other benefits from NOAA use of enhanced elevation data for this functional activity

Public/Social: Major	**Environmental: Minor**	**Strategic/Political: Moderate**

- Public safety benefits include the ability for the public to better understand the impacts of the flood forecasts provided by the NWS. Hydraulic modeling and mapping, developed using elevation data, improve communication of flood forecasts and risks.

Reference Cited

EASPI, Inc., 2002, Use and benefits of National Weather Service river and flood forecasts: National Hydrologic Warning Council, May, 21 p. plus three appendixes, accessed March 16, 2012, at http://www.nws.noaa.gov/oh/ahps/AHPS%20Benefits.pdf.

National Park Service

Points of Contact: Tammy Stidham (202) 619-7474 and David Duran (303) 969-2176, david_duran@nps.gov

The National Park Service (NPS) preserves unimpaired the natural and cultural resources and values of the national park system for the enjoyment, education, and inspiration of this and future generations. The NPS cooperates with partners to extend the benefits of natural and cultural resource conservation and outdoor recreation throughout this country and the world.

The NPS is divided into seven regions (fig. 1–7). There are 394 NPS units nationwide, including units in Puerto Rico, the U.S. Virgin Islands, Guam, and American Samoa.

Elevation data requirements differ because of the highly distributed nature of the NPS, and each unit has a separate congressionally defined enabling legislation, mission, and in some cases funding, resulting in varying responsibilities and associated unique requirements. The NPS also has several national level programs, including natural and cultural resources, visitor and resource protection, and facility management.

Figure 1–7. Map showing the delineations of the seven National Park Service regions. National parks, trails, and other areas are also shown. Modified from National Park Service (2011).

Examples of natural and cultural resources include rivers and streams, watersheds, wetlands, seashores, forests, vegetation, wildlife habitat, historical buildings, viewsheds, dams, archaeological sites, and trails and campgrounds used by park visitors.

Most NPS elevation requirements are best defined at the project level. Because of this and the distributed nature of the NPS and lack of tools and resources, it is difficult to summarize requirements, financial expenditures, or potential for quantifiable benefits. Requirements for elevation data are in general similar among NPS units. There are a wide variety of solutions to address NPS requirements for elevation data for the diverse variety of local needs. For example, QL1 and QL3 data are preferred for Alaska, just as they are for NPS units in the lower 49 States and

territories. However, the large size of NPS units in Alaska, their remoteness, perpetual cloud cover, current statewide lack of geodetic control, unavailability of nearby airfields, and other logistic factors make QL1 and QL3 data collection impractical; thus, QL5 becomes a practical solution because of the mechanics of current technology like the IFSAR data collector compared with lidar. IFSAR can penetrate through clouds, operates under all-weather conditions, and routinely flies long flight lines from distant airfields and at higher and safer altitudes.

Additional justification for why an IFSAR type of solution is a cost effective solution for Alaska, but not in the other 49 States:

- Lack of roads in Alaska and the high incidence of aircraft controlled flight into terrain (CFIT) accidents have established IFSAR as an Alaska statewide requirement for aviation safety and for search, rescue, and recovery of downed aircraft. For example, in autumn 2010, two aircraft crashed in remote areas of Alaska that required timely search and recovery. An Air Force F–22 aircraft crashed in an area already mapped with IFSAR, and an efficient search and recovery was based on those data. About the same time, an NPS aircraft crashed at Katmai National Park and Preserve, a region that did not have QL5 data, and the NPS search and in part discovery and recovery was hampered.
- Because of the lack of a suitable DEM (QL5) for which IFSAR satisfies minimal requirements, Alaska is the only State that does not have digital orthophoto coverage.
- P-band IFSAR offers the potential for mapping the geomorphology beneath glaciers.

Consistent with the NPS mission, NPS managers highlighted a single, all-inclusive functional activity with mission-critical requirements for enhanced elevation data:

- Preservation and Protection of Natural and Cultural Resources, under numerous business uses including #1, Natural Resources Conservation, and #13, Cultural Resources Preservation

NPS managers provided the following assessments of elevation data requirements and benefits received from the enhanced elevation data QL that they identified as mission-critical. Summarized details are provided in the following pages.

Preservation and Protection of Natural and Cultural Resources

Mission-Critical Requirements

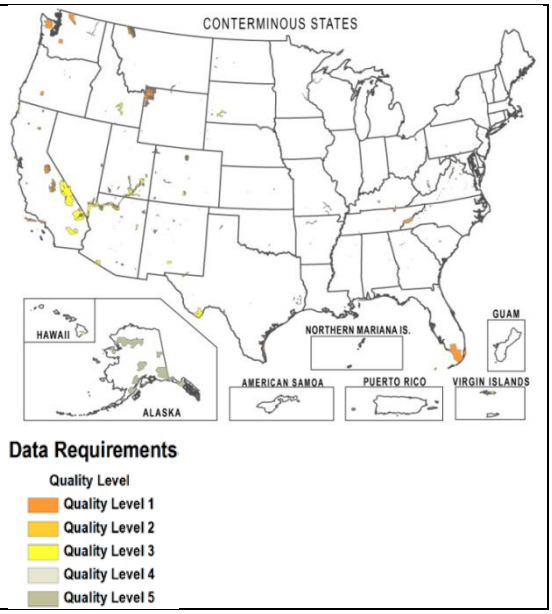
The NPS mission requirements can best be satisfied by three elevation data quality levels for management of natural and cultural resources—QL1 lidar for NPS units with dense forests and coastal areas subject to sea level rise in the lower 49 States and the U.S. territories; qL3 lidar for nonforested NPS units in the lower 49 States and the U.S. territories; and QL5 IFSAR data for NPS units in Alaska.

Update frequency: 6–10 years.

Business Use: Multiple business uses including Natural Resources Conservation, BU#1, and Cultural Resources Preservation, BU#13.

Estimated program budgets supported by elevation data: An unknown fraction of the more than $3 billion NPS budget request to Congress has mission-critical requirements for enhanced elevation data.

Quantifiable Benefits of Enhanced Elevation Data: Unable to estimate at this time.



In the critical decisionmaking processes, the current NED does not have the appropriate resolution or quality control. Questions, strategies, and decisions based on the NED concerning resources, visitor experience, recreation, safety, habitat assessments, mean high tide, watershed delineations, tree line elevation ascent, the spread of invasive species, wildfire behavior, sea level change, coastal inundation and erosion, and isostatic rebound need to be contained, and restrictions on use need to be documented.

High-quality elevation data (QL1, QL3) could be used by NPS park managers, researchers, and planners for multiple applications. DEMs and derivative products (slope maps, aspect maps, contours, and relief maps), where available,

are used to model vegetation, hydrologic drainage patterns, and wildlife habitat. DEMs are needed for mapping surfaces, computing volumetric changes of glaciers and sand, delineating floodplains and coastal wetlands, determining stream locations and flow patterns, and identifying cultural resources and landforms. DEMs are also used for habitat vulnerability assessments, storm surge simulations, glacial outburst floods, and tsunami and climate change scenarios. These are some of the requirements for the protection of natural and cultural resources.

A continued concern and risk is there are still no plans for a comprehensive, consistent, and sustainable data model that includes the entire United States and its territories. The following represents a small and incomplete sampling of requirements for an enhanced elevation model to meet NPS business requirements.

Operational benefits (internal) for the NPS of enhanced elevation data for this functional activity

Time/Cost Savings: Major	Mission Compliance: Major	$ Benefits: Unknown

- Engineering plans and designs for restoration of watersheds, stream banks, wetlands, forests, dams, and infrastructure are more efficient with QL1 lidar than with traditional USGS land surveys, especially when surveys cover broad areas. Many important restoration projects are in fact not cost effective to execute without available lidar-derived elevation data. Periodic elevation data updates are required for the ability of the NPS to monitor how restoration efforts are evolving (for example, volcanic activity, manmade alteration to terrain, landslide, and hydrologic actions).
- QL1 lidar enables the NPS to implement efficient sampling practices for natural resources inventory and monitoring, covering broad areas and minimizing the need for boots-on-the-ground inventories.
- QL1 data are mission-critical for many disciplines pertaining to natural and cultural resources, especially disciplines that model hydrology, sea level rise, vegetation, and habitat, for example.
- QL1 and QL3 (lidar) and QL5 (IFSAR) data are needed for production of orthophotography of national parks.

Customer service benefits (external) to the public from improved NPS products and services

Performance: Major	Timeliness: Moderate	Experience: Moderate	$ Benefits: Unknown

- NPS customers are the American public, park visitors, and communities that surround NPS lands. All customers benefit when QL1, QL3, and QL5 data enable natural and cultural resources to be preserved and protected for present and future generations.
- QL1 and QL3 data provide much better evaluation of resource inventories and conditions, more accurate park brochures, maps that are more engaging, more realistic visitor center displays and park ranger briefings, and better education opportunities for park visitors of resource protection and preservation.
- In Alaska, QL5 data are needed in order to produce the first-ever orthophotos statewide, including national parks where orthophotos are required by park managers and routinely requested by park visitors, especially hikers who might otherwise get lost in remote, unmapped areas. QL5 data are also needed in Alaska for safety of air navigation, search, and rescue.

Other benefits from NPS use of enhanced elevation data for this functional activity

Public/Social: Moderate	Environmental: Major	Strategic/Political: Major

- QL1, QL3, and QL5 data are mission-critical for glacier monitoring, evaluating erosion rates, assessing forest metrics, health, water resources management, landscape change detection, wildfire management, planning, and execution of restoration projects to name a few.
- QL1, QL3, and QL5 data help the NPS to better describe and model the status and trends of ecosystems, soils, vegetation, wildlife habitat, geologic features, and natural landscapes that make up our national parks.
- The national parks are public lands. By providing current information regarding the socially valued resources contained within parklands, the NPS is able to better understand, describe, and manage its land management obligations for the benefit of the public today and tomorrow.

Reference Cited

National Park Service, 2011, Harpers Ferry Center: National Park Service, accessed March 16, 2012, at http://www.nps.gov/hfc/cfm/carto-detail.cfm?Alpha=nps#.

National Science Foundation

Points of Contact: EarthScope, Ramon Arrowsmith, ramon.arrowsmith@asu.edu, *(480) 236-9226; NEON, Thomas Kampe,* tkampe@neoninc.org, *(720) 836-2414*

The mission of the National Science Foundation (NSF) is to promote the progress of science; to advance the national health, prosperity, and welfare; and to secure the national defense.

The NSF has supported the National Center for Airborne Laser Mapping as a facility that gathers high-resolution lidar topography for a range of Earth science needs as supported by the NSF Earth Sciences Division (EAR). For the National Enhanced Elevation Assessment, the NSF has identified two of the most evident and identifiable functional activities with mission-critical requirements for lidar data:

- EarthScope Initiative, under BU#9, Geologic Resource Assessment and Hazards Mitigation
- National Ecological Observatory Network (NEON), under BU#25, Education K–12 and Beyond

The value of lidar comes from its high spatial resolution; we can measure features at the appropriate scale. All other topographic data are coarser in resolution and thus the geometry of features that manifest phenomena is not directly accessible (it is below the grid scale) and cannot be represented directly. The ability to differentiate lidar returns from vegetative canopy, structures, and the ground permits characterization of biomass, canopy structure, burn severity; the built environment; and landforms otherwise obscured by vegetation. Furthermore, we have begun to see that differential lidar (3D differencing of lidar data gathered at different times over the same target) provides a truly unprecedented high accuracy view of the three dimensional changes in the Earth surface due to natural and anthropogenic processes including earthquakes, erosion and deposition, urbanization, and subsidence.

Lidar requirements and benefits for these two NSF functional activities are explained in the following pages. Both of these NSF programs share common benefits from nationwide lidar—the ability to evaluate all U.S. territory well beyond the relatively small areas sampled by these individual program initiatives, and mitigating uncertainties caused by extrapolating conclusions regarding unsampled areas. Thus, the scope, effect and overall value of both of these NSF initiatives would expand greatly as a result of nationwide lidar.

EarthScope Initiative

Mission-Critical Requirements

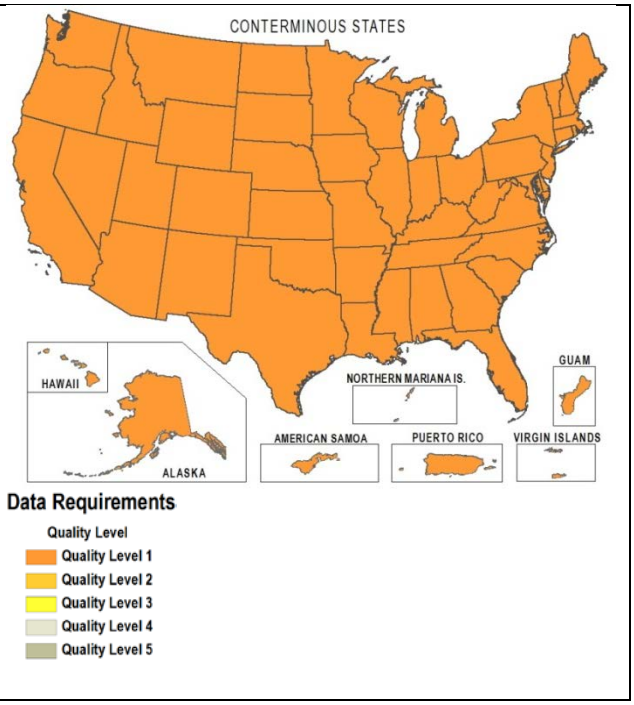
QL1 lidar is required nationwide, not just for selected areas where there is the greatest need for scientists to study seismic faults and their causes and effects. As was used in the EarthScope lidar acquisition, target areas were prioritized with community input gathered in a workshop process in which interested and informed parties met and provided guidance. However, nationwide lidar provides the ability to evaluate all U.S. territory well beyond the relatively small areas sampled by the EarthScope Initiative, and mitigating uncertainties caused by extrapolating conclusions regarding unsampled areas.

Update frequency: >10 years, with events-based new acquisition following a major seismic event.

Business Use: Geologic Resource Assessment and Hazards Mitigation, BU#9.

Estimated program budget supported by elevation data: Estimated to be $32 million per year.

Quantifiable benefits of enhanced elevation data: More than $5 million per year.



EarthScope is a program of the NSF that deploys thousands of seismic, GPS, and other geophysical instruments to study the structure and evolution of the North American continent and the processes that cause earthquakes and volcanic eruptions. It involves collaboration between scientists, educators, policymakers, and the public to learn about and utilize exciting scientific discoveries as they are being made. EarthScope provides a framework for broad, integrated studies across the Earth sciences, including research on fault properties and the earthquake process, strain transfer, magmatic and hydrous fluids in the crust and mantle, plate boundary processes, large-scale continental deformation, continental structure and evolution, and composition and structure of the deep Earth. In addition, EarthScope offers a centralized forum for Earth science education at all levels and an excellent opportunity to develop cyberinfrastructure to integrate, distribute, and analyze diverse datasets.

Lidar acquisition is a key component of the EarthScope effort that is complementary to the main observational assets. It provides data with a range of applications that will advance many of the EarthScope goals. The EarthScope lidar Working Group identified primary targets for data acquisition of active faults, ranked these targets, and proposed a data acquisition scheme. Within available funding, lidar data were acquired for some of the higher priority areas, but other areas remain to be acquired. The data that were gathered are now freely available and used by many scientists, engineers, and citizens from the NSF-sponsored Open Topography Web site (Open Topography, undated). EarthScope's regional active fault targets are

- Northern California, including the San Andreas Fault north of Parkfield and other major strands of the San Andreas Fault system. The 1906 San Francisco earthquake occurred along the San Andreas Fault in this area. The nine counties that comprise the greater San Francisco Bay area (population of more than 7 million) lie within this region, making this system of faults among the most important in the United States in terms of seismic hazard. The intense forest cover that blankets much of this region has hampered detailed study of these faults, making lidar an especially useful tool.
- Southern California, including the southern San Andreas Fault, the San Jacinto Fault, the Garlock Fault, the Eastern California Shear Zone south of Garlock, the Elsinore Fault, and regions of the transpressional faulting in the Transverse Range region. The great 1857 earthquake occurred along the San Andreas Fault in this region, and repeats of major events like it along the major strike slip faults represent significant hazard to the tens of millions of people living in the area. These target areas also lie at the heart of a geodetic-geologic mismatch controversy. For the Garlock Fault, the geologic rates are more rapid than the geodetic rates, whereas the opposite appears to be true for the Eastern California Shear Zone. Lidar is needed to resolve such scientific problems at the core of our understanding of fault mechanics.
- Eastern California, Walker Lane, and the Basin and Range Fault systems, including faults of the Eastern California Shear Zone north of the Garlock Fault. The motivation to establish a lidar archive is to allow assessment of longer term rates of fault displacement, which may be compared with modern geodetic measurements, to provide an initial database for a wide spectrum of geologists to study the processes attendant to the structural, physiographic, and geomorphic development of the Great Basin that results from the release of the ongoing accumulation of strain that is measured by the Plate Boundary Observatory, to document the slip character of historical earthquakes, and to provide an archive of sites that may be the locus of future earthquake displacements.
- The Intermountain Seismic Belt, including the Wasatch Fault, the Teton Fault, the Yellowstone Park area, and northern extensions of the system through Idaho and Montana. Targets for lidar acquisition focus on the geomorphology, slip-rates, and kinematics of seismogenic normal faulting, the structural and dynamic interactions between the Yellowstone volcanic hotspot and regional extension of the continental lithosphere, and the structural transition from extension to strike-slip faulting and contraction at the northern boundary of the Basin and Range Province. The magnitude 6.9 earthquake at Borah Peak, Idaho, in 1983 occurred in this region. The Teton normal fault poses significant earthquake hazard to the growing population of the Jackson Hole, Wyoming, region, including the possibility of dam failure, flooding, and disruption of irrigation for agriculture in adjacent parts of Idaho. The magnitude 7.3 earthquake at Hebgen Lake, Montana, in 1959 demonstrated the potential impact of ground rupture and shaking in mountainous terrain.
- Cascadia, including the Mad River and Little Salmon Fault zones in southern Cascadia, the Calawah Fault in the Washington forearc, and the Yakima Fold belt termination. This includes the highly populated Puget Sound and Portland, Oregon, regions. The Mad River and Little Salmon Faults in a sense also reflect the northernmost extent of the San Andreas plate boundary, although the linkage between these two segments of the North American plate boundary is not well understood. Lidar topography along these faults in concert with that obtained for northern California will provide an important dataset to improve our understanding of the links

between Cascadia and the San Andreas Fault. Recently, new active faults have been documented with lidar topography in Oregon in the area of Mount Hood (Rojas-Burke, 2011); this documentation was possible because of the high accuracy and vegetation penetration of the lidar technology.

- Alaska, including the Castle Mountain and Denali Faults and the Nenana River terraces. Alaska is the most seismically active region in the United States (fig. 1–8) because of plate interactions that include transform faulting, plate subduction, and microplate collision. Alaska contains the highest point in North America at more than 20,300 feet of elevation at Mount McKinley and one of the most spectacular coastal mountains belts on Earth where the Saint Elias Mountains are forming in response to collision of the Yakutat microplate in the transition from transform faulting along the Fairweather Fault to subduction and accretion at the northeastern end of the Aleutian trench. Farther west, subduction of the Pacific Plate creates the Alaska-Aleutian volcanic arc where there are scores of active volcanoes and frequent large to great magnitude earthquakes. Alaska is the premier place in the United States to study plate margin and intracontinental deformation driven by subduction and microplate collision. The latter process is of global significance because most mountain belts are formed largely by the collision and accretion of plate fragments over time. In Alaska, we are just learning how profound such collisions can be—low-angle subduction of the Yakutat microplate is now thought to drive active deformation far into the interior of the North American plate, over distances of 1,000 km inland. Although the population density of Alaska remains relatively small compared with that of much of the United States, there is significant risk to people and infrastructure. The loss of one key bridge near Wasilla, for example, would deny the use of State Highways 1 and 3 that provide the logistical lifeline to a broad area north and east of Anchorage. The State of Alaska is constantly rocked by large to great magnitude earthquakes. Figure 1–7 maps the major earthquakes in Alaska. The magnitude 9.2 earthquake of March 7, 1964, for example, ruptured the Aleutian subduction zone for hundreds of kilometers. Slip along this rupture was as high as 20 m. The event is the second largest historic earthquake. That earthquake's devastating effects are still visible to those driving south of Anchorage toward Seward.

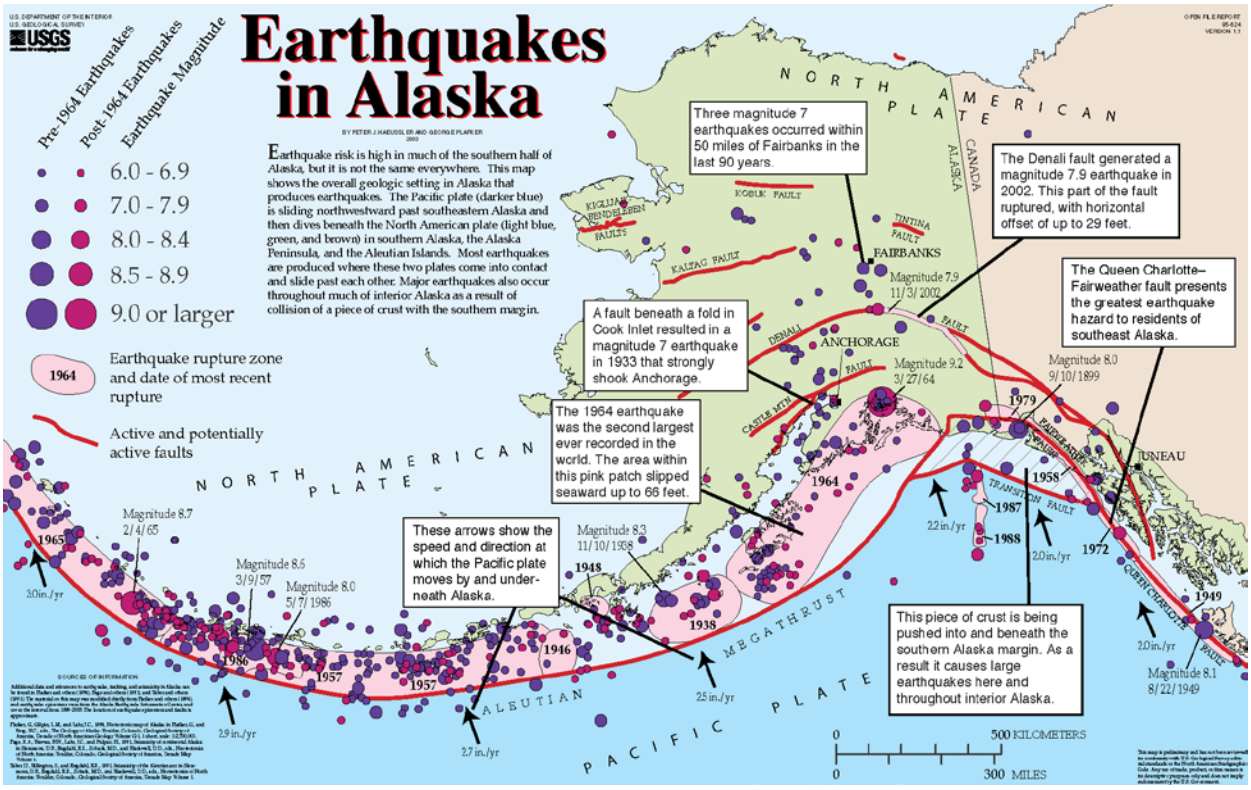


Figure 1–8. Map showing the overall geologic setting in Alaska that produces earthquakes. The Pacific plate (darker blue) is sliding northwestward past southeastern Alaska and then dives beneath the North American plate (light blue, green, and brown) in southern Alaska, the Alaska Peninsula, and the Aleutian Islands. Most earthquakes are produced where these two plates

come into contact and slide past each other. Major earthquakes also occur throughout much of interior Alaska as a result of collision of a piece of crust with the southern margin. From Haeussler and Plafker (1995).

Of course, there are many other earthquake hazards in the United States. The New Madrid Fault zone, for example, encompasses a broad area around the southeastern tip of Missouri where it joins with Tennessee, Illinois, and Arkansas. Three major earthquakes occurred here in 1811–1812, with magnitudes of 7.5 to 7.7. The geologic record of earthquakes from the period before 1811 reveals that the New Madrid seismic zone has repeatedly produced sequences of major earthquakes during the past 4,500 years. The New Madrid seismic zone remains a significant risk for damaging earthquakes. After a tsunami in Japan on March 11, 2011, and an earthquake centered in Mineral, Virginia, on August 24, 2011, there is increased interest in evaluating the effects of potential earthquakes on U.S. nuclear power plants as far as 1,000 miles away from the epicenter of an earthquake. Indeed, the high accuracy and vegetation penetrating capabilities of lidar are required for a more complete characterization of potentially active faults in the central and eastern United States and the Caribbean.

A recent lidar acquisition gathered more than 300 km^2 of high-quality lidar data in the area of the magnitude 7.3 April 4, 2010, earthquake of northern Baja California, Mexico (Open Topography, 2010). These data have been of great value in the detailed characterization of the complex surface rupture earthquake, and when combined with lidar data from before the earthquake gathered by the Mexican Statistic and Geographic Agency have provided a revolutionary view of the deformation along and between the faults that ruptured. This repeat capacity is a requirement and a major motivator for further data acquisition.

The EarthScope initiative has generally acquired lidar data in relatively narrow swath widths (typically 1 km, widened to 2 km of more in key regions) and up to 50, 100, or even 150 km long, which allowed more line-kilometers of data to be obtained. The unavoidable consequences of this choice are that areas away from the main fault strands are not mapped, more complex flight lines may be necessary, and the data obtained in the initial acquisition may have limited value to researchers interested in nonfault specific topics. EarthScope managers hope that their datasets will be augmented in the future with broader area data acquisition that mitigates these shortcomings. EarthScope endorses "before (B4)" style acquisition so that baseline data are available in broader seismic zones for comparison with lidar acquired after an event changes the topography. In general, the community has agreed with decisions to focus spatially and gather highest density and quality data.

EarthScope disseminates its data freely through the Open Topography Web site (Open Topography, undated), an initiative to build an online system that provides integrated access to high-resolution topographic data (including point cloud data) and Web-based processing tools. Open Topography enables the user community to share knowledge, experiences, and resources. Numerous workshops and significant training are available for students, educators, agency scientists and engineers, and consultants. The goal of Open Topography is to provide a portal where access to various public domain airborne and terrestrial lidar, bathymetry, and other topographic data can be centralized. Open Topography is a collaboration between computer scientists at the San Diego Supercomputer Center, Earth scientists at Arizona State University, and others. It is an excellent example of functioning cyberinfrastructure in the geosciences.

Operational benefits (internal) for the NSF of enhanced elevation data for this functional activity

Time/Cost Savings: Moderate	**Mission Compliance: Major**	**$ Benefits: Cannot quantify**

- QL1 lidar of designated areas will enable NSF scientists in the EarthScope community to perform basic research on seismic faults. Internationally, scientists have tried using elevation data of lesser accuracy and resolution and have concluded the QL1 lidar data are required to map seismic faults that are not visible when walking the terrain on top of such faults.

Customer service benefits (external) to the public from improved NSF products and services:

Performance: Major	**Timeliness: Moderate**	**Experience: Major**	**$ Benefits: >$5 million per year**

- The NSF lidar point cloud data are used by scientists everywhere for a broad array of Earth science research, especially as pertains to the potential mitigation of earthquakes. Open Topography serves hundreds of scientists with billions of lidar points with added processing and education.
- It is extremely difficult to estimate value to the public, which can be estimated to range between $5 million per year to tens of millions of dollars per year in savings to agencies who support data gathering in piecemeal, and

the economies of scale for acquisition as well as delivery for these data are very clear. The fundamental science that is performed helps to delineate the earthquake and other natural hazards for the entire United States; the damages from these hazards are estimated to be about $50 billion per year in total. An individual earthquake can easily cause upwards of $10 billion in losses. These data do not directly mitigate the losses, but their availability has enabled significant scientific insights that have refined our understanding of the probability of natural hazards, in particular their spatial disaggregation (for example, U.S. Global Change Research Program, 1997).

Other benefits from NSF use of enhanced elevation data for this functional activity

Public/Social: Major	Environmental: Moderate	Strategic/Political: Major

- Earthquakes have huge public and social consequences. When lidar is used to study the causes and effects of earthquakes, resultant actions to mitigate these consequences also have huge public and social benefits as well as strategic and political benefits in the long run. Mitigation includes the identification of need to purchase earthquake insurance and to build infrastructure to higher standards to withstand potential earthquakes of the future. In the case of recent earthquakes, especially Haiti, lidar data were gathered immediately after the earthquake and contributed to response and recovery activities (Open Topography, 2010b).

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U.S. Global Change Research Program, 1997, Natural hazards, human impacts, and disaster reduction: U.S. Global Change Research Program seminar, May 22, accessed March 19, 2012, at http://www.usgcrp.gov/usgcrp/seminars/97514DD.html.

National Ecological Observatory Network

Mission-Critical Requirements

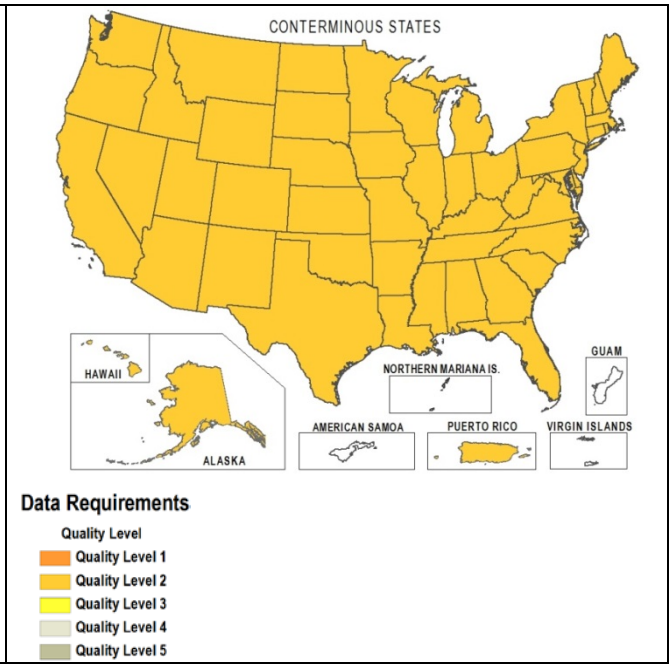
QL2 lidar is required nationwide so that NEON's lidar data, acquired annually of 60 representative sites (3 sites each in 20 domains), can be extrapolated nationwide with equally accurate lidar acquired less-frequently elsewhere.

Update frequency: 4–5 years, though annual updates would be preferred.

Business Use: Education K-12 and Beyond, including Basic Research, BU#25.

Estimated program budget supported by elevation data: $480 million.

Quantifiable benefits of enhanced elevation data: Cannot quantify.



Sponsored by the NSF, the National Ecological Observatory Network (NEON) is an ecological observation platform for discovering, understanding and forecasting the impacts of climate change, land use change, and invasive species on continental-scale ecology. NEON will operate for 30 years and gather long-term data on ecological response changes and on feedbacks with the geosphere, hydrosphere, and atmosphere. Local ecological measurements at sites distributed within 20 ecoclimatic domains across the contiguous United States, Alaska, Hawaii, and Puerto Rico will be coordinated with high resolution, regional airborne remote sensing observations. The land use analysis package will assimilate satellite remote-sensing data and topographic data from national databases that ecological modelers and forecasters can use to extend their models to a continental scale. The Airborne Observation Platform (AOP) is an aircraft platform carrying remote sensing instrumentation designed to achieve sub-meter to meter scale ground resolution, bridging scales from organisms and individual stands to satellite-based remote sensing. AOP instrumentation consists of a visual and short-wave infrared (VIS/SWIR) imaging spectrometer, a scanning small-footprint waveform lidar for 3D canopy structure measurements, and a high resolution airborne digital camera. AOP data will be openly available to scientists and will provide quantitative information on land use change and changes in ecological structure and chemistry including the presence and effects of invasive species. Three AOP aircraft will be flown, providing regular annual mapping of NEON sites.

The biology-focused NEON is an NSF-sponsored Earth science initiative to establish an ecological observation platform for discovering, understanding and forecasting the impacts of climate change, land use change, and invasive species on continental-scale ecology. Carbon dioxide, a key driver of climate change, is produced by a host of processes including clearing of forests, extraction and use of fossil fuels that affect the global energy balance. Invasive species modify the continental biosphere. Aquatic systems are coupled to terrestrial systems and the marine environment. Flowing water, which acts as a transducer of climate, land-use, and invasive species effects, spread their impacts from terrestrial and upstream centers of action downstream and into distant systems. Human activities such as urbanization create new connections; materials, organisms, and energy flow into cities from globally distributed sources and waste products are exported back into the environment.

For NEON to function as a continental-scale observatory, it must demonstrate that methods exist to produce continental estimates using NEON's observing strategy which is based on 20 ecoclimate domains (fig. 1–9), each including a core site and two relocatable sites. The first figure on the next page maps these domains with their core and relocatable sites, and the second figure maps the NEON domain representativeness. With NEON's own lidar sensor mapping only 60 sites annually, nationwide lidar could enable poorly represented areas to be better represented and perhaps well represented (fig. 1–10).

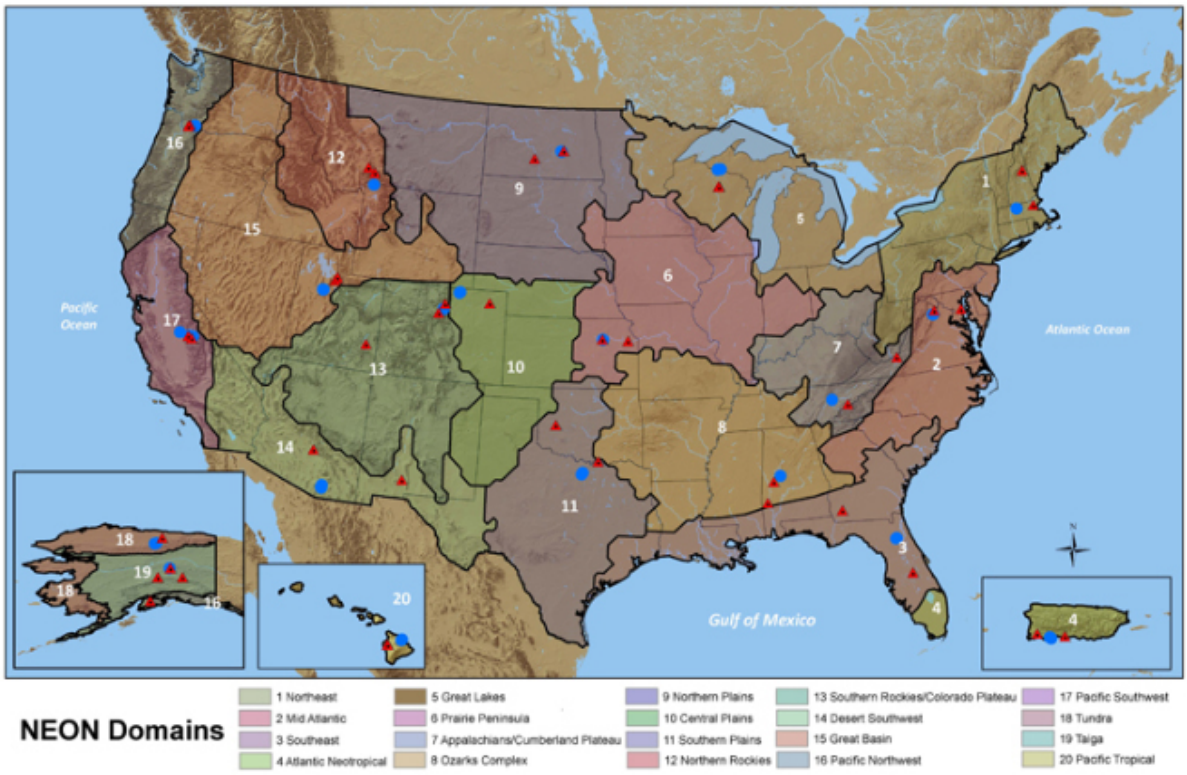


Figure 1–9. Map showing the domains of the National Ecological Observatory Network. Within each of the 20 domains, there is one core site (blue dots) and two relocatable sites (red triangles) that will be moved nominally at five-year intervals.

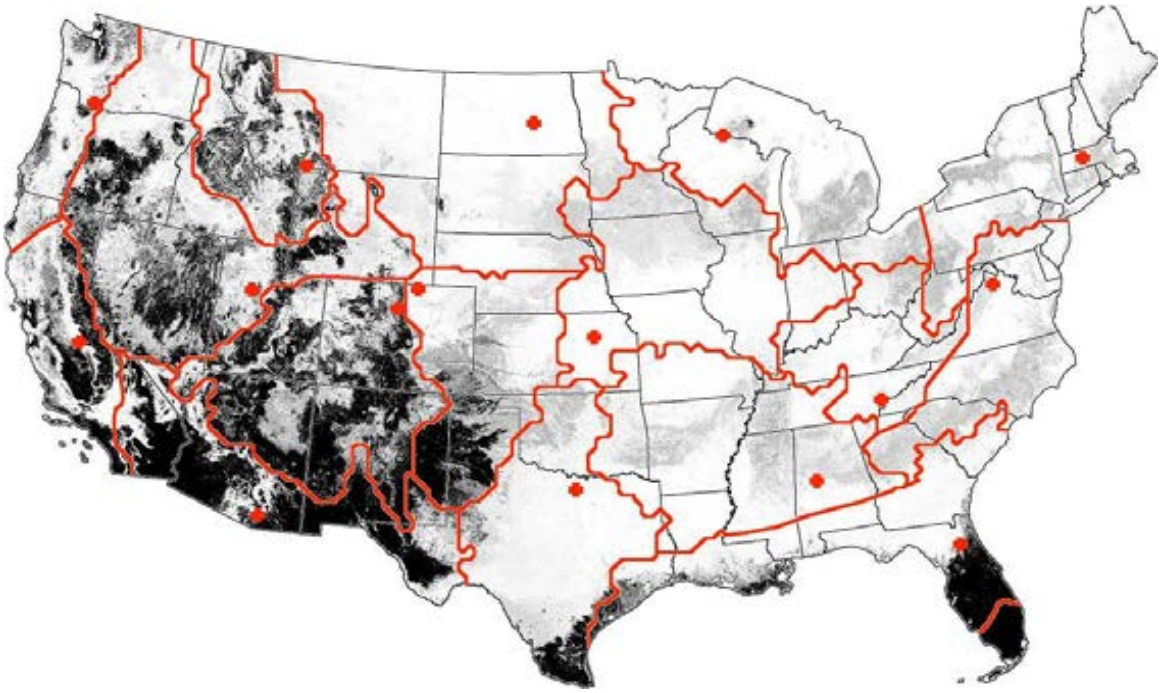


Figure 1–10. Map showing National Ecological Observatory Network representativeness. The locations of candidate core sites are represented by red symbols. The shading from white (well represented) to black (poorly represented) indicates the quality of representation for a given area, based on the set of candidate core sites.

NEON's educational and outreach programs will include numerous physical and virtual capabilities to enable education and public use of the facility, including: (1) a central web portal to provide on-line learning experiences, including access to scientific data, focused on the fundamental concepts associated with NEON; (2) a web portal providing tools for decisionmakers to use NEON data to make scientifically-based decisions related to climate and land-use change; (3) professional development opportunities to prepare educators to use NEON data and educational tools, provide opportunities for educators to contribute to education product development and facilitate community collaboration, and investment in effective ecological education; (4) research and internship opportunities for undergraduates to prepare future generations of ecological scientists and science, technology, engineering, and mathematics (STEM) professionals to use NEON data and broaden participation in STEM experiences by traditionally under-represented groups; and (5) workshops, seminars and courses to provide training and learning experiences for individuals to more effectively use and contribute to NEON data, tools, and learning experiences.

Operational benefits (internal) for the NSF of enhanced elevation data for this functional activity

Time/Cost Savings: Moderate	**Mission Compliance: Major**	**$ Benefits: Cannot quantify**

- The overarching scientific goal of NEON is to enable understanding and forecasting of the impacts of climate change, land use change, and invasive species on continental-scale ecology. To accomplish this, NEON must be able to extrapolate relationships between the ecosystem drivers (climate change, land-use change, and biological invasions) and the ecological consequences to areas not sampled by the NEON facilities, but where partial, extensively sampled, or gridded information is available. Nationwide lidar will help NEON with concerns about areas being under-sampled or under-represented, providing biomass statistics nationwide, for example, with more-complete data for nationwide assessments.

Customer service benefits (external) to the public from improved NSF products and services:

Performance: Major	**Timeliness: Major**	**Experience: Major**	**$ Benefits: Cannot quantify**

- Nationwide QL2 lidar, when openly available in the public domain to scientists, will provide quantitative nationwide information on land use change and changes in ecological structure and chemistry including the presence and effects of invasive species. This dramatically increases the value to scientists in developing nationwide conclusions, far beyond the 60 NEON sites.

Other benefits from NSF use of enhanced elevation data for this functional activity

Public/Social: Unknown	**Environmental: Major**	**Strategic/Political: Unknown**

- The biology-focused NEON is an NSF-sponsored Earth science initiative to establish an ecological observation platform for discovering, understanding, and forecasting the impacts of climate change, land use change, and invasive species on continental-scale ecology. The environmental benefits of lidar data for the success of this initiative are major but cannot be calculated.

Natural Resources Conservation Service

Point of Contact: Steve Nechero (817) 509-3366, Steven.Nechero@ftw.usda.gov

Programs of the Natural Resources Conservation Service (NRCS) help people reduce soil erosion, enhance water supplies, improve water quality, increase wildlife habitat, and reduce damages caused by floods and other natural disasters. Enhanced natural resources help sustain agricultural productivity and environmental quality while supporting continued economic development, recreation, and scenic beauty.

Seventy percent of the land in the United States is privately owned, making stewardship by private landowners absolutely critical to the health of our Nation's environment. Working at the local level in field offices at more than 3,000 U.S. Department of Agriculture (USDA) Service Centers in nearly every county in the Nation, the NRCS works with landowners through conservation planning and assistance to benefit the soil, water, air, plants, and animals for productive lands and healthy ecosystems.

Lidar and derivative data are critical to good conservation. NRCS experts from many disciplines help landowners conserve natural resources in efficient, smart, and sustainable ways. To this end, the NRCS has always valued elevation data in general, and slope, aspect, and curvature data in specific, for controlling the rates of erosion and runoff and for the use of irrigation systems, ponds, contours, terraces, and vegetation for soil and water conservation so that water is stored in the soil and does not contribute to floods or sediment loading from farm runoff.

Part of the NRCS Integrated Accountability System, the Performance and Results Measurement System (PRMS) is an Web-based data warehouse that allows the NRCS to report activity progress across the Nation (fig. 1–11). For the National Enhanced Elevation Assessment , the PRMS was used by the Conservation Engineering Division (CED) for detailed time and cost savings estimates from lidar. The rigorous cost benefit analyses by the CED and input from other NRCS representatives described below demonstrate that NRCS cost savings for programs with mission-critical requirements for lidar are probably within the range of 2 percent (conservative) and 5 percent (plausible).

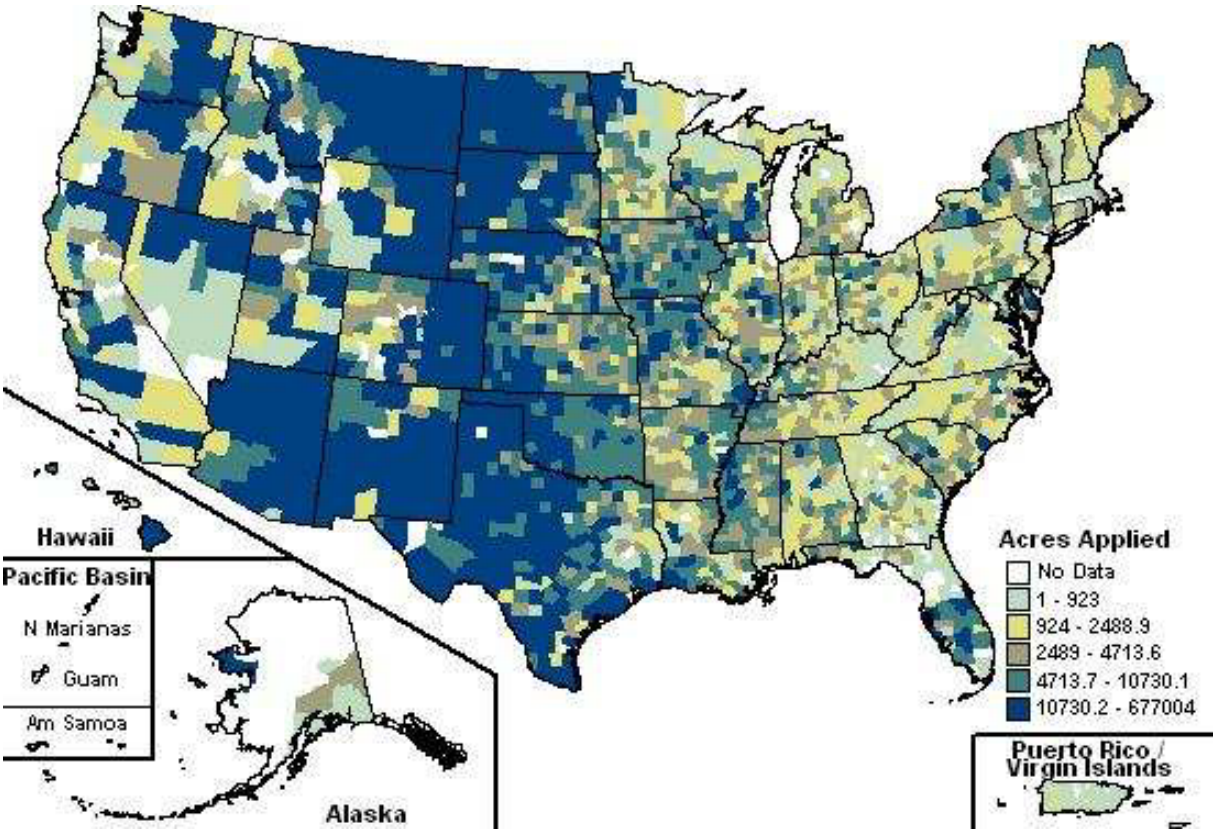


Figure 1–11. Performance Review and Management System data, displayed in maps and tables, are updated daily, for real-time monitoring of Natural Resources Conservation Service activities.

The total amount for technical assistance obligations in fiscal year 2010 was $1,120,884,884 or 30.36 percent of the total NRCS budget of $3.7 billion; financial assistance obligations amounted to $2.5 billion (Natural Resources Conservation Service, 2011). There is not direct link to high-resolution elevation for financial assistance. Activities of the Conservation Reserve Program (CRP) provided $56,792,351 in reimbursable funds in fiscal year 2010; a business case can be made for high-resolution elevation data for the wetland CRP.

The CED national discipline lead or co-lead for each national conservation practices standard (NHCP) estimated the time saved or enhanced production if QL2 lidar was available to assist with the planning, design, and construction of each practice. The CED used the 2010 PRMS data to obtain the applied amount. The estimated average hourly savings were based on non-entry-level professional employees. The total estimated savings was approximately $36 million.

NRCS managers identified two major functional activities with mission-critical requirements for enhanced elevation data:

- Conservation Engineering and Practices, under multiple business uses, primarily BU#1, Natural Resources Conservation
- NRCS Specialized Mapping Applications, under multiple business uses, primarily BU#1, Natural Resources Conservation

NRCS managers provided the following assessments of elevation data requirements and benefits received from the enhanced elevation data quality level that they identified as mission-critical. Summarized details are provided in the following pages.

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Natural Resources Conservation Service, 2011, FY 2010 EQIP contracts and dollars obligated: Natural Resources Conservation Service, accessed March 19, 2012, at http://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/national/programs/?&cid=stelprdb1044131.

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Conservation Engineering and Practices

Mission-Critical Requirements

Enhanced elevation data (QL2 lidar and QL5 IFSAR) for non-Federal lands, and a modernized IT infrastructure are mission-critical for a broad array of conservation engineering and practices for diverse conservation technical assistance (CTA) programs managed by the NRCS.

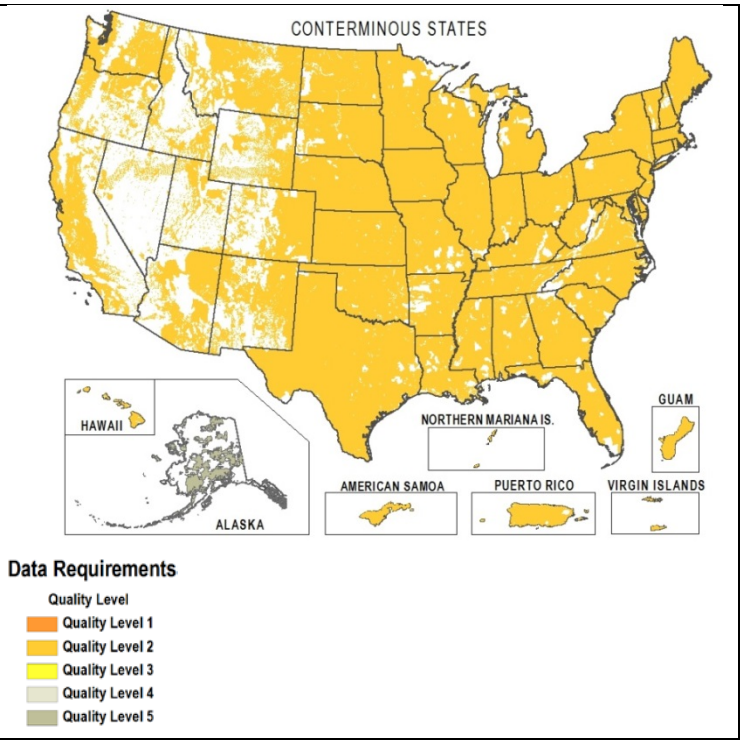
Update frequency: 6–10 years.

Business Use: Multiple, primarily Natural Resources Conservation, BU#1.

Estimated program budgets supported by elevation data: about $3 billion per year.

Quantifiable Benefits of Enhanced Elevation Data

The NRCS would save a minimum of $60 million per year from lidar, and possibly as much as $150 million per year if each Federal and State program were rigorously analyzed.



The USDA budget for FY2011 identifies $797 million for CTA activities that enable the NRCS to focus on the highest priority programs such as improving and streamlining technical assistance delivery to farmers, implementing Strategic Watershed Action Teams (SWAT), and updating the information technology (IT) infrastructure (which includes elevation data for mission-critical applications). This budget also includes mandatory Farm Bill programs for the Environmental Quality Incentives Program (EQIP), the Conservation Security Program, the Conservation Stewardship Program, the Agricultural Water Enhancement Program, and the Chesapeake Bay Watershed Program. Portions of these programs, which total about $3 billion, have mission critical requirements for lidar data for science-based conservation engineering and practices.

If the NRCS assumes a minimum 2 percent improvement in efficiency and (or) effectiveness for the programs with mission-critical requirements for lidar, the savings would be at least $60 million. This is believed to be a conservative estimate because the NRCS has more than 3,000 service centers throughout the United States and territories and could not possibly collect and aggregate realistic cost-benefit input from all. The NRCS deliberately selected a small number of representatives to participate in the questionnaire and workshop processes. Of 17 questionnaire responses, 13 specified major time and cost savings from lidar. Of these, only four provided specific cost-savings estimates:

- The only State engineer participant estimated $1.5 million per year savings for the EQIP and the Wetlands Reserve Program (WRP) in Minnesota alone by planning and design without field surveys. Similar, probable savings for the other States are unknown.
- The National Water Management Center estimated $2 million per year savings from reduced or eliminated stream cross-section surveys.

- Managers of the CED were tasked to systematically estimate time saved or production enhanced if high quality lidar was available to assist with planning, design, and construction of each practice. More than 100 practices were analyzed with the assistance of PRMS data, and 69 were determined to have major cost benefits from lidar. The CED computed savings of $35.7 million per year for this one division within the NRCS. No other division within the NRCS, or in any other Federal agency, expended this level of effort to rigorously compute cost savings from lidar.
- No specific cost savings were provided by the Conservation Planning and Technical Assistance Division (CPTAD) where respondents described major reductions in time and cost for field visits, performed more cost-effectively by terrain analyses performed in the office with lidar data.
- No specific cost savings were estimated by the Resources Inventory and Assessment Division (RIAD), which did provide detailed explanation of mission-critical needs for lidar for the National Resources Inventory (NRI) and Conservation Effects Assessment Project (CEAP).
- No specific cost savings were estimated by the Ecological Sciences Division (ESD) where lidar is known to be mission critical for diverse ecological analyses and studies.
- The Soil Survey Division (SSD) provided specific estimates of cost savings for the NRCS Specialized Mapping Applications functional activity, described below.

Operational benefits (internal) for the NRCS of enhanced elevation data for this functional activity

Time/Cost Savings: Major	**Mission Compliance: Major**	**$ Benefits: >$60 million per year**

- Of the 69 practices within the CED with computed cost savings from lidar, those engineering and design practices with savings of more than $1 million per year included for critical area planting, grade stabilization, grassed waterways, heavy use area protection, pipelines, ponds, riparian forest buffers, terracing, waste transfer, and wetland restoration; 59 other CED practices each had savings of less than $1 million per year.
- Elsewhere in the NRCS, respondents almost unanimously identified that major reductions in field surveys and reductions in field visits enabled by the use of lidar data would yield major time and cost savings and enable them to better serve more customers.

Customer service benefits (external) to the public from improved NRCS products and services

Performance: Major	**Timeliness: Major**	**Experience: Major**	**$ Benefits: Unknown**

- The 2008 Farm Bill offers incentives for voluntarily implementation of conservation structures and management practices. It provides conservation provisions to help reduce erosion, guard streams and rivers, and restore and establish fish and wildlife habitat. Lidar data help the government, landowners, and farm operators benefit from financial and economic incentives in such programs as the EQIP, the Chesapeake Bay Watershed Initiative, the WRP, the Wildlife Habitat Incentive Program, the Agricultural Management Assistance Program, the Conservation Stewardship Program, and the Grassland Reserve Program.

Other benefits from NRCS use of enhanced elevation data for this functional activity

Public/Social: Major	**Environmental: Major**	**Strategic/Political: Major**

- The customer service benefits described above provide broader public and social, environmental, and strategic and political benefits to all Americans sustained by a safe and healthy environment.

Specialized Mapping Applications

Mission-Critical Requirements

QL2 or QL3 lidar data for 49 States and U.S. territories, plus QL5 IFSAR data for Alaska, are required by the NRCS for soils mapping, floodplain mapping, and mapping of cultural and natural resources (for example, wetlands, grasslands, forests, and wildlife habitat).

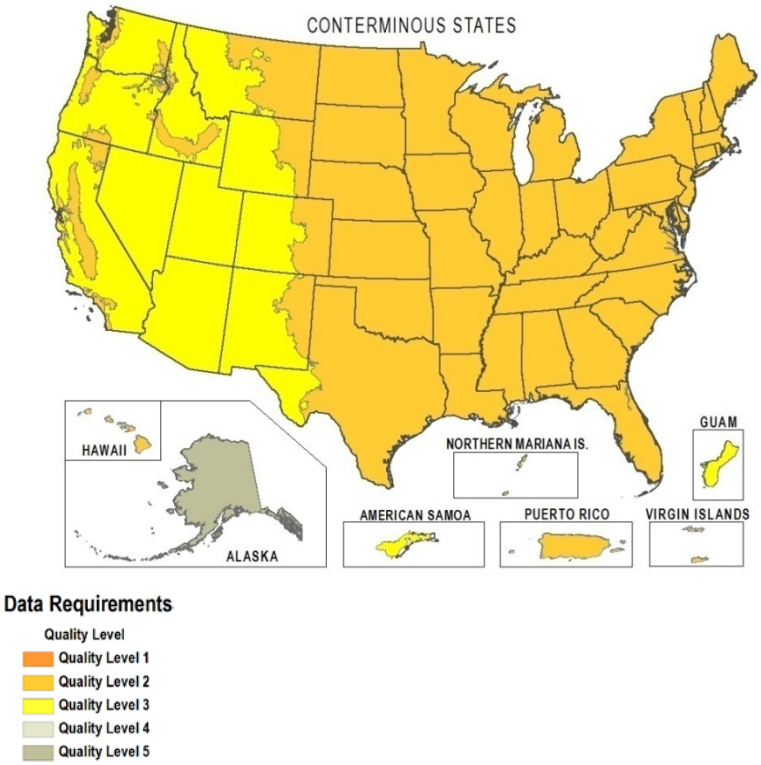
Update frequency: 6–10 years.

Business Use: Multiple, but primarily Natural Resources Conservation, BU#1.

Estimated program budget supported by elevation data: $941 million per year.

Quantifiable Benefits of Enhanced Elevation Data

$18.82 million per year for the NRCS, plus major unknown benefits to customers



In addition to CTA funding, the USDA budget for FY2011 identifies $127 million in discretionary funding for other conservation operations activities managed by the NRCS, including soil surveys, snow surveys, the grazing lands conservation initiative, and Plant Materials Centers. This budget also includes mandatory farm bill programs that require elevation data for the Wetlands Reserve Program ($502 million), the Farm and Ranch Lands Protection Program ($160 million), the Wildlife Habitat Incentive Program ($73 million), and the Grassland Reserve Program ($79 million). All these programs, which total $941 million, have mission-critical requirements for enhanced elevation data for accurate and up-to-date mapping of soils, floodplains, wetlands, grasslands, forests, and (or) wildlife habitat.

Operational benefits (internal) to the NRCS of enhanced elevation data for this functional activity

Time/Cost Savings: Moderate	Mission Compliance: Moderate	$ Benefits: $18.82 million per year

- The Soil Survey Division (SSD) recognizes that lidar derivatives (slope, aspect, and curvature) are the major parameters needed for semiautomated lidar enhanced soil survey (LESS) processes that will improve the Soil Survey Geographic Database (SSURGO). When lidar becomes available nationwide, savings of $10 million per year are estimated for lidar enhanced soil surveys alone.
- Lidar data are required in 49 States plus U.S. territories for mission-critical resource inventories and mapping activities dealing with floodplains, wetlands, grasslands, forests and (or) wildlife habitat. IFSAR is more suitable for performing such inventories and mapping activities in Alaska because of IFSAR's cloud-penetrating capabilities and reduced accuracy standards in remote areas.
- If the NRCS prior conservative estimate of 2 percent savings were applied against the $941 million program budget, this would equal estimated savings of $18.82 million per year. This is realistic when considering that lidar is mission-critical for many NRCS resource inventory and mapping requirements other than soils mapping.

Customer service benefits (external) to the public from improved NRCS products and services

Performance: Major	Timeliness: Major	Experience: Major	$ Benefits: Unknown

- Soils data from SSURGO are used nationwide for thousands of government and private business uses; all would benefit from improved soils data, but cost benefits cannot be quantified.
- Private land owners and farmers would benefit from the conservation operation activities summarized above. NRCS maps of floodplains, wetlands, grasslands, forests, and wildlife habitat, help the NRCS customer base to "see" existing conditions for which enhanced conservation practices are desired. Lidar-based maps or map graphics could be emailed to those seeking assistance.
- One respondent stated, "Better delineation of wetland areas and hydrology with farm tracts and watersheds. Better planning without field trips. Better planning of structural components because of known topography. Better understanding of erosion potential and ability to identify areas for water concentration. Help with identifying better areas of variability within a given farm tract. All of the above would contribute to improved water quality, reduced erosion, and the possibility of reduced flooding and better utilization of wetland functions within watersheds."

Other benefits from NRCS use of enhanced elevation data for this functional activity

Public/Social: Minor	Environmental: Moderate	Strategic/Political: Moderate

- The customer service benefits described above provide broader public and social, environmental, and strategic and political benefits to all Americans sustained by clean air, water, and a safe and healthy environment.

Nuclear Regulatory Commission

Point of Contact: Stuart Reiter, (301) 415-8701, stuart.reiter@nrc.gov

It is the mission of the U.S Nuclear Regulatory Commission (NRC) to license and regulate the Nation's civilian use of byproduct, source, and special nuclear materials to ensure adequate protection of public health and safety, promote the common defense and security, and protect the environment.

The NRC is responsible for regulating domestic activities related to radiation protection and nuclear safety for nuclear facilities and for promoting the common defense and security, and to protect the environment related to the uses of radioactive materials. The NRC issues licenses and oversees licensees for civilian uses of radioactive materials, including 104 commercial nuclear power reactors; 33 research and test reactors; approximately 4,500 licensed reactor operators; 40 uranium recovery sites; 9 major fuel cycle facilities; approximately 4,400 research, medical, industrial, government, and academic materials licensees; and an increasing number of independent spent fuel storage installations (currently 46 licensees).

For new reactor facilities, the NRC reviews applications submitted by prospective licensees, and (when appropriate) issues standard design certifications, early site permits, limited work authorizations, construction permits, operating licenses, and combined licenses. For new reactors and other proposed facilities, NRC staff use topographic data in a variety of review areas for the evaluation and independent confirmatory analysis of information submitted by an applicant with an application for a power plant or other applicable facility. NRC recognizes that enhanced elevation data will bring potential improvements to its mission-critical activities.

NRC managers identified a single functional activity with mission-critical requirements for elevation data:

- Nuclear Power plant Site Natural Phenomena Hazard Assessment and Risk Mitigation, under BU#9, Geologic Resource Assessment and Hazards Mitigation

NRC staff provided the following assessments of elevation data requirements and benefits received from the enhanced elevation data quality level that they identified as mission-critical. Summarized details are provided in the following pages.

Nuclear Power plant Site Natural Phenomena Hazard Assessment and Risk Mitigation

Mission-Critical Requirements

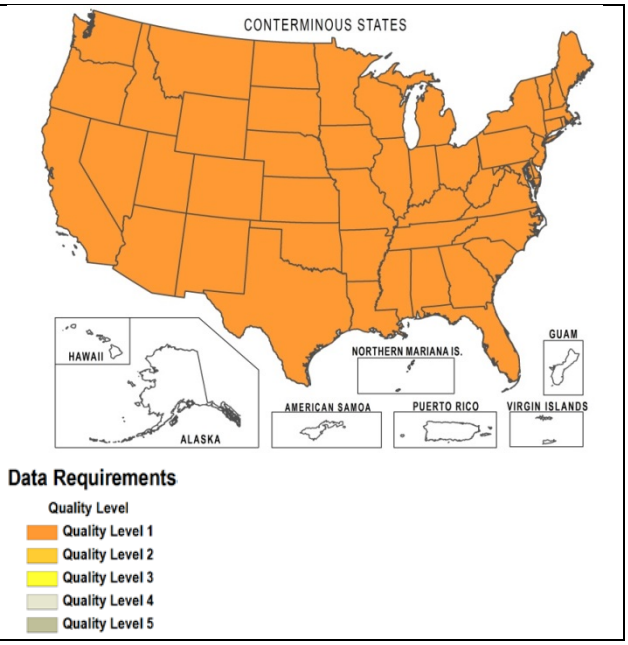
QL1 lidar data are needed of the conterminous United States for seismologic, geologic, and hydrologic safety reviews for new nuclear power reactor licensing and safe operations.

Update frequency: 6–10 years.

Business Use: Geologic Resource Assessment and Hazards Mitigation, BU#9.

Estimated program budget supported by elevation data: Unknown.

Quantifiable Benefits of Enhanced Elevation Data: Unable to estimate at this time.



For new reactor licensing, high-resolution elevation data would enhance the evaluation of potential hazard sources for proposed nuclear power plant sites.

The NRC would use high-quality lidar data to refine the identification of surface faulting geologic and tectonic structures, potential liquefaction sites, potential landslide areas, karst topography, surface water drainage, coastal flooding extents, and other flood prone areas.

Seismic hazard is a critical component in the assessment of siting of a nuclear power plant. QL1 lidar data will improve the information used in identifying and evaluating potential seismic sources. QL1 elevation data will be reviewed at least within 200 miles of a potential site, and farther, if large seismic sources exist outside of this radius. Because potential sites could be located almost anywhere, QL1 data are specified nationwide for assessment of the feasibility of potential sites.

Operational benefits (internal) to the NRC of enhanced elevation data for this functional activity

Time/Cost Savings: Moderate	**Mission Compliance: Moderate**	**$ Benefits: Cannot determine**

- Access to the most reliable data set for identification of geologic faults.
- Ability to identify young geologic faults not visible when walking over the terrain.
- Ability to identify and analyze tectonically active features efficiently (for example, growing anticlines over buried, active faults or truncated stream drainage networks).
- Ability to perform improved flood risk evaluation and flood hazard modeling of potential sites.
- Ability to use lidar point cloud data and GIS tools to answer siting questions.

Customer service benefits (external) to the public from improved NRC products and services

Performance: Moderate	**Timeliness: Moderate**	**Experience: Moderate**	**$ Benefits: Cannot estimate**

- The NRC could improve public health and safety decisions, complete technical reviews with greater efficiency and effectiveness, and produce an even higher quality safety analysis.

Other benefits from NRC use of enhanced elevation data for this functional activity

Public/Social: Moderate	**Environmental: Moderate**	**Strategic/Political: Moderate**

- Increased capability during public hearings to address related questions on safety and environmental issues including potential seismic activity within hundreds of miles from proposed facilities.
- Enhanced confidence in all safety evaluations containing a topographic component for proposed nuclear facility sites.

Office of Surface Mining Reclamation and Enforcement

Point of Contact: Dianne Osborne, (303) 293-5076, dosborne@osmre.gov

The mission of the Office of Surface Mining Reclamation and Enforcement (OSM) is to carry out the requirements of the Surface Mining Control and Reclamation Act (SMCRA) in cooperation with States and tribes. The primary objectives are to ensure that coal mines are operated in a manner that protects citizens and the environment during mining and assures that the land is restored to beneficial use following mining, and to mitigate the effects of past mining by aggressively pursuing reclamation of abandoned coal mines.

The OSM is a bureau within the DOI. It was established in 1977 when Congress enacted the SMCRA to regulate the manner in which coal mining was conducted to minimize the impacts on the environment. The OSM works with States and tribes to assure that citizens and the environment are protected during coal mining and that the land is restored to beneficial use when mining is finished. The OSM and its partners are also responsible for reclaiming and restoring lands and water degraded by mining operations before 1977. The SMCRA covers 36 different States with current or past coal mining.

The OSM oversees the regulation of coal mining operations to ensure that they are conducted in an environmentally responsible manner and that the land is adequately reclaimed during and following the mining process. Most coal-mining States now have the primary responsibility to regulate surface coal mining on lands within their jurisdiction. The OSM also partners with States and tribes to regulate mining on Federal lands and to support State regulatory programs with grants and technical assistance.

The mine permitting and monitoring process involves reviewing mine permits, issuing permits, and collecting bond fees from mining operators, monitoring mining operations for ongoing reclamation compliance, reviewing post-mining conditions for permit compliance, and release of bond monies.

The OSM also oversees the environmental restoration of abandoned mine lands (AML). These are lands and waters adversely impacted by inadequately reclaimed surface coal mining operations (pre-1977) on lands that were not subject to the reclamation requirements of the SMCRA. Grants are available to mining States for AML remediation and each State has annual goals for AML remediation. The OSM monitors AML remediation and releases bond monies after reclamation is complete.

OSM managers identified the following major functional activity with mission-critical requirements for elevation data:

- Regulation and Reclamation of Coal Mining Activities, under BU#10, Resource Mining.

OSM managers provided the following assessments of elevation data requirements and benefits received from the enhanced elevation data quality level that they identified as mission-critical. Summarized details are provided in the following pages.

Regulation and Reclamation of Coal Mining Activities

Mission-Critical Requirements

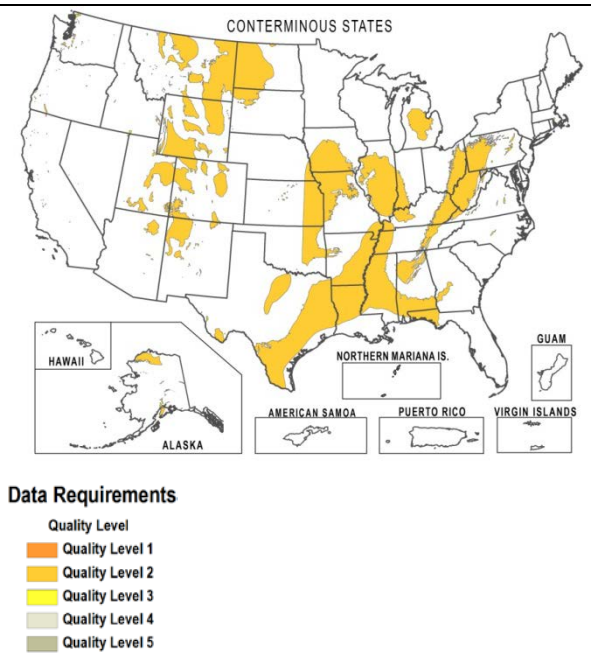
QL2 data are needed for all active mining areas as well as those in remediation. High-quality elevation data are used for reviewing and issuing mine permits, monitoring mining operations for ongoing reclamation compliance, and reviewing post-mining conditions for permit compliance.

Update frequency: Annually.

Business Use: Resource Mining, BU #10.

Estimated program budget supported by elevation data: $1.75 million per year.

Quantifiable Benefits of Enhanced Elevation Data: The OSM and its State partners could save $186,447 per year in internal costs.



Currently, the OSM monitors approximately 5,600 active mine permits in 27 States on a quarterly basis. Other activities, including AML remediation, occur within the 36 States with current or past mining activities. Annual or biannual data are needed for these activities.

Representative cross-sections along various lines within the mining operation are provided by mine operators as a part of the permit submittal and these locations are used to monitor ground conditions for permit compliance. Elevation data along the cross-sections are used to evaluate the slope and aspect of the lands. Surface water elevations and underwater streambed and lakebed data are also needed for these activities.

Elevation data are used by OSM for the following:

- Existing pre-mining contours and volumetric analyses are needed as the baseline against which to measure permit proposals, set bond amounts, and measure restoration activities.
- As mining operations continue, ongoing data collection is used to monitor backfill and grading activities and determine whether incremental reclamation activities have met permit requirements, thereby being eligible for release of bond monies.
- At the end of mining activities, elevation data are used to determine if reclamation is adequate and the landscape has been restored to its "original" condition within the requirements of the legislation.

Elevation data that are currently used to accomplish these activities are collected using lidar, traditional photogrammetric methods, and GPS field surveys. Some data are collected using aircraft and helicopters, and the OSM is investigating the feasibility of using satellite data and data from unmanned aircraft vehicles (UAVs). In 2010, the OSM and its State partners conducted 80,089 field inspections nationwide. Field inspections typically require 1 to 5 days per site at costs that range from $700 to $10,000 per site.

Operational benefits (internal) to the OSM of enhanced elevation data for this functional activity

Time/Cost Savings: Major	Mission Compliance: Major	$ Benefits: $186,447 per year

- For active mining operations, when lidar data are available, the requirements for field inspections can be reduced, although they cannot be eliminated. Bureau scientists can perform analyses using computer-aided design (CAD) or GIS software to ensure reclamation is correct and erosion is minimized. Cross-sections that correspond to those provided by the mine permittee can be cut from the lidar terrain data. Profiles of the terrain along the cross-sections can be generated and compared with the permit requirements in an office environment

resulting in a virtual inspection. Areas of concern can be identified in the office and targeted field inspections can be performed as needed, thereby reducing travel time and costs as well as time required in the field.

- A return-on-investment study conducted by the OSM and the West Virginia Department of Environmental Protection compared costs for performing similar activities using three methodologies—GPS field collection, photogrammetry, and lidar—for a 150-acre site in West Virginia. The study revealed that the lidar method was by far the most cost effective method as shown in the table below:

Method of data collection	Dataset density	Cost
Post-processed field collected GPS data	Low	$50,815
Photogrammetry	High	$72,267
lidar	Highest	$26,763

- The OSM also conducted a cost-benefit analysis in 2011 that indicated that the use of remote sensing (satellite data) to support field inspection would save $0.1747 per acre. The approximate acreage of disturbed mining areas is 1,067,241. Using this methodology, annual benefits are estimated to be $186,447 if the OSM were to receive lidar data annually.
- Potential unforeseen costs of remediating a site that is not reclaimed to the standards set forth in the permit and the costs of associated impacts, such as stream degradation, can be avoided using lidar data.
- For AMLs, lidar data can be used to identify the extent of features such as benches, high walls, subsidence, and slides. Fewer field inspections are required when lidar data are available.
- Lidar data provide reliable, quantifiable, accurate, and consistent information for the inspectors in the field.
- More frequent reviews of mining operations and reclamation activities.

Customer service benefits (external) to the public from improved OSM products and services

Performance: Major	Timeliness: Major	Experience: Major	$ Benefits: Cannot estimate

- The OSM's ability to monitor surface mining activities and AML remediation is improved and their response time is quicker.
- The OSM and mine operators can be on the same page when determining required actions.
- Bond monies can be released to permittees more quickly, allowing mining operators to begin operations in new areas of a site or new sites.
- More effective reclamation, thereby increasing the value of the land.
- Less reconstruction (for example, to correct grading problems or stream morphology) if problems can be identified and addressed more quickly.

Other benefits from OSM use of enhanced elevation data for this functional activity

Public/Social: Major	Environmental: Major	Strategic/Political: Major

- Ability for the OSM to better communicate with the public regarding mining-related issues, and environmental benefits that include more effective reclamation and (or) remediation efforts.
- Improved transparency, including better public outreach. Being able to take accurate maps to public hearings more efficiently and effectively allows OSM to educate the public and local officials concerning mining and reclamation issues.
- More accurate and effective reclamation designs that result in significant environmental benefits.
- Improved public safety due to the ability to better identify AML features that pose health and human safety concerns such as benches, high walls, subsidence, and slides.
- Greatly reduced danger from mining operations intersecting gas lines, buried water sources, or other catastrophic possibilities.
- Better collaboration with permittees.

Tennessee Valley Authority

Point of Contact: Roy Teal, (423) 751–6635, rjteal@tva.gov

The core mission of the Tennessee Valley Authority (TVA) is to improve the quality of life and economic prosperity for people and businesses in the Tennessee Valley by providing affordable electricity, economic and agricultural development, environmental stewardship, integrated river system management, and technological innovation. The TVA's vision is to be one of the Nation's leading providers of low cost and cleaner energy by 2020. More specifically, the TVA intends to be the Nation's leader in improving air quality, the Nation's leader in increased nuclear production, and the Southeast's leader in increased energy efficiency.

The TVA is the Nation's largest public power provider and is wholly owned by the Federal Government. The TVA was established by Congress in 1933 to provide for river navigation, flood control, and agricultural and industrial development and to promote the use of electric power in the Tennessee Valley region. The TVA service territory includes most of Tennessee and parts of Alabama, Mississippi, Kentucky, Georgia, North Carolina, and Virginia (fig. 1–12)—an area of 90,000 square miles with a population of 9 million; the TVA sells electricity to 155 power distributor customers and 56 directly served industries and Federal agencies.

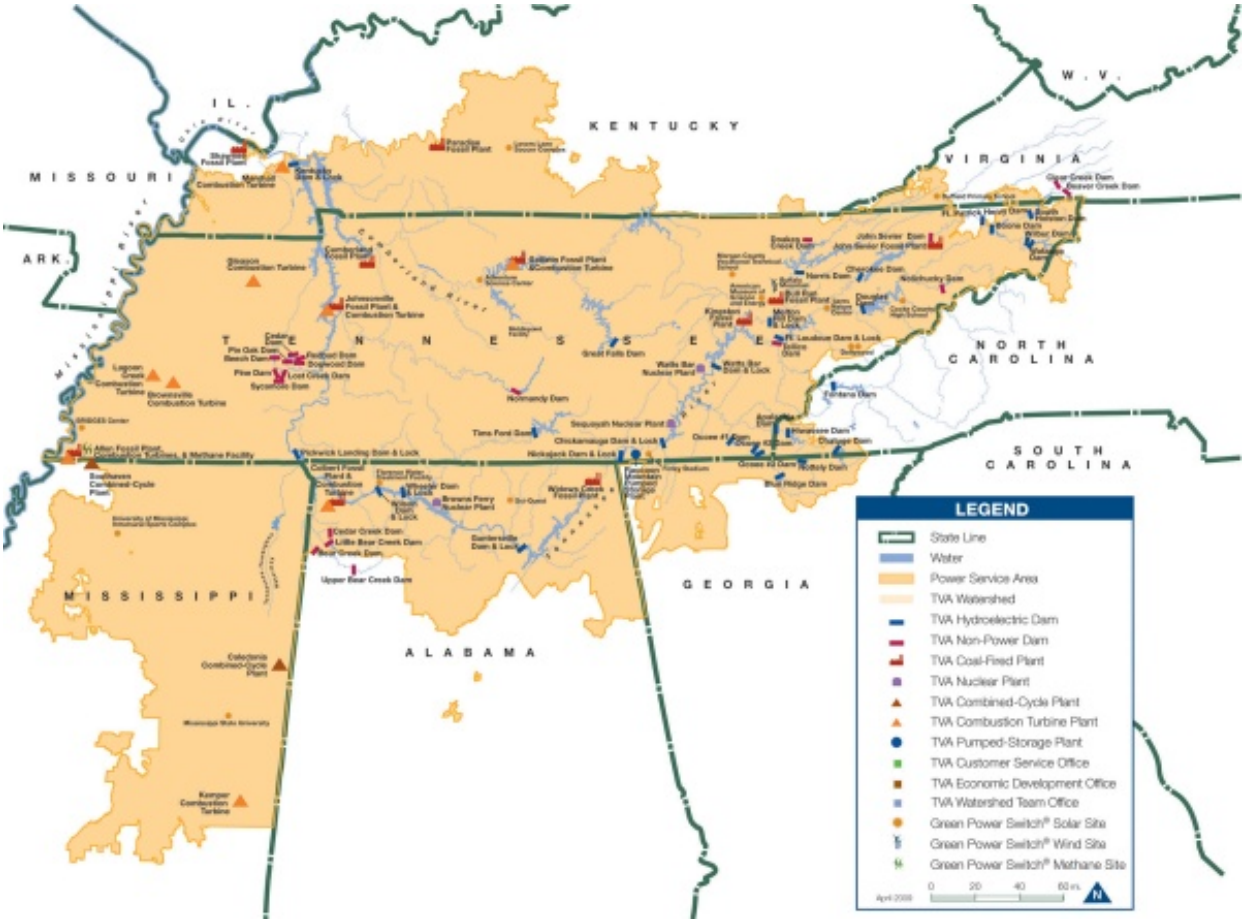


Figure 1–12. Map showing the extent of the area covered by the Tennessee Valley Authority.

The TVA operates 29 hydroelectric dams, 11 coal-fired power plants, 3 nuclear plants, and 12 natural gas-fired power facilities and supplies up to 37,188 million kilowatts of electricity, delivered over 16,000 miles of high-voltage power lines. The TVA also provides flood control, navigation, land management, and recreation for the Tennessee River system and works with local utilities and State and local governments to promote economic

development across the region. The TVA, which makes no profits and receives no taxpayer money, is funded by sales of electricity to its customers. Electricity prices in the TVA service territory are below the national average.

The TVA's Geographic Information & Engineering (GI&E) Department provides geospatial services across the TVA area, encourages the appropriate use of geospatial data and technologies to improve the effectiveness of TVA organizations, and leads enterprise GIS at the TVA to ensure data quality, improve consistency, eliminate duplication, and reduce total TVA costs related to geospatial data and technologies.

TVA managers identified four major functional activities with mission-critical requirements:

- Power Generation, Transmission Line, and Vegetation Management, under BU#21, Infrastructure and Construction Management
- Navigation and Flood Risk Mitigation, primarily under BU#14, Flood Risk Management
- Natural and Cultural Resource Management and Conservation, primarily under BU#1, Natural Resources Conservation
- Siting of Wind and Solar Generation Facilities, under BU#11, Renewable Energy Resources

TVA managers provided the following assessments of elevation data requirements and benefits received from the enhanced elevation data quality level that they identified as mission-critical. Summarized details are provided in the following pages.

Power Generation, Transmission Line, and Vegetation Management

Mission-Critical Requirements

QL1 lidar is required by TVA for new transmission line planning, vegetation management along transmission lines, uprate of transmission line studies, flood risk modeling that includes probability modeling and analysis for maximum flooding for generating power plants and substations, and detailed topographic mapping and site development.

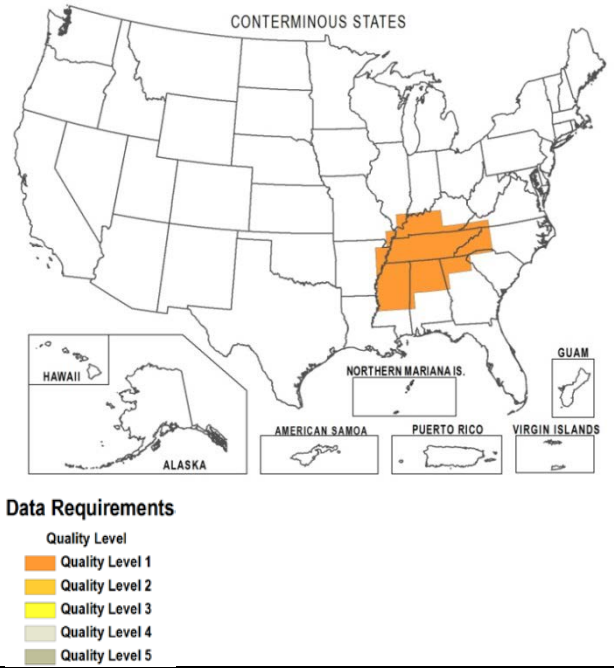
Update frequency: 2–3 years.

Business Use: Infrastructure and Construction Management, BU#21.

Estimated program budgets supported by elevation data: $21 million per year.

Quantifiable Benefits of Enhanced Elevation Data.

TVA would save an estimated $600,000 per year by using lidar data in lieu of field visits and traditional topographic surveys.



Providing dependable and reliable power generation and transmission is critical to the TVA, its customers, and the TVA's ability to meet or exceed industry and federal energy reliability standards.

To effectively plan, site, design, route, and construct newly proposed infrastructure such as power generating facilities, transmission lines, and other major TVA projects, the TVA requires accurate topographic data for locating and placement of new infrastructure. The TVA power service area represents an area of approximately 80,000 square miles of variable forested lands and tree densities, terrain, and watersheds; therefore, the TVA requires high-quality QL1 lidar for accurate flood risk modeling, including probable maximum flood, for generating plants and major substations. Bathymetric data are also desired.

TVA also requires QL1 lidar to support planned annual and seasonal inspections of right-of-ways and transmission lines to maintain required clearance from trees and encroachments. QL1 lidar data are required to support event

driven or project based inspection activities resulting from landslides, floods, or tornados, studies for uprating transmission lines, and infrastructure failures such as the Kingston Ash Spill failure or similar fossil, hydro, or nuclear emergencies.

Operational benefits (internal) for the TVA of enhanced elevation data for this functional activity

Time/Cost Savings: Major	Mission Compliance: Major	$ Benefits: $600,000 per year

- Overall operational costs would be reduced.
- The TVA would save an estimated $600,000 per year by using lidar data in lieu of field visits and traditional topographic surveys.
- Sections of the transmission system that were quickly rebuilt after broad outages (for example, due to tornados) can be re-evaluated with QL1 lidar data, which will improve the long-term operation of the system.
- The TVA could quickly and accurately model flood risks to its power generation and transmission facilities so mitigation steps can be expedited.
- QL1 data could enable the TVA to make better decisions regarding the need to acquire additional flowage easement property.
- QL1 lidar could enable the TVA to meet North American Electric Reliability Corporation (NERC) compliance standards and improve vegetation management, and rating, uprating, or reconductoring decisions (fig. 1–13).

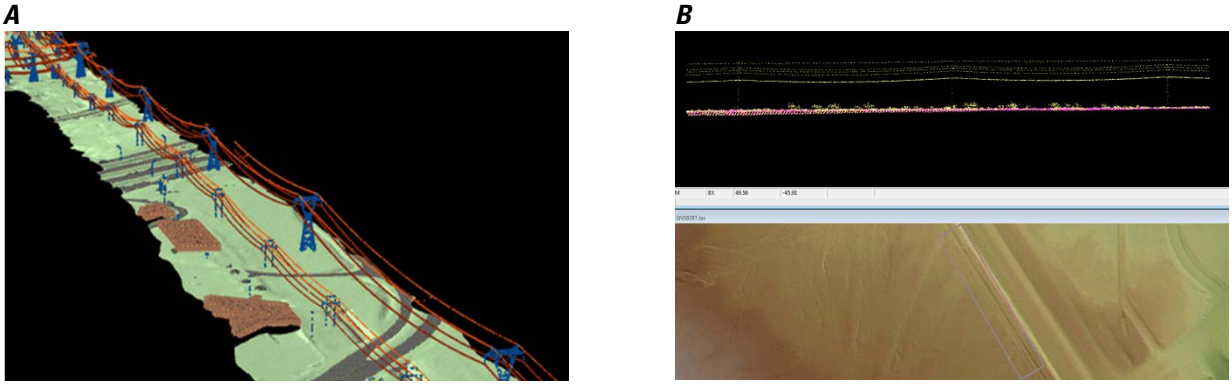


Figure 1–13. *A*, For narrow corridors, lidar from helicopters is commonly used for mapping of catenaries, and vegetation management of high-voltage transmission lines; photograph courtesy SAM, Inc., used with permission. *B*. For broad areas, high-resolution lidar from fixed wing aircraft could be used for vegetation management and mapping of catenaries of major transmission lines and even small electric lines; photograph courtesy Towill, Inc., used with permission.

Customer service benefits (external) to the public from improved TVA products and services

Performance: Moderate	Timeliness: Moderate	Experience: Moderate	$ Benefits: Unknown

- Customers would benefit from improved services, including potential reductions in power outage due to vegetation coming in contact with transmission lines.
- With QL1 lidar coverage throughout its power service area, the TVA would be better able to meet or exceed planned schedules for modernization programs, thereby expediting services to its customers.

Other benefits from TVA use of enhanced elevation data for this functional activity

Public/Social: Moderate	Environmental: Moderate	Strategic/Political: Moderate

- Better lidar data yields better analyses and improved decisions by the TVA. This increases public confidence when the TVA provides detailed analyses and graphics at public outreach sessions or for nuclear licensing.
- Increased reliability in the delivery of power will benefit the public with decreased likelihood of service interruption.
- Data would be readily available for quick turnaround of unscheduled projects.

Navigation and Flood Risk Mitigation

Mission-Critical Requirements

QL2 lidar are required by the TVA for flood risk analysis resulting from catastrophic dam failures (for example, due to acts of terrorism, seismic events, or floods). These data are also required for inland waterway navigation channel maintenance.

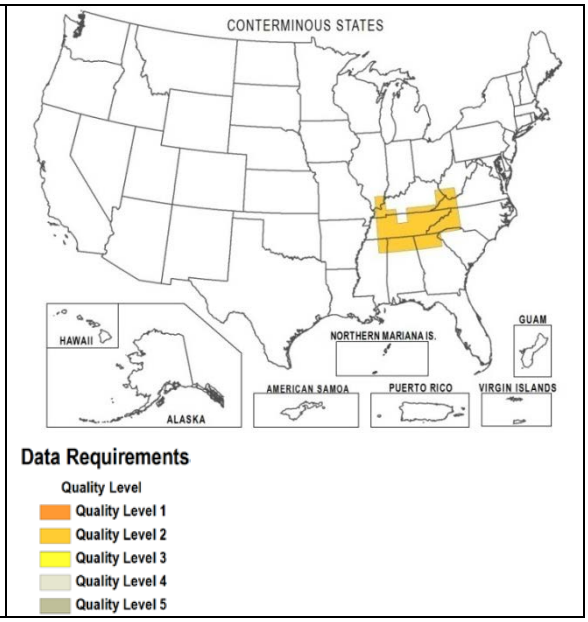
Update frequency: 4–5 years. Event driven data are also needed.

Business Use: Flood Risk Management, BU#14.

Estimated program budgets supported by elevation data: $2.5 million per year.

Quantifiable Benefits of Enhanced Elevation Data

TVA would save an estimated $100,000 per year by using QL2 lidar data in lieu of field visits and traditional topographic surveys.



The TVA requires high-quality lidar data to support its Dam Safety and Inland Waterway Navigation Programs within the Tennessee River Valley, covering approximately 40,000 square miles. The TVA currently relies on USACE data, USGS-supplied NED data, or data from State or local governments. For the Dam Safety Program, which has oversight of 365 dams, lidar data are required to perform flood risk analysis of potential catastrophic dam failures due to terrorism or seismic events. The TVA also requires lidar data to support the development of risk mitigation strategies and risk analysis studies to assess structural integrity of dams and dikes due to changes in dam volumes caused from siltation, landslides, or storm events. Lidar data assist the TVA in accurately capturing heights of dams and dikes and in the calculations of water volumes. Bathymetric data are also desired.

Example If lidar and bathymetric data had been available for the Kingston, Tennessee, ash spill, which covered approximately 300 to 500 acres, the TVA would have been better able to answer questions pertaining to the pre-event levels of ash distribution versus post-event levels and the relative environmental impact.

The TVA Inland Waterway Navigation Program requires lidar and bathymetric data to monitor siltation in barge canals and waterways and to manage contractors hired to perform dredging operations to verify work performed. The TVA uses cross-section measurements at 25-foot intervals to assess the extent of sediment build up.

Operational benefits (internal) to the TVA of enhanced elevation data for this functional activity

Time/Cost Savings: Moderate	Mission Compliance: Moderate	$ Benefits: $100,000 per year

- The TVA would save an estimated $100,000 per year by using QL2 lidar data in lieu of field visits and traditional topographic surveys.
- The TVA could calculate economic damages and population at risk with added certainty.
- More detailed data would allow for better TVA decisionmaking in a variety of navigation projects. Time and cost savings may be moderate since lidar would only supply data for a portion of the bathymetry needed.
- Improved accuracy of potential flooding under various event scenarios will allow the TVA to manage the flow of the Tennessee River more effectively.

Customer service benefits (external) to the public from improved TVA products and services

Performance: Major	Timeliness: Moderate	Experience: Moderate	$ Benefits: Unknown

- Customers would receive higher quality products.
- Updated TVA emergency action plans would greatly improve the TVA dam safety customer experience.
- Much more accurate data would be available for meeting customer needs.

- The improved accuracy of predicted inundation extents under real or potential rainfall events will allow property owners to better prepare for and mitigate potential damage due to flooding.

Other benefits from TVA use of enhanced elevation data for this functional activity

Public/Social: Moderate	Environmental: Minor	Strategic/Political: Moderate

- Improved TVA emergency action plans would benefit local response units and public confidence in TVA products and preparedness.
- More accurate data would enhance safety, educational outreach, and allow more accurate updates to Tennessee River navigation charts.

Natural and Cultural Resource Management and Conservation

Mission-Critical Requirements

QL1 lidar are required by TVA for NEPA assessments and impact studies, nonpoint source pollution modeling, reservoir shoreline stabilization and stream bank erosion, and cultural resource site identification and management.

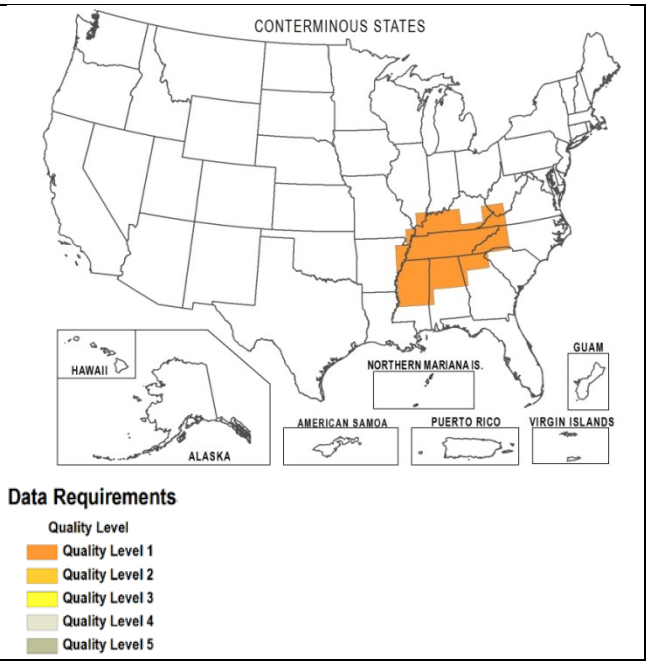
Update frequency: 2–3 years. Event driven data are also needed.

Business Use: Natural Resources Conservation, BU#1, and BU#13, Cultural Resource Management and Conservation.

Estimated program budgets supported by elevation data: $10 million per year.

Quantifiable Benefits of Enhanced Elevation Data

TVA would save an estimated $150,000 per year by using lidar data in lieu of field visits and traditional topographic surveys.



The TVA requires QL1 lidar data to manage its environmental, wetlands, reservoir and streamline, and cultural resource management programs for the Tennessee River Valley and TVA power service areas. Cultural resource management requires high quality QL1 lidar to support high-level research involving microtopographical detection and delineation of cultural resources and detailed monitoring of site conditions in heavily forested and sensitive environments. Similarly, the TVA requires QL1 lidar data to support NEPA environmental assessments and development of environmental impact analysis studies. The TVA continuously monitors shoreline erosion using detailed flood data and topographical contour data for measurement of runoff direction; for siting of newly proposed roads, trails, and recreational areas; and for mapping, identification, management, and conservation of wetlands.

In addition to already available elevation data, the TVA has a need for event driven data as well (for example, planned and unplanned projects related to storm flooding and landslide events, new construction of infrastructure, roads, transmission lines, recreation and park areas, and environmental assessments and accidents).

Operational benefits (internal) to the TVA of enhanced elevation data for this functional activity

Time/Cost Savings: Moderate	Mission Compliance: Major	$ Benefits: $150,000 per year

- The TVA benefits operationally from accurate and current data of flood risks, shorelines, shoreline erosion, and runoff direction.
- QL1 lidar helps the TVA in locating historic, cultural resources as well as new roads and trails; siting for recreation areas such as camping, day use, and picnic areas; location of encroachments on Federal lands; and 3D modeling for public presentations.

- With QL1 lidar data available over the entire area of operations (rather than small, isolated areas only), the TVA will be able to analyze and study an entire area rather than just small localized areas on a case-by-case basis.
- The TVA would save an estimated $150,000 per year by using lidar data in lieu of field visits and traditional topographic surveys.
- High-quality lidar data will simplify and speed up the work of analysts and help them develop and maintain strong products.
- Better data yields better analyses of natural and cultural resources, including improved resource discovery, definition, monitoring, and management.

Customer service benefits (external) to the public from improved TVA products and services

Performance: Moderate	**Timeliness: Moderate**	**Experience: Moderate**	**$ Benefits: Unknown**

- The public benefits from TVA's better planning of facilities, including recreational areas, better protection from flooding, and better preservation of natural and cultural resources.
- High-quality lidar data help the TVA develop better products and provide better services to its customers.
- QL1 lidar provides TVA customers with timely, efficient, and cost-effective management and conservation of natural and cultural resources.

Other benefits from TVA use of enhanced elevation data for this functional activity

Public/Social: Major	**Environmental: Major**	**Strategic/Political: Moderate**

- The same lidar data used by the TVA also enhance the opportunities for economic development throughout the TVA service area. For example, lidar data typically save more than $25,000 for each site being considered for commercial development by reducing needs for site topographic surveys.
- QL1 lidar data will provide better information to the public during the NEPA review process.
- Better data yields better results. These results can then benefit the environment and aid in public awareness and conservation efforts.
- Improved data can raise public awareness and will be beneficial to the environment.
- Higher resolution data would help develop products that could be used to include the public for conservation and awareness and would benefit the environment.
- Higher resolution data contribute to improved cultural resource management.

Siting Wind and Solar Generation Facilities

Mission-Critical Requirements

QL4 or higher resolution elevation data from imagery are required by the TVA for planning and siting of future wind and solar power generation facilities.

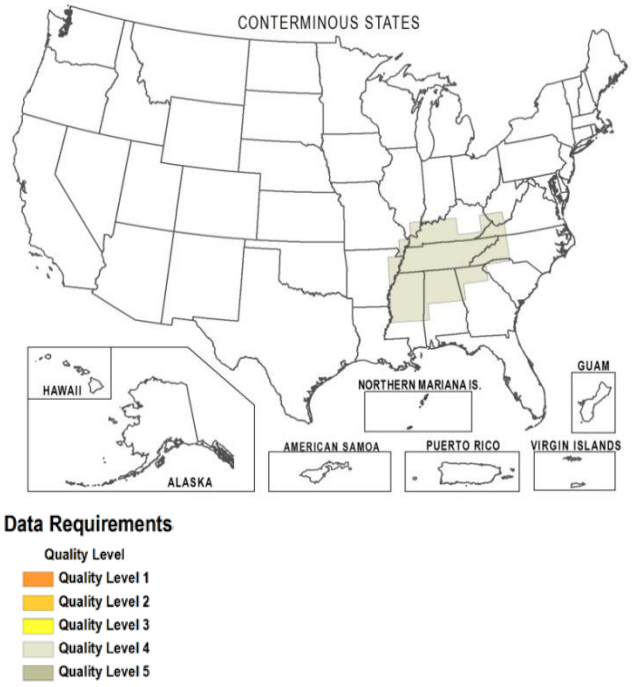
Update frequency: 6–10 years.

Business Use: Renewable Energy Resources, BU#11.

Estimated program budgets supported by elevation data: $3 million per year.

Quantifiable Benefits of Enhanced Elevation Data

TVA would save an estimated $50,000 per year by using photogrammetric DEMs from existing imagery in lieu of more expensive land or aerial surveys.



The TVA requires QL4 elevation data from existing imagery for planning and siting of future wind and solar generation facilities. The TVA considers the currently available NED data of sufficient spatial accuracy but not current enough to meet its needs for this purpose. The TVA currently operates one wind generation facility and several small solar generation sites in the Tennessee River Valley with several wind and solar generation projects projected for the future.

Operational benefits (internal) to the TVA of enhanced elevation data for this functional activity

Time/Cost Savings: Minor	**Mission Compliance: Minor**	**Benefits: $50,000 per year**

- Improved siting for wind and solar generation facilities.
- The TVA would save an estimated $50,000 per year by using photogrammetric DEMs from existing imagery in lieu of more expensive land or aerial surveys.

Customer service benefits (external) to the public from improved TVA products and services

Performance: Minor	**Timeliness: Minor**	**Experience: Minor**	**$ Benefits: Unknown**

- Potentially improved public acceptance of TVA proposed renewable energy sites.

Other benefits from TVA use of enhanced elevation data for this functional activity

Public/Social: Moderate	**Environmental: Moderate**	**Strategic/Political: Moderate**

- Additional energy from renewable sources; reduced carbon footprint.

U.S. Army Corps of Engineers

Points of Contact: Nancy Blyler, Nancy.J.Blyler@hq02.usace.army.mil*, (202) 761–7755, and David Finnegan,* David.Finnegan@usace.army.mil*, (603) 646-4106*

The mission of USACE (or Corps) is to provide vital public engineering services in peace and war to strengthen our Nation's security, energize the economy, and reduce risks from disasters. In achieving this mission, USACE must contribute to the national welfare and serve the public by providing quality and responsive services to the Nation, the Army, and other customers in a manner that is environmentally, economically, and socially sustainable and that focuses on public safety and collaborative partnerships.

With engineer divisions and districts nationwide (fig. 1–14), USACE is a steward for some of the Nation's most valuable natural resources and must ensure its customers receive products and services that provide for sustainable solutions that address short and long-term environmental, social, and economic considerations.

Figure 1–14. Map showing operational divisions of the U.S. Army Corps of Engineers. Map is from U.S. Army Corps of Engineers, undated.

USACE's major functional activities include the following:

- Protection and Management of the Natural Environment, primarily under BU#1, Natural Resources Conservation
- Restoration of Aquatic Ecosystems, primarily under BU#2, Water Supply and Quality
- Flood Risk and Emergency Management, primarily under BU#14, Flood Risk Management
- Infrastructure and Construction Management, under BU#21, Infrastructure and Construction Management
- National Coastal Mapping Program, under BU#4, Coastal Zone Management and BU#19, Marine Navigation and Safety

For each of these functional activities, USACE managers provided the following assessments of requirements for elevation data and benefits received from lidar data that they identified as mission-critical. Summarized details are provided in the following pages. While recognizing that lidar is mission-critical for water resources and related management tasks, USACE does not have hard numbers to support the estimated cost savings listed below; therefore, conservative percentages were used in lieu of higher percentages that were estimated by managers and technical staff who participated in the USACE questionnaire process and workshop that reviewed requirements and benefits.

Reference Cited

U.S. Army Corps of Engineers, [undated], Where we are—U.S. Army Corps of Engineers, accessed March 23, 2012, at http://www.usace.army.mil/Locations.aspx.

Protection and Management of the Natural Environment

Mission-Critical Requirements

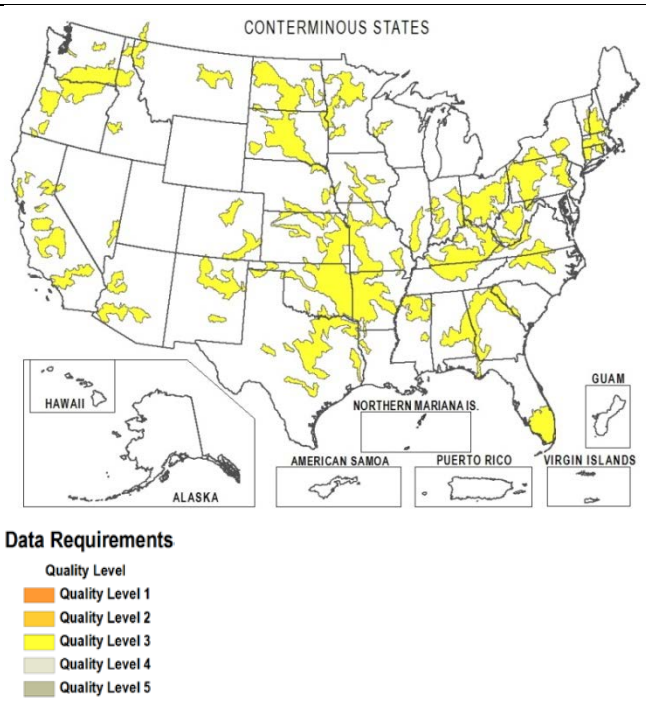
QL3 lidar data are essential for USACE's protection of wetlands, rivers and streams, dunes, beaches, and habitat and for cleanup of sites contaminated by chemical, radiological, biological, and other wastes.

Update frequency: 6–10 years.

Business Use: Natural Resources Conservation, BU#1.

Estimated program budgets supported by elevation data: The civil works budget for fiscal year 2011 lists $108 million for environmental stewardship, $130 million for formerly utilized sites remedial action plan (FUSRAP), and $280 million for recreation. Of these three programs, the major elevation-related program pertains to stewardship of watersheds that flow into USACE reservoirs; therefore, only the $108 million environmental stewardship program was considered for cost benefits from lidar.

Quantifiable Benefits of Enhanced Elevation Data: Time and cost savings from lidar were identified as "major" with a 10 percent increase in effectiveness. When assuming a conservative 2 percent savings from enhanced elevation data, the dollar benefits would equal $2.16 million per year.



USACE is the steward of the lands and waters at Corps water resources projects. Its natural resources management (NRM) mission is to manage and conserve those natural resources consistent with ecosystem management principles, while providing quality public outdoor recreation experiences, to serve the needs of present and future generations. Elsewhere, Corps districts nationwide promote community-based recreation and conservation, including at local parks, greenways, beaches, and waterways.

USACE administers provisions of the Clean Water Act and Federal wetland regulations. USACE is also responsible for cleanup of contaminated soils and hazardous areas of FUSRAP.

Operational benefits (internal) to USACE of enhanced elevation data for this functional activity

Time/Cost Savings: Major	Mission Compliance: Major	$ Benefits: $2.16 million per year

- Elevation data are critical for modeling of storm water as well as point- and nonpoint-source pollution of water. Accurate hydrologic and hydraulic modeling is key to environmental cleanup projects that include liquids or chemicals.
- For any given project, the effectiveness of USACE to protect wetlands, rivers and streams, beaches, and dunes is increased by at least 10 percent by the availability of accurate and current digital elevation data.
- The civil works budget for fiscal year lists $108 million for environmental stewardship, $130 million for FUSRAP, and $280 million for recreation. Of these three programs, the major elevation-related program pertains to environmental stewardship of watersheds that flow into USACE reservoirs; therefore, only the $108 million environmental stewardship program was considered for cost benefits from lidar. When using an estimated 2 percent cost benefit instead of 10 percent estimated increase in effectiveness, the dollar value of lidar data would be $2.16 million per year.

Customer service benefits (external) to the public from improved USACE products and services

Performance: Major	Timeliness: Major	Experience: Moderate	$ Benefits: Unknown

- USACE is able to be proactive in protecting wetlands, rivers and streams, dunes, and beaches by having accurate and current elevation data, readily available and accessible for modeling and analysis rather than researching individual projects to determine if data might be available somewhere, using inaccurate and obsolete data from the NED, and (or) contracting separately for acquisition of lidar data. Acquiring lidar on an as-needed basis is far more expensive and delays critical decisionmaking.

Other benefits from USACE use of enhanced elevation data for this functional activity

Public/Social: Major	Environmental: Major	Strategic: Major

- Elevation data that accurately model terrain slope, aspect, and curvature are critical for plans to protect the environment from various sources of pollution or contamination. The success of USACE in performing this mission has significant social, environmental, and strategic benefits.
- USACE is the Nation’s largest provider of Federal recreation opportunities, and the Corps’ recreation areas contribute to the success of the administration’s great outdoors initiative. Elevation data are required for design and construction of all lakes and other recreational facilities.

Restoration of Aquatic Ecosystems

Mission-Critical Requirements

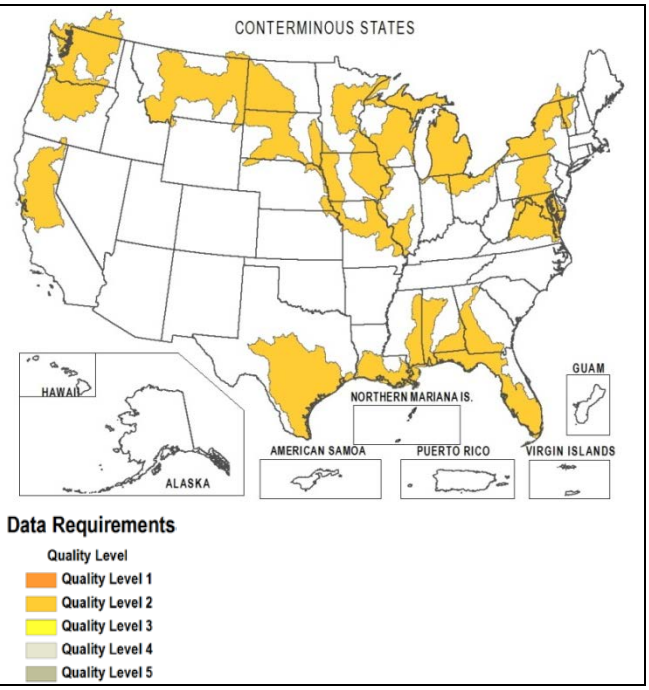
QL2 lidar data are critical for mapping, modeling, assessment, and restoration of aquatic ecosystems.

Update frequency: 6–10 years.

Business Use: Water Supply and Quality, BU#2.

Estimated program budgets supported by elevation data: The civil works budget for fiscal year 2011 lists $586 million for aquatic ecosystem restoration; the percentage of this budget supported by elevation data is unknown but believed to be high because restoration of ecosystems is highly dependent on high-accuracy, high-resolution lidar data.

Quantifiable Benefits of Enhanced Elevation Data: Time and cost savings from lidar were identified as "major." When assuming a conservative 2 percent savings from lidar data determined to be mission critical, the dollar benefits would equal $11.72 million per year.



The priorities of the USACE aquatic ecosystem restoration program are coordinated with and informed by interagency collaboration to restore nationally significant ecosystems, including the California Bay Delta, the Chesapeake Bay, the Everglades, the Great Lakes, the Gulf coast, and numerous smaller project areas.

Operational benefits (internal) to USACE of enhanced elevation data for this functional activity

Time/Cost Savings: Major	Mission Compliance: Major	$ Benefits: $11.72 million per year

- High-accuracy lidar data are routinely required as mission-critical for assessing aquatic ecosystems and developing plans for their restoration.
- Feasibility studies, EIAs, cost estimates, and other planning documents require current and accurate elevation data.
- Elevation data used in feasibility studies are used in benefit and cost analyses to decide if a project is ever funded and implemented.
- Costs are greatly reduced when such data are available.
- The civil works budget for fiscal year 2011 lists $586 million for aquatic ecosystem restoration. The dollar value of lidar is estimated to be at least 2 percent of the overall $586 million per year project costs because this mission could not be performed without lidar. This amounts to a savings of $11.72 million per year.

Customer service benefits (external) to the public from improved USACE products and services

Performance: Major	Timeliness: Major	Experience: Moderate	$ Benefits: Unknown

- The American public is best served when aquatic ecosystem restoration projects are effective, efficient, and timely.
- Corrective actions are expedited, often by a year or more, when accurate and current elevation data are available.
- The success or failure of a project often depends upon the availability of accurate and current elevation data.

Other benefits from USACE use of enhanced elevation data for this functional activity

Public/Social: Minor	Environmental: Major	Strategic: Moderate

- Projects that preserve the Florida Everglades, the Great Lakes, the Gulf coast, and other national aquatic treasures have immense benefits not just environmentally, but socially, politically, and strategically as well.

Flood Risk and Emergency Management

Mission-Critical Requirements

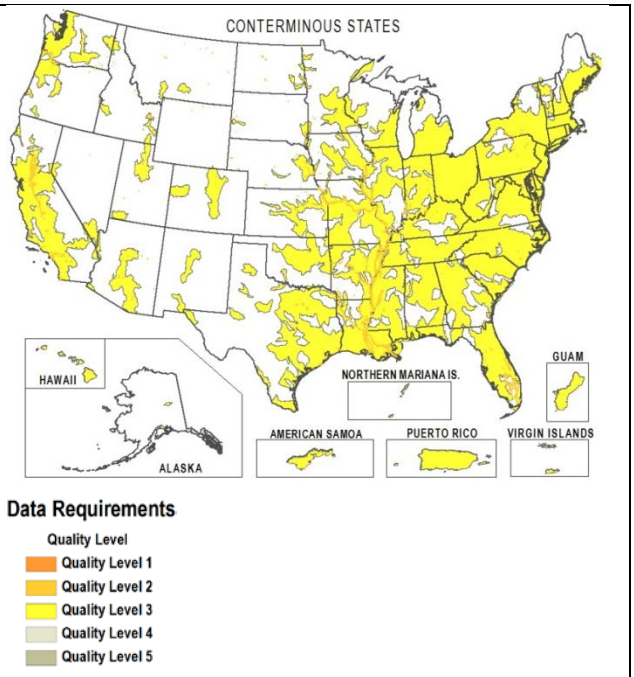
QL3 lidar data are mission-critical for hydrologic and hydraulic modeling and flood risk assessments and mapping in areas of high flood risk; QL2 lidar data are required for dam and levee safety programs of the Corps. Elevation data enable emergency response from terrorist attacks or natural disasters.

Update frequency: 6–10 years.

Business Use: Flood Risk Management, BU#14.

Estimated program budgets supported by elevation data: The civil works budget for fiscal year 2011 lists $79 million for coastal flood and storm damage reduction, $1.464 billion for inland flood and storm damage reduction, and $43 million for emergency management. Of this, $1.543 billion is largely dependent on lidar.

Quantifiable Benefits of Enhanced Elevation Data: Time and cost savings from lidar were identified as "major." When assuming a conservative 2 percent savings from lidar data determined to be mission critical, the dollar benefits would equal $30.86 million per year.



The NFIP reduces future flood damage through hazard identification and mapping, effective community floodplain management, and insurance protection for property owners. The NFIP flood risk identification, floodplain management land use, and building standards reduce the costs and consequences of flooding by an estimated $1 billion per year. USACE supports FEMA in execution of portions of the NFIP, including flood studies and dam and levee safety programs.

For USACE flood risk mapping and analysis in selected areas of high flood risk, QL3 lidar data are mission-critical for hydrologic modeling of watersheds, hydraulic modeling of floodplains, computation of water surface elevations for predicted flood events, modeling of these flood events, and delineation of floodplains for floods of specified frequency. USACE manages a comprehensive levee safety initiative to help ensure that Federal levees are safe and to assist non-Federal parties to address safety issues with their levees. For USACE dam and levee safety programs, QL2 lidar is required.

Lidar data are also invaluable for response and recovery from acts of terrorism, earthquakes, tsunamis, volcanoes, hurricane tidal surges, tornadoes, and wildfires. Post-event lidar is typically compared with pre-event lidar for change detection and debris modeling.

Operational benefits (internal) to USACE of enhanced elevation data for this functional activity

Time/Cost Savings: Major	Mission Compliance: Major	$ Benefits: $30.86 million per year

- QL3 lidar yields accurate flood risk mapping—key to NFIP program success.
- QL3 lidar, when available wherever needed, saves time in looking for required elevation data in piecemeal fashion from multiple sources.
- QL3 lidar reduces costs for ground surveys of stream cross-sections.
- QL3 lidar expedites completion of flood studies, reduces production schedules.

- QL2 lidar enables accurate dam breach inundation mapping.
- QL2 lidar enables remote monitoring and assessment of levees for safety.
- The civil works budget for fiscal year 2011 lists $79 million for coastal flood and storm damage reduction, plus $1.464 billion for inland flood and storm damage reduction—both programs that are largely dependent on lidar data used exclusively for hydrologic and hydraulic modeling. The dollar value of lidar is estimated to be at least 2 percent of the overall $1.543 billion program costs because these missions could not be performed without lidar. Thus, the annual dollar benefit is estimated to be $30.86 million per year.

Customer service benefits (external) to the public from improved USACE products and services

Performance: Major	Timeliness: Major	Experience: Major	$ Benefits: Major, but cannot estimate

- Flood maps that accurately depict flood risks enable floodplain managers and homeowners to take proactive steps to mitigate flood risks and reduce flood damages by $1 billion per year, although not all these savings can be directly attributed to enhanced elevation data. Although the lidar dollar benefits to the public are believed to be hundreds of millions of dollars annually, USACE can primarily only claim benefits from an improved dam and levee safety programs, and we do not know the value of these programs as a total of the overall $1 billion per year reduced flood damages.
- Lidar data enables real-time flood inundation warnings to sandbag, move valuables, and evacuate.
- Timely response to natural disasters and acts of terrorism.

Other benefits from USACE use of enhanced elevation data for this functional activity

Public/Social: Major	Environmental: Minor	Strategic: Major

- Major social benefits are in protecting the public from flood losses and (or) mitigating those losses and in the government's response to disasters.
- Major strategic benefits are gained by getting the public to recognize the validity of flood maps, in predicting flood risks, and getting floodplain managers and homeowners to take steps necessary to mitigate those risks.

Infrastructure and Construction Management

Mission-Critical Requirements

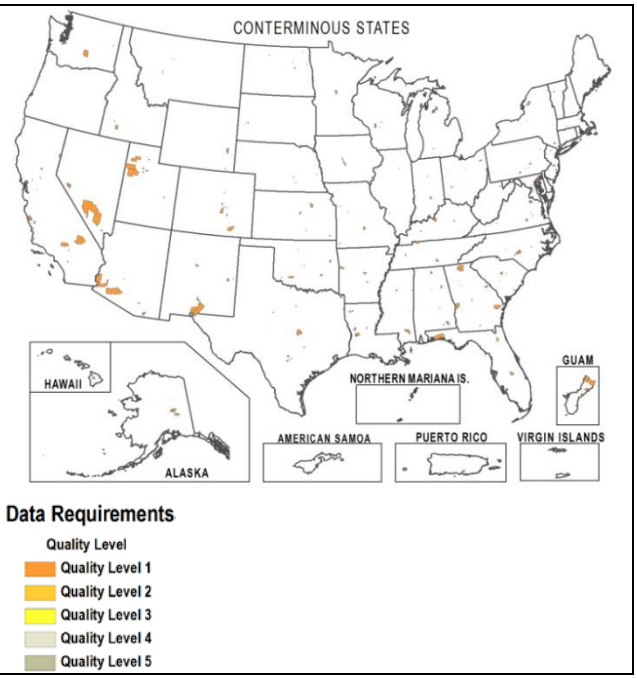
QL1 lidar is required of Army and Air Force installations for planning, feasibility studies, and benefit-to-cost ratios to decide if projects should receive funding and proceed to construction phases. Land surveys are still required for final construction design and stakeout.

Update frequency: 6–10 years.

Business Use: Infrastructure and Construction Management, BU#21.

Estimated program budgets supported by elevation data: The FY12 construction program is funded at $1.558B.

Quantifiable Benefits of Enhanced Elevation Data: $15.58 million per year



Operational benefits (internal) to USACE of enhanced elevation data for this functional activity

Time/Cost Savings: Major	Mission Compliance: Major	$ Benefits: $15.58 million per year

- Lidar topographic surveys are ideal for project planning, preliminary design of drainage features, cut and fill calculations, tree removal estimates, and cost estimation. Final construction design and stakeout requires conventional land surveys.
- Lidar can eliminate topographic survey costs in the planning stages of construction projects.
- Lidar data, available in advance, typically reduces design schedules by 20 percent.
- The FY2012 construction program is funded at $1.558 billion. When assuming a conservative 1 percent savings as a result of having lidar data already available for planning, estimating of cut and fill and tree removal, and drainage design, the savings amount to $15.58 million per year.

Customer service benefits (external) to the public from improved USACE products and services

Performance: Major	Timeliness: Major	Experience: Moderate	$ Benefits: Unknown

- Construction projects typically start 12 to 18 months sooner when lidar data are available and used for planning and preliminary design. This also accelerates the construction phase and delivery of completed projects to clients.

Other benefits from USACE use of enhanced elevation data for this functional activity

Public/Social: Moderate	Environmental: Moderate	Strategic: Moderate

- Social, environmental, and strategic goals are enhanced when high accuracy elevation data are used for project planning, EIAs, and other documentation, leaving no doubt that USACE is professional and conscientious in project management.

National Coastal Mapping Program

Mission-Critical Requirements

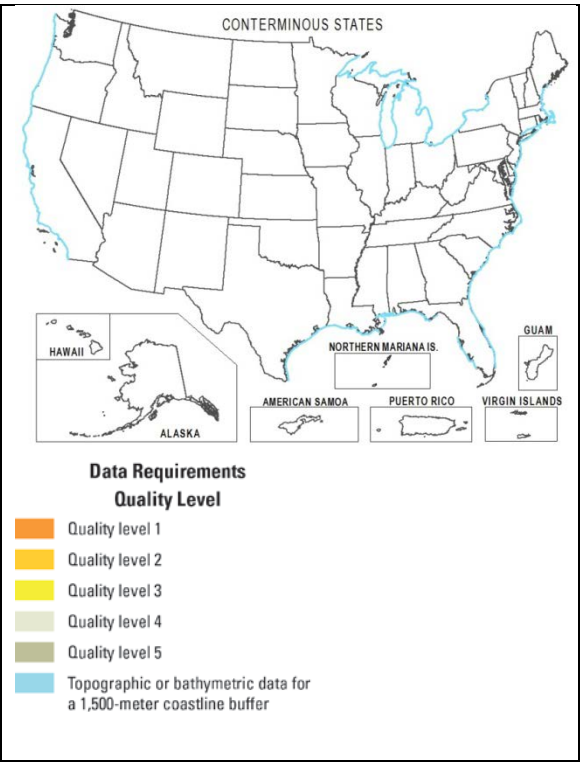
The National Coastal Mapping Program (NCMP) was established to provide recurring, regional, high-resolution, high-accuracy, data necessary to implement regional sediment management practices at USACE coastal navigation projects. The NCMP is executed by the Joint Airborne lidar Bathymetry Technical Center of Expertise (JALBTCX) using the Compact Hydrographic Airborne Rapid Total Survey (CHARTS) sensor suite. Bathymetric and topographic lidar, a digital aerial camera, and a hyperspectral imager deployed on a single aircraft enable concurrent physical and environmental characterization of beaches, wetlands, marshes, estuaries, and barrier islands. The program focus area is the active portion of the beach and nearshore and as such, data are required along sandy shorelines from offshore depth of closure to 1 mile onshore.

Update frequency: 2–3 years (currently acquired on a 5-year cycle because of resource limitations).

Business Use: Coastal Zone Management, BU#4, and Marine Navigation and Safety, BU#19.

Estimated program budgets supported by elevation data: Unknown.

Quantifiable Benefits of Enhanced Elevation Data: Unknown.



Since 1994, USACE has operated the Scanning Hydrographic Operational Airborne lidar Survey (SHOALS) and the CHARTS systems that collect and fuse topographic and bathymetric lidar and spectral imagery in support of USACE navigation and U.S. Naval Oceanographic Office overseas tactical charting requirements. In 2012, they will be operating the new Coastal Zone Mapping and Imaging lidar (CZMIL), which is expected to have improved depth measurements and environmental characterization. The JALBTCX is headed by USACE and executes the NCMP. The goal of the program is to provide regional recurring, high-resolution, high-accuracy data necessary to implement regional sediment management practices at USACE coastal navigation projects.

NCMP products and services include shoreline mapping, shoreline change analysis, coastal structure analysis, shoreline protection, land cover classification, landscape changes, geomorphological feature extraction, dredging management, coastal operations and navigation, navigation channel availability, environmental products, submerged aquatic vegetation species discrimination, stamp sands migration, surf zone changes, and various other datasets made available to the public on Digital Coast, which is the NOAA Coastal Service Center (National Oceanic and Atmospheric Administration, undated).

Operational benefits (internal) to USACE of enhanced elevation data for this functional activity

Time/Cost Savings: Major	**Mission Compliance: Major**	**$ Benefits: Unknown**

- The NCMP already satisfies major mission requirements of USACE, NOAA, the U.S. Navy, the USGS, and others.
- The JALBTCX is heralded as an example of diverse Federal, State, and local agencies working together to satisfy common needs.
- NCMP data and information products support regional sediment management and a number of other activities in the USACE, including regulatory, flood damage reduction, asset management, emergency operations, and environmental stewardship. The data are widely used by the Federal community, specifically for FEMA RiskMap modeling efforts; USGS coastal and marine geology and extreme storm studies; and NOAA nautical chart production.

Customer service benefits (external) to the public from improved USACE products and services

Performance: Major	**Timeliness: Major**	**Experience: Major**	**$ Benefits: Unknown**

- The JALBTCX is heralded as an outstanding example of diverse Federal, State, and local agencies working together to satisfy common needs, avoiding duplicate programs by multiple agencies.
- NCMP data support State and local government efforts in shoreline management, environmental permitting, emergency management, marine spatial planning, and planning for resilient communities.

Other benefits from USACE use of enhanced elevation data for this functional activity

Public/Social: Major	**Environmental: Major**	**Strategic/Political: Major**

- USACE and the JALBTCX work closely with NASA's Earth Science Applications Directorate, the University of New Hampshire, the University of Southern Mississippi, the Naval Oceanographic Office, the U.S. Naval Research Laboratory, The Nature Conservancy, FEMA, the USGS, the EPA, and various offices within NOAA to address coastal environmental issues that have major public and social and strategic and political implications, especially when the public focus is on climate change and sea level rise.

Reference Cited

National Oceanic and Atmospheric Administration, [undated], Digital coast—NOAA Coastal Services Center: National Oceanic and Atmospheric Administration, accessed March 23, 2012, at http://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=0CCoQFjAA&url=http%3A%2F%2Fwww.csc.noaa.gov%2Fdigitalcoast%2F&ei=W3psT-6tOMLs0gHVh7m6Bg&usg=AFQjCNFKlKesOY0XQT-GpczAZSi_KqFGkQ.

U.S. Bureau of Reclamation

Point of Contact: Kurt Wille, (303) 445-228, kwille@usbr.gov

Reclamation, one of eight bureaus under the DOI, manages water resources, including dams, reservoirs, and hydroelectric power facilities, in the 17 Western States of the United States. Its main customers are the States, irrigation districts, tribal entities, the FWS, and NOAA fisheries. The mission of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

Reclamation manages all aspects of its water resources, including water quality, supply, delivery, and conservation; dam safety; flood risk modeling and management; river restoration; facilities design, construction, maintenance, and management; and fisheries management.

Reclamation has constructed more than 600 dams and reservoirs and is the largest wholesaler of water in the country. Reclamation is also the second largest producer of hydroelectric power in the western United States. Reclamation is currently managing 339 dams and 58 powerplants within 188 project sites. In addition to Reclamation's customers in 17 States and tribal nations, irrigation districts, the FWS, the NPS, and the NOAA Fisheries Service. Reclamation also works closely with USGS regarding streamflows and other water resources conditions and with the EPA regarding water quality.

Reclamation currently acquires QL1 lidar data and bathymetric data of selected streams as needed for projects. Reclamation's current uses of lidar and bathymetric data include project design and construction, monitoring river flows and fish habitats, reservoir volume calculations, water forecasting, habitat mapping, identification of restoration opportunities, performing hydrodynamic modeling, dam inundation modeling, groundwater and surface water modeling, hydrologic and hydraulic modeling, and sediment and flow modeling.

Reclamation managers identified the following major functional activity with mission-critical requirements for enhanced elevation data:

- Management of Resources Related to Delivery of Water and Power, primarily BU#2, Water Supply and Quality

Reclamation managers provided the following assessments of elevation data requirements and benefits received from the enhanced elevation data quality level that they identified as mission-critical. Summarized details are provided in the following pages.

Management of Resources Related to Delivery of Water and Power

Mission-Critical Requirements

QL2 lidar is required for monitoring river flows and fish habitats, reservoir volume calculations, water forecasting, habitat mapping, identification of restoration opportunities, and modeling and analysis.

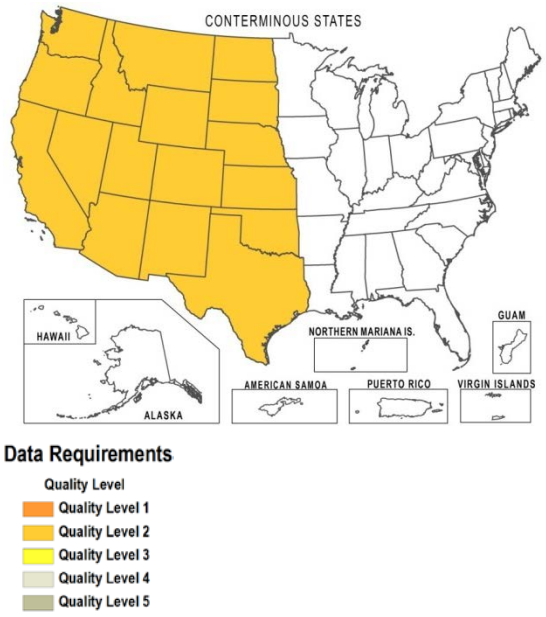
Update frequency: 2–3 years.

Business Use: Water Supply and Quality, BU#2.

Estimated program budget: $90 million per year.

Quantifiable Benefits of Enhanced Elevation Data

Potential benefits of $3.35 million per year could be realized by Reclamation and its customers through the availability of high quality elevation data. Benefits would be realized from reduced data acquisition costs to Reclamation, reduced labor costs on design and construction of new projects, reduced possibility of errors resulting from use of disparate datasets, and savings to Reclamation from having stakeholders perform some of their own analyses.



Reclamation has determined that lidar QL2 data that cover their areas of interest would meet many of their needs, especially for modeling purposes. However, for project design and construction, higher accuracy data and field surveys will be needed for specific project areas. Additionally, Reclamation requires bathymetric data for specific project areas as well.

Operational benefits (internal) to Reclamation of enhanced elevation data for this functional activity

Time/Cost Savings: Major	Mission Compliance: Major	$ Benefits: $2.75 million per year

- High quality, consistent elevation data would lead to better output products. The ability to model seamlessly across Reclamation project areas would improve the accuracy of the modeling, including hydrodynamic modeling, dam inundation modeling, groundwater and surface water modeling, hydrologic and hydraulic modeling, and sediment and flow modeling.
- The existence of readily available high-quality elevation data would greatly reduce data acquisition and processing costs. Considerable time would be saved from not having to search for the best available data, which may otherwise be missing, inconsistent, or of questionable quality. Furthermore, a certain portion of survey and field work would no longer be necessary. Reclamation estimates a combined total savings of up to $2 million per year.
- Additionally, high-quality elevation data would allow Reclamation to perform higher resolution modeling and analysis that is currently impossible due to data acquisition costs. Higher resolution modeling and analysis would provide Reclamation a better understanding of conditions downstream of its facilities. This increased understanding could reduce or eliminate potential future loss of life or catastrophic economic impact.
- With high accuracy elevation data, design and construction of projects could be initiated more quickly and project labor costs would be reduced. Reclamation estimates an agency-wide savings of $750,000 per year.

Customer service benefits (external) to private and public partners from improved Reclamation products and services

Performance: Major	Timeliness: Major	Experience: Major	$ Benefits: $600,000 per year

- Reclamation would be able to produce higher quality products, more quickly, and for lower cost. These improved products, including improved water forecasts and inundation modeling and mapping, would better meet the needs of Reclamation's customers (States, tribal nations, water districts, and water users).
- Reduced opportunity for errors that result from use of fragmented and disparate datasets. Potential savings of $500,000 per year.
- Improved ability to communicate to stakeholders and the public about priorities for restoration or areas at risk.
- Consistency in data would result in Reclamation and its customers having a common point of reference.
- More accurate elevation data resulting in more detailed analyses would create greater confidence in the modeling results.
- Modeling of low flow spillway releases from dams or canal failure could be performed in areas where cost prohibits them now, providing improved emergency evacuation planning. This increased understanding has the potential to reduce or eliminate potential future loss of life or catastrophic economic impact.
- Stakeholders can perform their own analyses. In interagency programs (like the San Joaquin River Restoration Program) where Reclamation is a partner agency, having readily available elevation data that all parties can access could save Reclamation up to $100,000 per year by having stakeholders perform analysis on their own.

Other benefits from Reclamation use of enhanced elevation data for this functional activity

Public/Social: Major	Environmental: Major	Strategic/Political: Moderate

- Improved perception of the agency through higher quality products. High-quality elevation data aid in conveying confidence to stakeholders and the public on the results of analysis, on meeting program targets for restoration, or on scenarios that may be generated from models.
- High-quality elevation data can be used to better plan for flood evacuations and to support decisionmaking tools for dam safety risk analysis studies.
- High-quality elevation data aid in better project planning.

- Environmental benefits from high-quality elevation data would include hydrologic and hydraulic studies related to fish habitat-, erosion-, and climate change-related analyses.

U.S. Forest Service

Point of Contact: Everett Hinkley, (703) 605-4580, ehinkley@fs.fed.us

The mission of the U.S. Forest Service (USFS) is to sustain the health, diversity, and productivity of the Nation's forests and grasslands to meet the needs of present and future generations.

Established in 1905, the USFS is an agency of the USDA. The USFS manages 193 million acres of public lands in 155 national forests and 20 grasslands. The National Forest System has lands throughout 44 States, Puerto Rico, and the U.S. Virgin Islands. The lands compose 8.5 percent of the total land area in the United States.

The USFS accomplishes this mission through five main activities:

- protection and management of natural resources on National Forest System lands
- research on all aspects of forestry, rangeland management, and forest resource use
- community assistance and cooperation with State and local governments, forest industries, and private landowners to help protect and manage non-Federal forest and associated range and watershed lands to improve conditions in rural areas
- achieving and supporting an effective workforce that reflects the full range of diversity of the American people
- international assistance in formulating policy and coordinating U.S. support for the protection and sound management of the world's forest resources

The USFS works closely with other land management agencies, such as the BLM and the NPS, and agencies such as the Agency for International Development, the U.S. Department of State, and the EPA, as well as with nonprofit development organizations, wildlife organizations, universities, and international assistance organizations.

Lidar plays an important role for the USFS in two categories: vegetation classification and mapping and topographic analysis: Some important applications include:

- Vegetation mapping
- Forest inventories (canopy height, mean diameter, volume, biomass, basal area, hardwood and conifer discrimination, canopy density)
- Wildland fuel assessments (canopy height, base height, bulk density, fuel volume)
- Wildlife habitat assessments (percent cover, canopy height, hardwood and conifer discrimination, diameter class)
- Monitoring canopy change (height growth, blowdown, mortality, harvest areas)
- Topographic mapping
- Engineering (DEM production and corridor mapping)
- Floodplain (watershed mapping and flood risk assessment)
- Landslide hazard assessment
- Stream channel mapping (terrain mapping for channel restoration)
- Geologic mapping (landform detection and fault-line mapping)

USFS managers identified the following major functional activities with mission-critical requirements for elevation data:

- Forest Inventory and Assessment, under BU#5, Forest Resources Management
- Wildfire Management, under BU#16, Wildfire Management, Planning, and Response
- Watershed Analysis, under BU#3, River and Stream Resource Management
- Soils and Geology Inventory, under BU#1, Natural Resources Conservation
- Wetlands Mapping and Characterization, under BU#1, Natural Resources Conservation
- Infrastructure Management, under BU#21, Infrastructure and Construction Management

USFS managers provided the following assessments of elevation data requirements and benefits received from the enhanced elevation data quality level that they identified as mission-critical. Summarized details are provided in the following pages.

Forest Inventory and Assessment

Mission-Critical Requirements

The USFS requires QL1 lidar of all USFS lands and all forested areas in non-USFS lands in CONUS, plus QL5 IFSAR for all forested areas in Alaska, for vegetation inventories and forest inventory analyses in all forested lands.

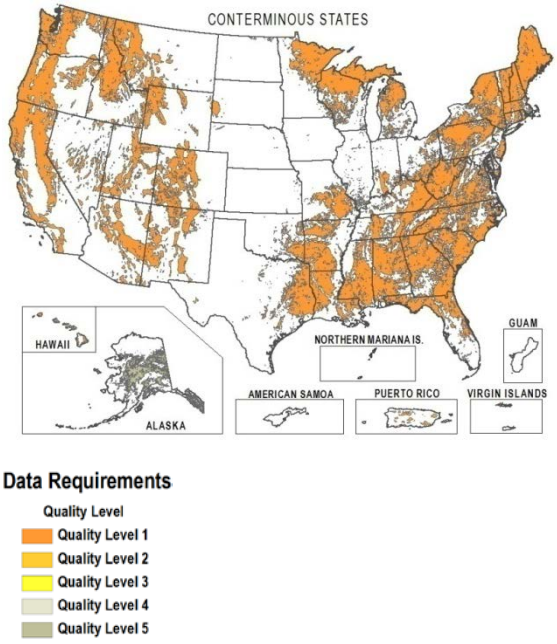
Update frequency: 4–5 years.

Business Use: Forest Resources Management, BU #5.

Estimated program budget: $175 million per year.

Quantifiable Benefits of Enhanced Elevation Data

The USFS has estimated that approximately $10 million per year could be saved on field sampling for forest inventories and assessments if high quality elevation data were available for its areas of interest.



The USFS has determined that QL1 data are needed for the forest inventories and assessments it must conduct in CONUS. However, QL5 data would be acceptable for Alaska.

The USFS Forest Inventory and Analysis (FIA) Program provides assessments of America's forests. As the Nation's continuous forest census, this program projects how forests are likely to appear 10 to 50 years from now. This enables the USFS to evaluate whether current forest management practices are sustainable and to assess whether current policies will allow the next generation to enjoy America's forests as we do today.

The FIA Program develops reports on the status and trends in forest area and location; species, size, and the health of trees; total tree growth, mortality, and removals by harvest; wood production and use rates by various products; and forest land ownership. The USFS has significantly enhanced the FIA Program by changing the scope from a periodic survey to an annual survey, by increasing its capacity to analyze and publish data, and by expanding the scope of data collection to include soil, understory vegetation, tree crown conditions, coarse woody debris, and lichen community composition on a subsample of its plots. High-quality elevation data are an essential input into the forest inventories and assessments needed by the FIA Program.

The work involved in preparing the forest inventories involves different elevation quality levels—the ground surface information requires QL3 (to provide a ground elevation reference for tree heights) but a more dense point cloud is required to characterize vegetation conditions (at least 4 pulses per square meter). A national forest inventory would require a combination of lidar data and field measurements conducted in a coordinated effort so as to accurately georeference the plot locations.

Operational benefits (internal) to the USFS of enhanced elevation data for this functional activity

Time/Cost Savings: Moderate	Mission Compliance: Moderate	$ Benefits: $10 million per year

- It has been shown that the accuracy and cost of a lidar-based inventory summarized at the stand level is comparable to traditional stand exams for structural attributes and that lidar data are able to provide information across a much larger area than the stand exams alone.
- USFS testing in pilot areas indicates that very expensive sampling in the field can be greatly reduced through the use of QL1 lidar data in combination with field sampling and modeling. The USFS estimated cost savings for equivalent accuracy data could be on the order of 10 percent over broad areas of forest lands, resulting in savings on the order of $10 million per year (Hummel and others, 2011). However, these savings are based on

lidar acquisition costs that are almost double what should be expected for a national program, so savings could be as high as 60 percent (on the 5 percent or 10 percent of the points sampled).

- In addition to cost savings from field sampling, large-area, high-quality elevation data would provide more spatially complete vegetation information than existing field-based methods. This would allow more complete monitoring of changes to vegetation conditions. This point-in-time snapshot of conditions would represent a major improvement over sparse field plots measured over a 10-year period and summarized at the county level.
- QL1 lidar data would enable the USFS to quantify forest canopy structure with a higher level of detail and accuracy than has been available in the past. The lidar-derived information can be used to quantify and model general canopy structure, wildlife habitat, forest fuel loads, and forest inventory variables (for example, biomass, volume, and basal area) with more efficiency, accuracy, and confidence. This information assists in making efficient and informed forest resource decisions. The availability of QL1 lidar data across all USFS lands would improve decisionmaking processes and increase the capability of the USFS to manage its forest resources with increased efficiency and confidence on a national level.
- Additionally, if the data were already acquired, USFS regions could focus resources on collaboration and strategies for utilizing the technology instead of building partnerships and raising funds to acquire lidar data. Through the National Digital Elevation Program (NDEP), additional funding may be saved through lidar project partnering and data acquisition with other agencies and organizations.
- Access to improved elevation data would add value to many USFS maps and geospatial products.
- Inventory and monitoring does not currently exist in interior Alaska. IFSAR data would be better than the currently available data for Alaska and could be collected far more easily than lidar due to inclement weather constraints.

Customer service benefits (external) to private and public partners from improved USFS products and services

Performance: Moderate	Timeliness: Moderate	Experience: Moderate	$ Benefits: Cannot estimate

- Enhanced elevation data would provide improved model inputs and improved forest inventory information, especially from difficult to visit grid points.
- Clients would receive wall-to-wall vegetation information and bare-Earth models. All information would represent the same point in time compared to data summarized from plots measured over a 10-year period. Clients would be provided with spatially explicit, high-resolution data products as compared to gross summaries.
- From QL1 lidar data and associated forest structure derivatives, the USFS is able to provide the public with a better inventory of existing forest resources and wildlife habitat. This allows the USFS to act as a better steward of the Nation's forest resources for the public. The USFS could provide the public with a better national inventory of existing forest resources, wildlife habitat, and areas of high fire risk.
- With elevation-derived products available in online databases, clients could summarize the information for their specific area-of-interest.

Other benefits from USFS use of enhanced elevation data for this functional activity

Public/Social: Moderate	Environmental: Major	Strategic/Political: Moderate

- Lidar data could be used to better educate the public on forest restoration issues as well as interface issues between wildland and urban lands.
- Better information leads to better planning and management, which potentially would lead to better environmental sustainability. A snapshot of vegetation conditions could help monitor over a long time period changes caused by climate change.
- Data could provide for inventory and monitoring that cannot be done now.
- The USFS would be better able to document and quantify its efforts in managing forest resources in the way that the public wants or has mandated. For instance, if the USFS is mandated to protect certain wildlife habitat, lidar data will allow the USFS to model that habitat across the landscape and determine appropriate management decisions based on current conditions. By utilizing lidar technology to quantify and verify the results of forest management activities, the USFS can have increased confidence in the evidence used to support NEPA disclosures to the public.

- Accurate elevation data are critical for providing accurate quadrangle maps and forest visitor maps to the many visitors throughout the national forest system.
- Safety is critical, and accurate data help improve safety.

Reference Cited

Hummel, Susan, Hudak, A.T., Uebler, E.H., Falkowski, M.J., and Megown, K.A., 2011, A comparison of accuracy and cost of lidar versus stand exam data for landscape management on the Malheur National Forest: Journal of Forestry, July/August, p. 267–273, accessed March 23, 2012, at http://www.treesearch.fs.fed.us/pubs/38392.

Wildfire Management

Mission-Critical Requirements

The USFS requires QL1 lidar of all USFS lands in CONUS, QL3 lidar of forested areas in non-USFS lands in CONUS, plus QL5 IFSAR for all forested lands in Alaska for fire modeling, post-fire response planning, and ground fuel mapping.

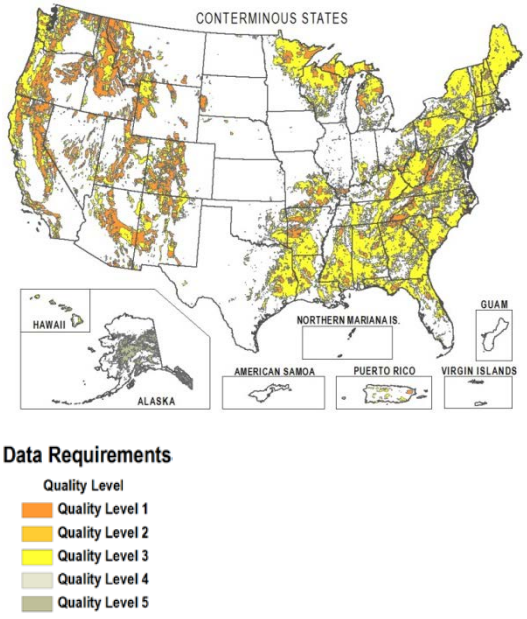
Update frequency: 4–5 years for QL1 data, 6–10 years for QL3 data, and >10 years for QL5 data.

Business Use: Wildfire Management, Planning, and Response, BU#16.

Estimated program budget: $346 million per year.

Quantifiable Benefits of Enhanced Elevation Data

USFS has estimated that over $1 million per year could be saved using enhanced elevation data.



The USFS requires elevation data for wildfire management for the following activities:

- Fire modeling and post-fire response planning (requires QL3 elevation data updated every 6–10 years)
- Ground fuel mapping (requires QL1 elevation data updated every 4–5 years)

The USFS works closely with the BLM on wildfire management issues.

Operational benefits (internal) to the USFS of enhanced elevation data for this functional activity

Time/Cost Savings: Moderate	Mission Compliance: Moderate	$ Benefits: >$1 million per year

- QL1 lidar data would provide great benefit to BAER mapping and to improved fire behavior modeling. QL3 lidar would be a big benefit to the fire management in non-USFS areas based on feedback from GIS specialists. The BAER teams would also be able to better predict peak runoff flows and sediment delivery with better elevation data, allowing for improved post-fire remediation prescriptions.
- Improvements to geospatial decision support data for wildfire will yield tangible savings, which will vary from year to year depending on the severity of the fire season. The value saved could be $1 million per year or more, based on an assumption that a 0.3 to 1 percent savings per year could be realized in all phases of fire mapping and recovery over the 10-year life of the elevation data.
- The mapping of hot pixels (fire) is critical for tactical fire mapping support. Accurate terrain information is critical to the correct geospatial placement of the fire pixels.
- Lidar data would improve safety for the firefighters on the ground and for low-flying aircraft supporting firefighting efforts. High-quality elevation data would allow for more accurate information to support aircraft safety, situational awareness, incident support, fire modeling, and equipment location and configuration,

including placement of aircraft and weather stations. Accessibility and use of aircraft, including rappelling support, would be significantly improved.

- Improved elevation data has led to better modeling and understanding of wildfire spread and impacts on the land. This is very significant in regards to post-fire analysis and the stabilization of the land. The emerging use of high-quality elevation data is focused on the use of data with real-time or post-event processing of imagery.
- Using QL1 lidar data and associated forest structure derivatives, the USFS is better able to identify areas of high fire risk.

Customer service benefits (external) to private and public partners from improved USFS products and services

Performance: Major	Timeliness: Major	Experience: Moderate	$ Benefits: Cannot estimate

- Incident command requires fire mapping data for daily tactical planning sessions.
- High-quality elevation data would improve safety when dealing with aircraft on incidents. Accurate information about aerial hazards including mountain peaks and other hazards is critical for safety issues. Improved accuracy of elevation data would potentially save lives on incidents. For modeling and locational analysis, this accuracy would provide better information overall.
- Better information for resource program managers in their decision processes. Better quality elevation data leads to better modeling and better results.
- Consistent nationwide elevation data would be a major benefit is for development of consistent and repeatable analysis.

Other benefits from USFS use of enhanced elevation data for this functional activity

Public/Social: Moderate	Environmental: Moderate	Strategic/Political: Moderate

- Public safety improvements would be realized from better knowledge of forest fuel conditions and fire risk.
- Improved elevation data would lead to better management of America's public lands, therefore benefiting everyone.

Watershed Analysis

Mission-Critical Requirements

QL3 lidar is required for all hydrologic unit codes (HUCs) that touch USFS lands, except for QL5 IFSAR for USFS lands in Alaska, for hydrologic and hydraulic modeling and mapping of floodplains on USFS lands.

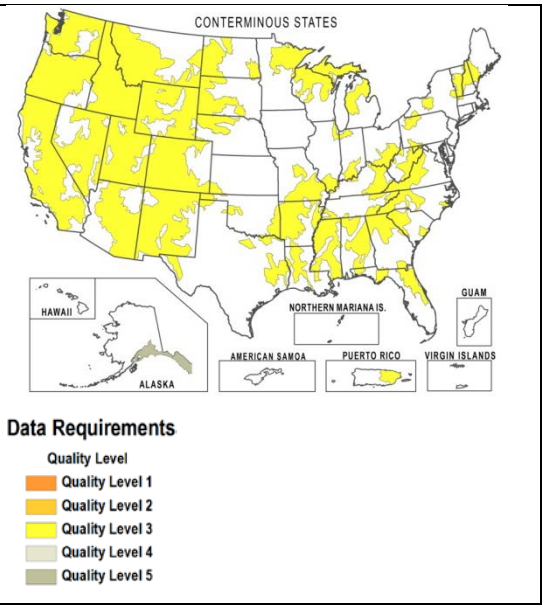
Update frequency: 6–10 years.

Business Use: River and Stream Resource Management, BU#3.

Estimated program budget: $182 million per year.

Quantifiable Benefits of Enhanced Elevation Data

USFS has estimated that more than $1 million per year could be saved using enhanced elevation data.



High-accuracy elevation data are needed for hydrologic and hydraulic analyses needed for mapping floodplains on USFS lands, as well as for hydraulic modeling of known critical locations and for placement of new structures.

Operational benefits (internal) to the USFS of enhanced elevation data for this functional activity

Time/Cost Savings: Major	Mission Compliance: Major	$ Benefits: >$1 million per year

- High-quality elevation data are critical to the hydraulic modeling and mapping of flood prone areas. If high-accuracy elevation products derived from lidar became available across entire USFS units, projects could be placed on the landscape with less risk of loss of public investment, resources, and property damage and to human safety. For example, resource managers would know the inherent risk of the placement of recreation facilities on a well delineated floodplain.
- A better ground surface model under canopy could provide significant benefits to hydrologic and hydraulic modeling and improved ecosystem management. It also would help with improved NEPA and Environmental Impact Statement (EIS) reports.
- Improvements in the elevation dataset for watershed analysis could yield a 0.5 to 1 percent improvement in costs and functional improvements, resulting in an estimated $1 million per year in savings over the 10-year life of the elevation data.
- Enhanced elevation data would be useful for predicting downstream flow and impacts during high-water events, leading to improved road, bridge, and facilities design.

Customer service benefits (external) to private and public partners from improved USFS products and services

Performance: Major	Timeliness: Moderate	Experience: Major	$ Benefits: Cannot estimate

- High-quality elevation data result in enhanced decision support to USFS managers who ensure public safety in flood-prone areas. Resources can be more effectively placed using more refined geographic information about the extents of forecasted flood prone areas.
- The integration of high accuracy elevation data help ensure the longevity of implemented projects and guard against risk to the safety of visitors using National Forest System lands. Risks can be identified and analyzed at more locations and addressed more quickly.

Other benefits from USFS use of enhanced elevation data for this functional activity

Public/Social: Major	Environmental: Minor	Strategic/Political: Major

- The ability to accurately model hydrologic and hydraulic processes would be greatly enhanced with higher resolution elevation datasets made available USFS-wide. Using high-accuracy DEMs and their derivatives can increase the efficient allocation of staff and monetary resources to locations that pose the highest risk to public safely and ecological value.
- The watersheds of more than 3,000 municipalities are managed or begin on public lands. Better elevation data would lead to better management of this precious, critical resource.

Soils and Geology Inventory

Mission-Critical Requirements

QL2 lidar is required for all USFS lands in CONUS and QL5 IFSAR is required for all USFS lands in Alaska for soil and geology inventories of Federal forest lands.

Update frequency: > 10 years.

Business Use: Natural Resources Conservation, BU#1.

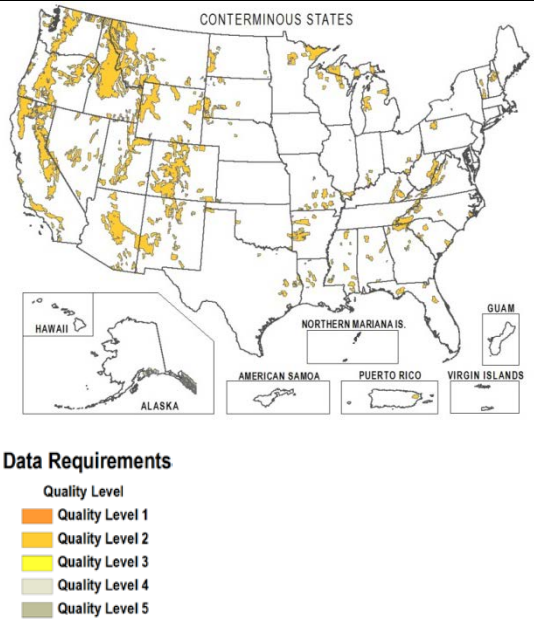
Estimated program budget: $87 million per year.

Quantifiable Benefits of Enhanced Elevation Data

The USFS has estimated that $800,000 per year could be saved on soils inventories for the 16 million acres of USFS lands that remain to be completed.

There may be some benefit to improved geology mapping by showing previously hidden structure in heavily forested areas.

The use of lidar would lead to better understanding and prediction of landslides and improved repair after events.



The USFS is relatively new to the application of lidar data to natural resource management. The USFS existing collection of high-accuracy elevation products was primarily created using traditional field collection methods on a project-by-project basis as critical needs arose.

The use of elevation data in mapping applications has greatly increased the capability of the USFS to spatially identify and locate individual soil components. Soil types are highly correlated to elevation, landscape position, and land shape. The use of high quality elevation data at the soil map unit scale could increase the probability of correctly identifying and locating individual soil components within map units.

Operational benefits (internal) to the USFS of enhanced elevation data for this functional activity

Time/Cost Savings: Moderate	Mission Compliance: Moderate	$ Benefits: $800,000 per year

- High-quality elevation data would increase the speed and efficiency of soils inventories. A congressionally mandated national cooperative survey of Federal lands is underway. Currently, soil inventories of 16 million acres of USFS lands remain to be completed. The USFS estimated that $8 million could be saved in the mapping of soils and ecological inventory units ($0.50 per acre times 16 million acres) using high quality elevation data as compared to the current process which relies on photogrammetrically derived DEMs. Over the 10-year life of the elevation data, this would result in annual savings of up to $800,000 per year. NOTE: It is likely that the estimate of 16 million acres in the USFS that need soil and ecological unit inventory at a cost of $8 million or $0.50 per acre using new technology is a significant underestimate. In region 4 of the USFS alone, 16.3 million acres does not meet National Cooperative Soil Survey standards. The use of high-resolution elevation data would be of benefit to the project if it occurs.
- Total costs are $1.50 per acre with standard soil survey and about $3.00 per acre for ecological unit mapping at 1:24,000 scale of mapping. Using high-quality elevation data with digital soil and ecological unit mapping applications may bring the cost down by saving on-the-ground reconnaissance and map unit verification time; however, field-plot-level data collection will still be required for identification of components to be used in the digital mapping. Updates of the elevation data would be needed only once for soil and ecological unit mapping. The next update would be the next mapping and that occurs about once every 50 years if needed. Historically, within such time spans, technology has changed, and new methods are used.

Customer service benefits (external) to private and public partners from improved USFS products and services

Performance: Moderate	Timeliness: Moderate	Experience: Moderate	$ Benefits: Cannot estimate

- Landslide prediction would be improved. Currently these assessments are done using coarsely mapped topographic and geologic datasets. Using high-accuracy DEMs and their derivatives can increase the efficient allocation of staff and monetary resources to locations that pose the highest risk to public safely and ecological value. There will be significant savings in staff time using lidar data through reductions in required field visits (soil pits). However, total savings cannot be estimated at this time.

Other benefits from USFS use of enhanced elevation data for this functional activity

Public/Social: Moderate	Environmental: Moderate	Strategic/Political: Moderate

- High-accuracy lidar data can lead to improved public safety. Safe roads and facilities require knowledge of soils and geology to ensure stable road surfaces and side-slopes, which is predicated on using an accurate model of topography.

Wetlands Mapping and Characterization

Mission-Critical Requirements

QL2 lidar is required for all USFS lands in CONUS and QL5 IFSAR for USFS lands in Alaska for slope calculations and wetlands delineations, which are used for habitat analysis.

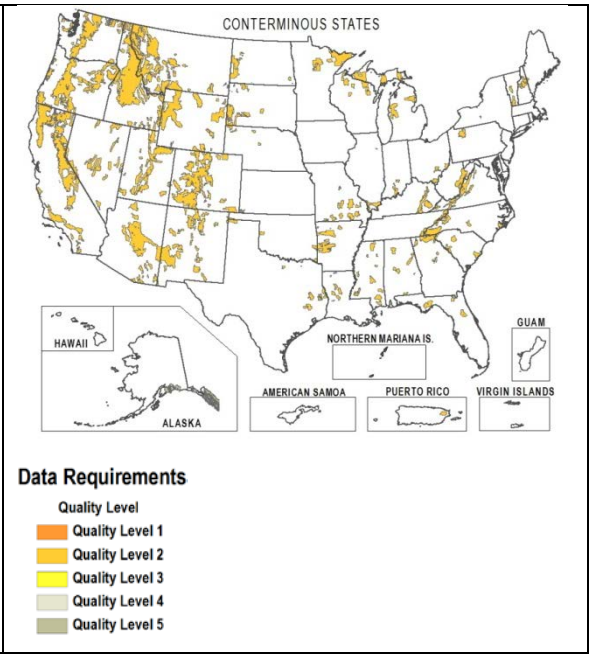
Update frequency: 6–10 years.

Business Use: Natural Resources Conservation, BU#1.

Estimated program budget: $200,000 per year.

Quantifiable Benefits of Enhanced Elevation Data

The USFS has estimated that $10,000 per year could be saved on elevation data processing if hydroenforced elevation data of suitable quality were readily available in its areas of interest.



The USFS requires hydroenforced elevation data at QL2 for all USFS lands for use in delineating and characterizing wetlands. Hydroenforcement refers to the processing of mapped water bodies so that lakes and reservoirs are level and so that streams flow downhill. Wetlands data are in turn used for habitat analysis.

Operational benefits (internal) to the USFS of enhanced elevation data for this functional activity

Time/Cost Savings: Major	Mission Compliance: Major	$ Benefits: $10,000 per year

- High-quality elevation data would improve the ability of the USFS to accurately map wetland boundaries, other environmentally critical areas, and surface water flow pathways, especially in areas of low relief.
- Hydroenforced data collected for the entire USFS study area would provide significant cost savings since the USFS is currently processing lidar data to derive hydroenforced data (for example, culvert removal). It should be noted that there is very little hydroenforcement done at the USFS at this time.

- Improved, hydroenforced data for wetlands mapping and characterization would reduce the amount of field work currently performed. Field visits could be reduced by as much as 5 percent if improved elevation data were available, resulting in an estimated $10,000 per year in savings.

Customer service benefits (external) to private and public partners from improved USFS products and services

Performance: Moderate	**Timeliness: Moderate**	**Experience: Moderate**	**$ Benefits: Cannot estimate**

- Improved ability to meet customer needs for improved targeting and assessment of conservation management practices.
- Improved speed and consistency at which the USFS is able to produce maps and other products.

Other benefits from USFS use of enhanced elevation data for this functional activity

Public/Social: Minor	**Environmental: Major**	**Strategic/Political: Unknown**

- High-quality elevation data would improve the ability of the USFS to accurately map wetland boundaries and perform habitat analyses, especially in areas of low relief.

Infrastructure Management

Mission-Critical Requirements

QL1 lidar is required for all USFS lands in CONUS and QL5 IFSAR for USFS lands in Alaska for design and placement of infrastructure (for example, roads, trails, culverts, buildings, outhouses, campgrounds, and fish passages) on USFS lands.

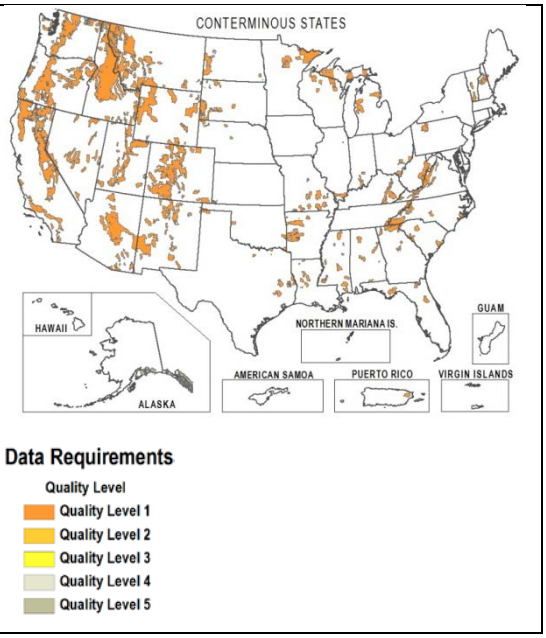
Update frequency: 4–5 years.

Business Use: Infrastructure and Construction Management, BU#21.

Estimated program budget: $495 million per year.

Quantifiable Benefits of Enhanced Elevation Data

The USFS has estimated that savings of $10 million per year could be realized through reduced need for field surveys and less staff time performing risk reduction assessments of USFS facilities.



High-accuracy elevation products are used in the design and placement of capital improvements, such as buildings, roads, trails, and telecommunications facilities. The cultural resource inventory is first stratified by using detailed analysis of the landscape. The planning and implementation of linear features such as roads and trails require high accuracy elevation data as input into automated models, including hydraulic modeling and floodplain mapping to ensure that infrastructure is not placed at risk.

Operational benefits (internal) to the USFS of enhanced elevation data for this functional activity

Time/Cost Savings: Major	**Mission Compliance: Major**	**$ Benefits: $10 million per year**

- The availability of high accuracy elevation products will reduce the amount of time presently consumed by resource specialists to manually compute and assess topographic conditions to use in assessing appropriate structure design and logistics of design implementation. The amount of necessary field survey will be reduced, while a higher accuracy of estimates for these resource conditions based on topographic mapping will be realized.

- One engineer estimated that he could have saved a month's worth of his time if he had a lidar survey instead of a ground-based survey in a particular watershed he was working on. That equates to a salary savings of $8,000 for one person on one project. Extrapolating this information to similar annual work, the USFS estimated that $10 million annually could be saved in field surveys.
- If high-accuracy elevation products derived from lidar became available across all USFS units, projects could be placed on the landscape with less risk of loss of public investment, resource and property damage, and to human safety.

Customer service benefits (external) to private and public partners from improved USFS products and services

Performance: Major	**Timeliness: Moderate**	**Experience: Major**	**$ Benefits: Cannot estimate**

- Projects can be completed more quickly because time needed for field surveys can be reduced or eliminated rather than waiting for the availability of field survey crews, modeling can commence as needed, which would result in significant cost savings.
- High-accuracy elevation data can be used to help ensure the longevity of implemented projects and guard against risk to public safety of visitors using the National Forest System lands. Risks could be identified with higher accuracy, analyzed at more locations, and addressed more quickly.
- The identification of sites most suited to cultural resource discovery can be quickly located and even the features themselves can often be detected using high accuracy elevation products. This can save staff time and money. It should be noted that the USFS currently does not do a lot of this kind of work, so the cost savings would be modest for this particular service benefit.

Other benefits from USFS use of enhanced elevation data for this functional activity

Public/Social: Major	**Environmental: Minor**	**Strategic/Political: Moderate**

- High-accuracy lidar data can lead to improved public safety. Safe roads and facilities are always the goal in facilities management and design. When approaching road design, several aspects of safety, including a stable road surface and side-slopes, are predicated on using accurate models of topography. High-accuracy elevation datasets provide the engineer with the tools to quickly plan for safe routes in the most cost effective manner. This type of data USFS-wide could facilitate the development of accurate assessments in support of Forest Plan documents.
- The identification of cultural resources could be enhanced and hastened. These enhanced products could be available for forest plan analysis on a USFS-wide scale.

U.S. Geological Survey

Point of Contact: Dick Vraga, (608) 821–3896, rsvraga@usgs.gov

The USGS serves the Nation by providing reliable scientific information to describe and understand the Earth; minimize loss of life and property from natural disasters; manage water, biological, energy, and mineral resources; and enhance and protect our quality of life.

The USGS is a science organization that provides impartial information on the health of our ecosystems and environment, the natural hazards that threaten us, the natural resources we rely on, the impacts of climate and land-use change, and the core science systems that help us provide timely, relevant, and useable information.

As the Nation's largest water, Earth, and biological science and civilian mapping agency, the USGS collects, monitors, analyzes, and provides scientific understanding about natural resource conditions, issues, and problems. The diversity of USGS scientific expertise enables it to carry out large-scale, multidisciplinary investigations and provide impartial scientific information to resource managers, planners, and other customers.

The USGS is focused on some of the most significant issues society faces, in which natural science can make a substantial contribution to the well-being of the Nation and the world:

- climate and land use change
- core science systems
- ecosystems
- energy and minerals, and environmental health
- natural hazards
- water

USGS managers identified nine major functional activities with mission-critical requirements for elevation data:

- Geologic Mapping, under BU#9, Geologic Resource Assessment and Hazards Mitigation
- Seismic Hazards, under BU#9, Geologic Resource Assessment and Hazards Mitigation
- Landslide Hazards, under BU#9, Geologic Resource Assessment and Hazards Mitigation
- Volcano Hazards, under BU#9, Geologic Resource Assessment and Hazards Mitigation
- Water Resource Planning and Management, under BU#2, Water Supply and Quality, and BU#3, River and Stream Resource Management
- Coastal Zone Management and Sea Level Rise and Subsidence, under BU#4, Coastal Zone Management, and BU#15, Sea Level Rise and Subsidence
- Flood Risk Management, under BU# 14, Flood Risk Management
- Mapping, Monitoring, and Assessment of Biological Carbon Stocks, under BU#1, Natural Resources Conservation
- Mapping, Monitoring, and Assessment of Habitat, under BU#7, Wildlife and Habitat Management

USGS managers provided the following assessments of elevation data requirements and benefits received from the enhanced elevation data quality level that they identified as mission-critical. Summarized details are provided in the following pages.

Geologic Mapping

Mission-Critical Requirements

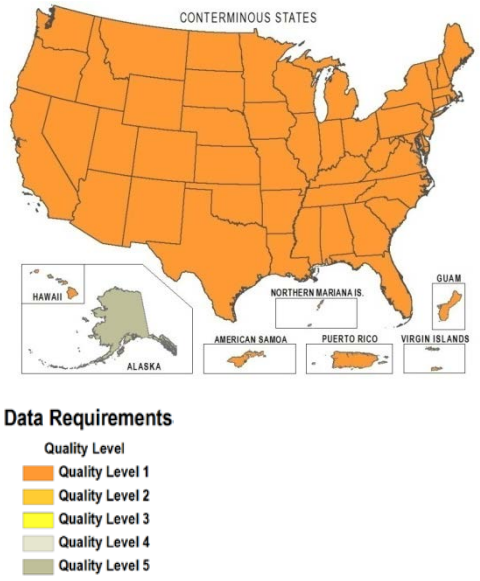
High-density and high-accuracy QL1 lidar data are essential for most geologic mapping, particularly for young deposits and landforms, which are those most essential to understanding Earth hazards, groundwater, climate change, and sand and gravel resources. The resolution and accuracy of elevation data limit the thematic resolution of geologic maps.

Update frequency: 6–10 years.

Business Use: Geologic Resource Assessment and Hazards Mitigation, BU#9.

Estimated program budget supported by elevation data: $30 million per year.

Quantifiable Benefits of Enhanced Elevation Data: $10 million per year.



The National Cooperative Geologic Mapping Program (NCGMP) supports geologic mapping by the USGS, State geologic surveys, and universities. This mapping guides assessment and development of solid-Earth resources (base and precious metals, sand and gravel, coal, oil, and natural gas), provides a framework for assessment and mitigation of earth hazards (landslides, earthquakes, mine collapse, floods), is essential to groundwater investigations, provides a much-needed context for climate-change studies, underlies local land-use planning, and supports site-specific engineering studies by the geotechnical industry. The annual budget for the NCGMP is about $30 million.

Some projects within the NCGMP, primarily in the Pacific Northwest where lidar data have been acquired by the Puget Sound lidar Consortium and the Oregon lidar Consortium, have more than a decade experience working with lidar elevation data. With these data, geologic maps are more detailed and conceptually superior. The improvement is especially significant for identification of young (Quaternary) deposits and landforms and for the evaluation of Earth hazards (landslides, earthquakes), study of groundwater resources, and assessment of sand and gravel resources. The greater spatial accuracy greatly benefits map users because lidar-based geologic maps can commonly be interpreted at the parcel level. Previously, this precision was rare for general-purpose geologic maps produced by public agencies.

Nationwide QL1 lidar elevation data would extend these benefits to all activities supported by the NCGMP. There will be no problem with uptake of high-resolution lidar topography by the NCGMP community. In addition, there are selected areas where science investigations may require higher point density, such as mapping of detailed geologic fault and landslide features. The USGS estimated that, currently, less than 10 percent of the work supported by NCGMP is in areas where lidar data are available. With nationwide lidar data, modest efficiencies and much-improved science will be possible with lidar extended to all of USGS-supported programs. The USGS estimated that the direct benefit of nationwide QL1 lidar coverage to the NCGMP would be $10 million per year.

The NCGMP strongly supports acquiring lidar data at about 8 pulses per square meter (QL1). There are three reasons for recommending this data quality level:

- The experiences from the projects in the Pacific Northwest have shown that there is more support for acquisition of high-quality data from significant cooperators than for lower quality data.
- The USGS has substantial experience with both 1- and 8-pulse-per-square-meter data in forested areas. The difference in DEM quality is significant, even though 8-pulse-per-square-meter data are gridded at 1- or 2-m resolution. The higher resolution data result in more laser point returns from the ground surface rather than vegetation thereby producing higher quality DEMs that are easier to interpret and can be interpreted more confidently.
- When better elevation data are made available to the geologic research community, productive and remunerative uses of these data will be found.

Where does the NCGMP need enhanced elevation data? By statute, the focus of the NCGMP is the Nation. America needs better elevation data everywhere; however, the NCMGP cannot use better data everywhere all at once.

- In the long term (>10 years), NCGMP needs are not particularly predictable, as geologic map-related concerns evolve (for example, from resources to hazards to biologic and geologic interaction and climate change).
- In the short term (1–5 years), NCGMP needs are predictable, and collaboration between the NCGMP and an enhanced elevation program would be useful.

The scope of the NCGMP includes Alaska where lidar is not the best technological solution. The NCGMP would benefit from acquisition (by purchase and public-domain release of existing data or purchase of new data) of about 5-m-horizontal resolution and 1-m-vertical accuracy airborne IFSAR data.

Operational benefits (internal) to the USGS of enhanced elevation data for this functional activity

Time/Cost Savings: Minor	**Mission Compliance: Major**	**$ Benefits: $5 million per year**

- Time and cost savings within the NCGMP are likely to be modest. Geologic mapping with high-resolution lidar topography is a little faster than mapping without. The increased productivity will almost certainly be absorbed in making better and more maps with the same resources.
- More extensive, better elevation data will clearly result in increased mission compliance. Spatial precision of geologic maps improves dramatically. For 7.5-minute quadrangle-format maps, the improvement is typically between 5 to 15 meters and 30 to 100 meters. Thematic accuracy increases as well, in some cases doubling the number of units that can be mapped.
- It is expected that the use of lidar topography across the NCGMP will result in a benefit equivalent to one-third the overall cost of the program (about $30 million per year) and these benefits will be shared equally between the NCGMP and external collaborators and clients, resulting in $5 million per year in benefits.

Customer service benefits (external) to the public from improved USGS products and services

Performance: Major	**Timeliness: Minor**	**Experience: Major**	**$ Benefits: $5 million per year**

- Improved spatial and thematic accuracy of geologic maps (for example, better delineation of landslides) will be a major benefit to traditional customers of the USGS. Spatial precision appropriate to parcel-level studies should make USGS maps relevant to more users.
- An additional benefit is the use of detailed shaded relief as a base for portraying geology. Experience has shown that such shaded-relief based maps are readily understood by most people. Furthermore, portrayal of geology on detailed shaded relief allows ready evaluation of the quality of the geologic mapping.
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Other benefits from USGS use of enhanced elevation data for this functional activity

Public/Social: Moderate	**Environmental: Major**	**Strategic/Political: Major**

- The NCGMP experiences considerable pressure to make geologic mapping relevant to a wider audience than the traditional audiences of the mineral-resource and fossil-fuel industries. Better elevation data are key to this improved relevance. In particular, there is a rough correspondence between spatial scale and temporal scale in geologic understanding. The fossil-fuel focused studies of the past tended to look at phenomena (development of fold-and-thrust belts, basin subsidence) that have vertical scales of kilometers and temporal scales of tens to hundreds of millions of years. Current hazard-focused investigations look at landslides and fault scarps with vertical scales of meters and temporal scales of years to centuries. High-resolution lidar data allow the investigation of phenomena with vertical scales of decimeters (or even centimeters) and temporal scales of weeks to years and could make geologic mapping more relevant to biologic and ecologic concerns.

Seismic Hazards

Mission-Critical Requirements

Defining the location and relative activity of active faults requires high-resolution topography (QL1 lidar) to define and map areas of past surface rupture.

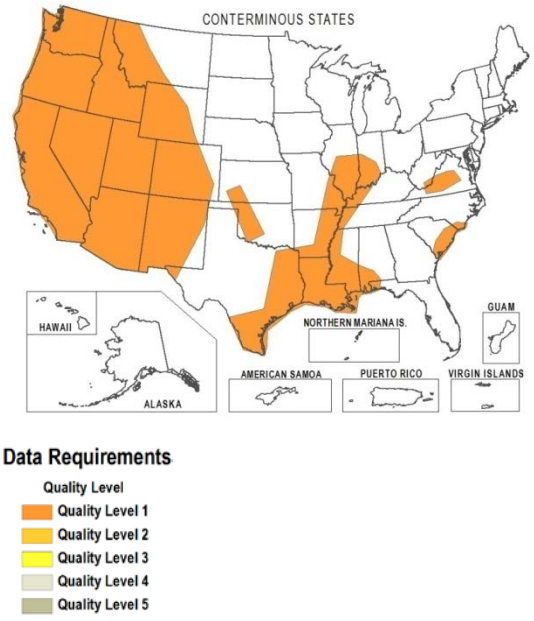
Update frequency: 6–10 years.

Business Use: Geologic Resource Assessment and Hazards Mitigation, BU#9.

Estimated program budget supported by elevation data: $25 million per year.

Quantifiable Benefits of Enhanced Elevation Data

Benefits are expected to be major but undetermined. Initial lidar mapping in central Washington helped identify three new active faults near a $12 billion (building costs) nuclear waste treatment plant being built to treat 55 million gallons of nuclear contaminated waste at the former Hanford Nuclear Reservation. The financial benefits of lidar for detecting active faults near critical facilities are huge but cannot be estimated with any degree of certainty.



The Earthquake Hazards Program (EHP) is part of the USGS effort to reduce earthquake hazards in the United States. The EHP is the USGS component of the congressionally established, multiagency National Earthquake Hazards Reduction Program (NEHRP). The USGS participates in the NEHRP with FEMA, the National Institute of Standards and Technology (NIST), and the NSF. In the 2004 reauthorization of the NEHRP by Congress, NIST was given the lead role to plan and coordinate this national effort to mitigate earthquake losses by developing and applying Earth science data and assessments essential for land-use planning, engineering design, and emergency preparedness decisions.

Earthquakes pose significant risk to 75 million Americans in 39 States. The USGS is the only Federal agency with responsibility for recording and reporting earthquake activity nationwide. Citizens, emergency responders, and engineers rely on the USGS for accurate and timely information on where an earthquake occurred, how much the ground shook in different locations, and what the likelihood is of future significant ground shaking.

Operational benefits (internal) to USGS of enhanced elevation data for this functional activity

Time/Cost Savings: Major	Mission Compliance: Major	$ Benefits: Cannot determine

- Operational benefits for seismic hazard research center on the ability of the USGS to identify and define specific faults and earthquake hazards to a higher degree than before. The ability to image and map faults beneath this vegetation canopies and quickly map and assess these faults is critical to the USGS ability to accurately define the seismic hazards for any given region.

Customer service benefits (external) to the public from improved USGS products and services

Performance: Minor	Timeliness: Major	Experience: Major	$ Benefits: Major but undetermined

- USGS customers realize the benefits of lidar by having seismic hazard assessments completed in a more timely and accurate manner. With lidar, users are able to go into a new research area and quickly assess the entire area for surface ruptures and deformation in ways that were unavailable a decade ago. Specialists are now beginning to use lidar to assess tsunami hazards along the coasts of Washington and Oregon—this technique was unavailable before the advent of low-cost, high-resolution lidar mapping.
- Discovery of 12 new faults in western Washington during the past 10 years came about through the use of lidar surveys to identify surface ruptures from past earthquakes previously hidden from view by thick vegetation.

- Lidar mapping led to the discovery of a surface rupture along the Tacoma, Wash., fault, leading to a redesign of structural elements of a $735 million suspension bridge during construction of the bridge across the Tacoma Narrows in Washington.

Other benefits from USGS use of enhanced elevation data for this functional activity

Public/Social: Major	Environmental: Major	Strategic/Political: Major

- When lidar enables the identification of active faults near planned nuclear waste treatment facilities or a major suspension bridge so that proactive mitigation steps can be taken to avoid potential catastrophe in the future, the public and social, environmental, and strategic and political benefits are major.

Landslide Hazards

Mission-Critical Requirements

Defining the location and relative activity of landslide processes requires high-resolution QL1 lidar to define the spatially limited, steepest extents of watersheds, as well as hill-slope roughness characteristics to assess activity.

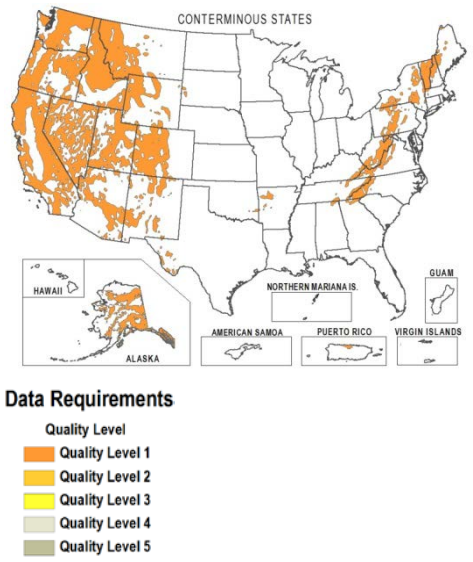
Update frequency: 4–5 years.

Business Use: Geologic Resource Assessment and Hazards Mitigation, BU#9.

Estimated program budget supported by elevation data: $2.2 million per year.

Quantifiable Benefits of Enhanced Elevation Data

Benefits of about $20.25 million per year are anticipated from reductions in data acquisition and processing costs as well as reduced losses from landslides.



The Landslide Hazards Program (LHP) supports the USGS mission to serve the Nation by providing reliable scientific information to minimize loss of life and property from natural disasters. The LHP's mission is to provide information that leads to the reduction of losses from landslides and an increase in public safety through improved understanding of landslide hazards and strategies for hazard mitigation, with much of this effort reliant on adequate topographic data. In pursuit of the program mission, the LHP conducts landslide hazard assessments, pursues landslide investigations and forecasts, provides technical assistance to respond to landslide emergencies, and engages in outreach activities, all of which would benefit from high resolution, seamless lidar data.

Research on landslide hazards addresses fundamental questions of where and when landslides are likely to occur; the size, speed, effects of landslides; and how to avoid or mitigate those effects. Such research is essential if the LHP is to make significant progress in addressing landslide problems triggered by severe storms, earthquakes, volcanic activity, coastal wave attack, and wildland fires in the United States. Public and private decisionmakers increasingly depend on information that the LHP provides before, during, and after a disaster so that they can live, work, and build safely. Seamless, high-resolution topographic data will significantly assist researchers to refine forecasts of where and when landslides will occur and thus be better suited to provide meaningful information to decisionmakers. Landslide runout paths and evacuation routes could be determined with greater accuracy.

Similarly, the NCGMP provides accurate geologic maps and 3D-framework models that help to sustain and improve the quality of life and economic vitality of the Nation and mitigate natural hazards. Funding from the LHP and the NCGMP is used by landslide researchers to use lidar-derived topography to document and further the understanding of landslide and surface erosion processes. Furthermore, geomorphic process mapping in steep lands dictates the use of topographic data at the scale at which the processes are operating. Numerous sediment transport processes driving patterns of erosion simply cannot be represented by data of a quality less than QL1. Geomorphic process mapping relies on such topographic data for base maps and derivative products (for example, gradient, curvature, and flow routing).

Operational benefits (internal) to the USGS of enhanced elevation data for this functional activity

Time/Cost Savings: Major	Mission Compliance: Major	$ Benefits: $0.25 million per year

- The USGS has taken the lead in developing a strategy for landslide hazards mitigation on behalf of a large multisector, multiagency stakeholder group involved in landslide hazards mitigation. The USGS derives its leadership role in landslide hazard-related work from the Disaster Relief Act of 1974 (42 U.S.C. §5201 et seq.). For example, the USGS has been delegated the responsibility to issue disaster warnings for an earthquake, volcanic eruption, landslide, or other geologic catastrophe. The delivery of high-resolution lidar topography would assist the agency to succeed in this mandate by decreasing the areal extent of false positive identification of landslide susceptibility.
- Many of the existing topographic data are not of sufficient resolution to capture landslide processes. Shallow landslides that can mobilize into fast-moving damaging and deadly debris flows, for example, may initiate as areas with small source areas (tens of square meters). Defining the source location of these features dictates a topographic dataset with sufficient resolution to mimic the scale of the process-scale footprint on the ground. Similarly, defining the relative activity level of large deep-seated landslides requires a point spacing that can represent the high-frequency hummocky topography characteristic of recent displacement. In order to be consistent with future time-series lidar surveys, QL1 data or better are needed. Such topographic difference maps could be used similarly to IFSAR to delineate areas of active deformation. Increased resolution of surface morphology could assist in defining the 3D depth and structure of larger landslides. Time series could be collected either on a set time interval or on an event basis. Events would be defined so that the regional level of landsliding is widespread, such as occurring in conjunction with a large earthquake or storm sequence that results in the declaration of a State- or Federal-level disaster area. Seamless QL1 lidar data would provide a major time and cost savings ($0.25 million per year) in the realm of slope stability hazard delineation and mission compliance by reducing the time spent having to contract and process the new data and increased efficiency in determining relative landslide susceptibility.

Customer service benefits (external) from improved USGS products and services

Performance: Major	Timeliness: Major	Experience: Moderate	$ Benefits: >$20 million per year

- The acquisition of a seamless, high-quality topographic dataset will be of widespread use to the greater community associated with landslide hazard and risk. For example, research scientists would benefit by being able to develop and test new initiation and runout models. Geotechnical engineers and geomorphologists would benefit by linking the material properties of the underlying rocks and soil of the landscape with the long-term landslide process signature expressed by the topography. Other Federal agencies, such as NOAA, the NWS, the USFS, and FEMA, would benefit for similar reasons. NOAA, for example, could refine estimates of the influence of topography on precipitation distribution. Consultants and nongovernmental organizations in the engineering and geologic sectors would be able to start projects with framework topographic data in hand without having to contract separately for each individual project. State agencies, such as State geological surveys, offices of emergency services, and fire control, could all quickly adopt high-resolution topography into their landslide-related decisionmaking processes. At the local level, regional parks and sheriffs, for example, could plan for evacuations and staging areas.
- Hazard analyses derived from national high-resolution topography would lead to decreased landslide-related losses by approximately $20 million dollars. Future hazard analyses derived from high-resolution topography would lead to a reduction in landslide-related losses by restricting future development in unstable areas and encouraging remediation measures where infrastructure and property already exists. Losses from landslides in Oregon, for example, range from $10 million to hundreds of millions per year, making landslides one of the most common and destructive natural hazards in the State. Lidar maps are the basis for creating very accurate landslide inventory maps, identifying 3 to 200 times the number of landslides located when mapping the same areas using other available technologies.

Other benefits from USGS use of enhanced elevation data for this functional activity

Public/Social: Major	Environmental: Moderate	Strategic/Political: Major

- National-scale, high-resolution lidar data would facilitate potential new partnerships between government at all levels, academia, and the private sector to refine landslide research, mapping, assessment, real-time monitoring,

forecasting, information management and dissemination, mitigation tools, and emergency preparedness and response. Such new technological advances would also enlist the expertise associated with other related hazards, such as floods, earthquakes, and volcanic activity, and use incentives for the adoption of loss reduction measures nationwide.

Volcano Hazards

Mission-Critical Requirements

The USGS needs accurate, high-resolution QL1 lidar data pre-eruption of at least every high-priority volcano to improve hazard maps, geologic maps, and flow models that use topography as a model parameter. Post-eruption topography will better characterize new hazards from slope and lava dome instability. QL2 and QL3 data are needed for lower priority volcanoes.

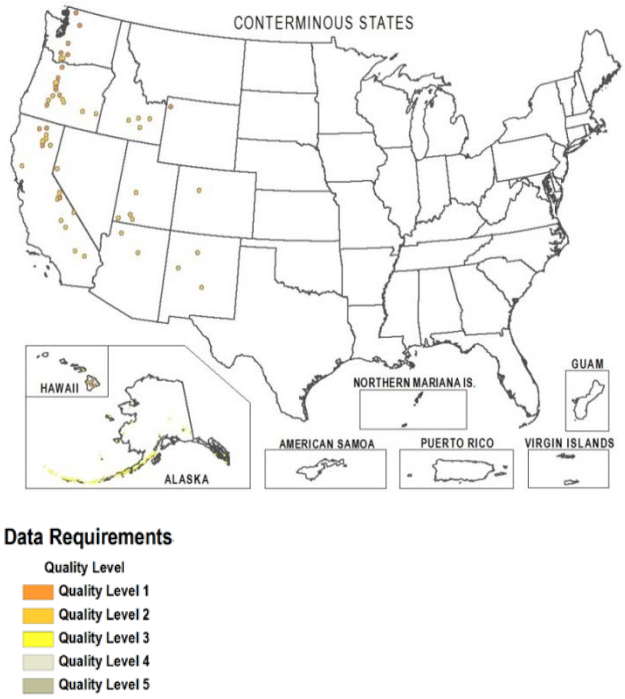
Update frequency: 4–5 years, more frequently during and after major eruptions.

Business Use: Geologic Resource Assessment and Hazards Mitigation, BU#9.

Estimated program budget supported by elevation data: $10 million per year.

Quantifiable Benefits of Enhanced Elevation Data

High quality lidar data of each active U.S. volcano would improve USGS hazard assessments and lahar flow models that would potentially result in at least $11 million per year savings averaged over major decadal scale eruptions.



Lidar data of volcanic edifices and their drainages provide useful information to observatories and community partners before, during, and after volcanic eruptions. The USGS needs accurate, high-resolution, pre-eruption data for at least every high-priority volcano to improve hazard maps, geologic maps, and flow models that use topography as a model parameter. During volcanic eruptions, acquisition of high-resolution elevation data, especially for significant events, will provide better estimates of the volume of eruptive products, such as pyroclastic flows, lahars, and lava flows, and will permit assessment of changes in volcano and dome structure, as well as changes in available ice-volumes for future flows. After an eruption, specialists need good elevation data of the new volcanic landscape to provide a base for future eruptions and to monitor erosion and instabilities in the new deposits. In the aftermath of a large eruption, volcanic landscapes can change quickly, and repeat lidar surveys would permit quantitative assessment of these changes, which may be important to or govern ecologic recovery of the affected areas or drainages.

Operational benefits (internal) to the USGS of enhanced elevation data for this functional activity

Time/Cost Savings: Major	Mission Compliance: Major	$ Benefits: $1 million per year

- Significant gains (on the order of $1 million per year) in efficiency of product generation and accuracy would be realized. Having nationally consistent lidar would save time and funds acquiring and processing inferior elevation data from optical stereosatellite sources. More work could be completed in the office, and less field time would be required, significantly reducing field-related costs.
- Improved elevation data combined with high-resolution satellite data help geologists map volcanic deposits and edifice structure in advance of often short and expensive helicopter-based field expeditions. Through preliminary mapping on high resolution 2D and 3D visualizations of these combined datasets, less time is spent determining unit boundaries, freeing up more time to complete detailed stratigraphic studies and sampling of deposits. The USGS Volcano Science Center has begun to use more high-resolution satellite data to map and plan instrument deployment logistics at remote field sites, but the highest resolution elevation data to improve

flow models and assess lava flow structure do not yet exist. With helicopters costing as much as $6,000 per day in Alaska, time saved in the field positively affects the available budget by focusing work on the most critical details. Many large volcano eruptions in the United States have occurred during winter where new deposits are often covered with snow soon after deposition, making it more difficult to map and identify deposits later. Acquisition of high-resolution elevation data immediately after large eruptive events would significantly increase the Alaska Volcano Observatory's effectiveness in mapping and assessment of volcanic hazards.

Customer service benefits (external) to the public from improved USGS products and services

Performance: Minor	Timeliness: Moderate	Experience: Moderate	$ Benefits: $10 million per year

- USGS customers realize the benefits of lidar by having seismic hazard assessments completed in a more timely and accurate manner. With lidar, specialists are able to go into a new research area and quickly assess the entire area for surface ruptures and deformation in ways that were unavailable a decade ago.
- Sharing of data among partner agencies would provide a significant cost savings. Most U.S. volcanoes are located in national parks, wildlife refuges, or other Federal lands. Any elevation data acquired would be useful to the land managing agencies.
- USGS volcano hazard products developed using high-resolution elevation data will reduce costs to USGS customers by providing more timely and accurate maps and models to emergency planners. With lidar, specialists are able to assess edifice stability and refine lahar flow models in ways that were unavailable a decade ago. As other agencies and commercial vendors continue to provide publically accessible high-resolution data, especially through Google Earth, both the public and community partners will expect America's hazard products and models to keep pace.
- Lidar datasets for volcanoes and areas downstream provide essential elevation information to scientists, emergency response teams, and land-use planners. The financial savings come from the combined use of these data by many agencies and municipalities for modeling everything from volcanic debris flow hazards to identifying buildings at risk from volcanic ash deposits based on roof size and structure. Other savings will come through improved land-use planning and zoning made possible with models derived, in part, from higher resolution elevation data. Use of high-resolution elevation data for hazard assessment will result in a much higher level of accuracy of hazard zone maps and decrease the uncertainty of quantitative estimates of the magnitude of certain types of hazardous phenomena such as lahars and floods.

Other benefits from USGS use of enhanced elevation data for this functional activity

Public/Social: Minor	Environmental: Minor	Strategic/Political: Minor

- Timely volcano deformation maps can identify potential areas of edifice or lava dome failure during periods of volcanic unrest. Loss of life or property can be significantly reduced because deformation maps can help identify previously unknown points of failure and help with estimates regarding the scale of a pending eruption. Early recognition and monitoring of such deformation is important for real-time hazard assessment where as much advance warning as possible is desirable.
- The resulting increase in accuracy of hazard maps and assessments would better portray areas at risk to various types of volcanic hazards and thus enable better assessment of environmental impacts. High-resolution elevation data allow for more efficient assessment of potential network, instrument, or other field study sites depending on long-range telemetry and for low-impact site development and repeat access.

Water Resource Planning and Management

Mission-Critical Requirements

Enhanced elevation data from QL3 through QL1 and bathymetric data are required for a range of surface water, groundwater, and water quality investigations designed to support State and local agencies with water resource planning and management needs.

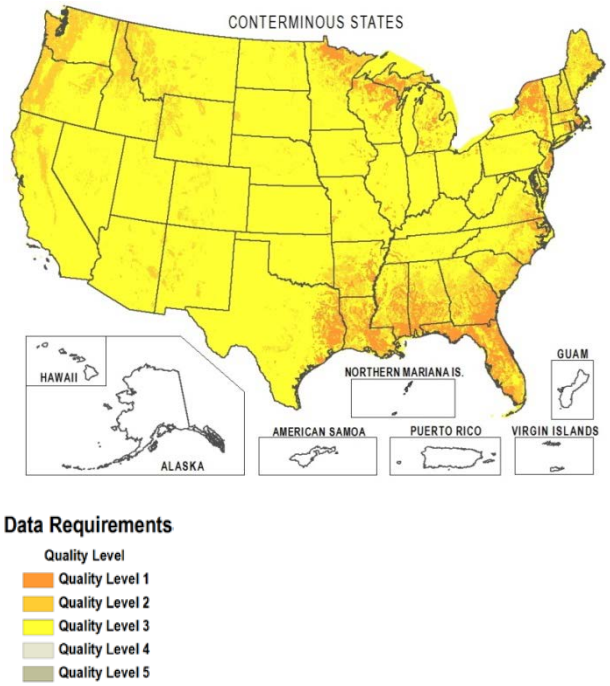
Update frequency: 4–5 years.

Business Use: Water Supply and Quality, BU#2, and River and Stream Resource Management, BU#3.

Estimated program budget supported by elevation data: $228 million per year.

Quantifiable Benefits of Enhanced Elevation Data

Time and cost savings are major, but financial benefits cannot be quantified.



Studies by the USGS in support of water resource planning and management include ecological flow analyses, watershed assessments, water-supply and water-quality assessments, water-level data collection, statistical analyses of available data to describe current and historical water quantity and quality and water use, groundwater-table and stream mapping, and development of statistical models for estimating streamflow statistics at ungaged locations. These studies usually are done in cooperation with Federal, State, and local agencies through the National Cooperative Water Program. Hydrologic (watershed) and groundwater models are tools that require elevation data to gain a better understanding of hydrologic systems and how historical, current, and potential future anthropogenic activities and climate change can affect water resource quality and availability.

Accurate bare Earth elevation data are essential for modeling inundation areas, stream channels, areas of ponding and groundwater recharge, and ecological flow analysis. For upland areas with sparse vegetation or deciduous vegetation, a higher quality level is not necessary to capture bare Earth values accurately. Areas with extremely dense vegetation (pocosin wetlands, marshlands, pine forests) are more problematic. Higher point density or alternative elevation model development is necessary in these areas. Canopy density is important as a guide, but knowledge of vegetation type is more important in predicting whether lidar will penetrate the vegetation and provide a bare Earth return.

Operational benefits (internal) to USGS of enhanced elevation data for this functional activity

Time/Cost Savings: Major	Mission Compliance: Major	$ Benefits: Major, but cannot estimate

- Readily available lidar-based elevation data that are preprocessed into a seamless, highly accurate, nationwide DEM will help improve the timeliness and accuracy of results from a wide variety of hydrologic investigations. For example, elevation data are used to construct and calibrate groundwater and surface-water flow models, for mapping of stream channels, and for mapping of biota and anthropogenic activities adjacent to and within stream channels. Elevation data also are used to delineate watersheds and to compute numerous watershed physical characteristics that are used as explanatory variables in statistical analyses to develop equations for estimating stream flow statistics at ungaged sites. Time, effort, and money that currently are spent to acquire and process elevation data from other sources will be dramatically reduced or eliminated if lidar-based data become available through the NED. In addition, this effort will provide uniformity in data collection, processing, resolution, and accuracy. If hydrologic break lines also become available, then lidar-based elevation data could be vertically and horizontally integrated with hydrography to generate accurate flow lines, which

would also save weeks of processing time on a typical project. Project scopes can be expanded and analysis can be done in areas that would typically not have been possible either because of budget or accessibility issues.

- Availability of accurate lidar-based land-surface elevation data will improve the accuracy of watershed and groundwater models. These data will allow for more accurate drainage-basin delineations, determinations of stream-channel cross-sections and profiles, and other parameters for watershed models. These data also will lead to more accurate determinations of water-table elevations at well locations used for groundwater model calibration, leading to improved modeling of water-level changes due to pumping and varying climate conditions. Field surveys currently performed to obtain data needed for watershed and groundwater model construction may be eliminated when lidar-based elevation data are available, thus saving project time and cost. For example, an estimated 100 to 160 man-hours were saved by using lidar-derived DEMs for a groundwater investigation in Carson Valley, Nevada, instead of field-data collection, to determine accurate altitudes for irrigation canal networks to ensure correct flow direction, and to estimate canal widths for input to stream flow routing software. In surface water studies in the western United States, where snowmelt contributes substantially to water supply, lidar-derived DEMS can help improve snowmelt runoff models, which can directly affect water-supply estimates.
- In the arid southwest, lidar-derived DEMs can aid in determining potential areas of groundwater discharge. Understanding the extent and location of these areas is central to developing more accurate estimates of discharge in groundwater budgets and groundwater flow models.
- Ecological-flow studies can encompass a variety of activities, including stream flow, water-quality, geomorphologic and biological sampling of streams, water-use data collection, stream mapping, hydrologic and water-quality modeling, and statistical analyses. Lidar-based elevation data would benefit such studies by allowing for more accurate stream mapping, watershed delineations, and model parameterization. Better definition of channels and ditches in the landscape can lead to more accurate mapping of water features, both historic and current, and a better understanding of flow regimes.

Customer service benefits (external) to the public from improved USGS products and services

Performance: Minor	**Timeliness: Moderate**	**Experience: Major**	**$ Benefits: Unknown**

- Cooperators and the public rely on the USGS to be an impartial source of scientific information, including data collection, dissemination, and regional environmental investigations. Nationwide access to enhanced digital elevation data will allow the USGS to better meet the expectations of the public and to better perform its mission. In addition, the dissemination of these data will allow the public to utilize these vital datasets for their own needs.
- The USGS provides a range of environmental data that many agencies use to make planning and management decisions. Decisions on source-water protection areas, water-quality standards, total maximum daily load values, flood-inundation areas, and minimum-flow standards are often based on data and analyses that the USGS provides. Greater accuracy and improved resolution of USGS elevation products will increase the confidence in decisions based upon these data.
- All States have agencies that perform water-quality assessments that require a GIS layer representing streams and surface water bodies as a means to index their EPA and (or) other Federal and State reporting requirements. A stream layer derived from current QL3 or QL2 lidar and 1-ft resolution imagery will provide these agencies with accurate geospatial representations of their statewide hydrographic features and watershed boundaries.
- A federal elevation program that is implemented in a manner to take advantage of State budget cycles and State elevation requirements will likely receive the support of States that will cooperatively participate in the collection of high-resolution elevation data.

Other benefits from USGS use of enhanced elevation data for this functional activity

Public/Social: Major	**Environmental: Major**	**Strategic/Political: Moderate**

- Access to lidar data provides the ability to recognize landscape features that are not visible even with high-resolution imagery. This allows scientist to analyze their work with a new perspective and understanding that was not available previously.
- The access to highly accurate elevation data will drive many research and program areas that would not have been possible without access to these data. Many applications in 3D modeling, network analysis, fusion of

imagery, and sensors have only been touched upon as research areas and have the potential to revolutionize the way water data are analyzed and visualized.

- Other benefits include maintaining a high quality of life through proper management of our natural resources and promoting a better economic climate through investments in data collection, analysis, and investigation of our natural resources. Additional benefits could result from our increased understanding of surface and groundwater quality, quantity, stream morphology, water resource uses and impacts, and flood inundation mapping, which will increase the potential to save loss of property and life.
- The collection of enhanced elevation data on a national scale will help strengthen the reputation of the USGS as a premier source of environmental science information.

Coastal Zone Management and Sea Level Rise and Subsidence

Mission-Critical Requirements

Accurate and up-to-date coastal topographic maps from QL2 lidar and bathymetric lidar are required by land use planners to establish building set-backs, inventory wetland and agricultural land resources, and to identify flood and hurricane hazard zones.

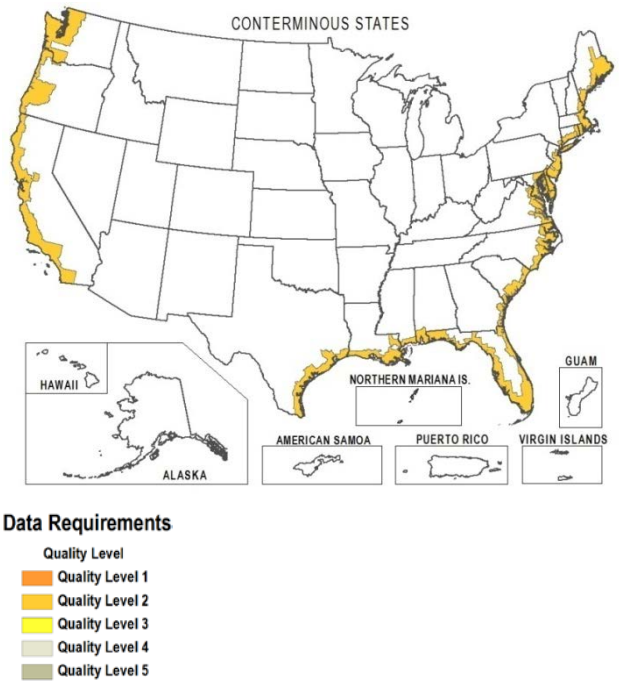
Update frequency: 4–5 years.

Business Use: Coastal Zone Management, BU#4, and Sea Level Rise and Subsidence, BU#15.

Estimated program budget supported by elevation data: $46 million per year.

Quantifiable Benefits of Enhanced Elevation Data

Hurricane storm surge threatens coastal communities and watersheds. Potential benefits of topographic and bathymetric lidar of coastal areas are major, but cost benefits cannot be estimated with any degree of certainty.



Quantitative high-resolution information on coastal elevation is needed for resource management and planning, establishing political and jurisdictional boundaries, navigation, and scientific research. Accurate and up-to-date coastal topographic maps from QL2 lidar and bathymetric data are required at the most basic level by land use planners to establish building set-backs, to inventory wetland and agricultural land resources, and to identify flood and hurricane hazard zones. Lidar enables the rapid collection of very accurate elevation data over large areas, and recently, lidar has been widely applied to map coastal geomorphology, leading to improved knowledge of coastal geomorphic processes. Moreover, applications to coastal hazard prediction and mitigation; dune, forest, and wetland ecology; and benthic structure and ecosystem function have arisen.

For coastal zone management and sea level rise applications, it appears that nearly all requirements would be met by data at QL2 including bathymetric measurements, at a 4- to 5-year repeat cycle but with the additional requirement to also collect data for specific locations after certain events. Nationwide coverage of ocean coastal areas is needed.

Operational benefits (internal) to USGS of enhanced elevation data for this functional activity

Time/Cost Savings: Major	Mission Compliance: Major	$ Benefits: Cannot determine

- Vast regions beneath the world's coastal oceans are unmapped or poorly mapped, yet human societies require this spatial knowledge for navigation, commerce, and ecosystem-based policies to guide decisionmaking. Blue-green wavelength lidar data can provide highly resolved bathymetric surfaces. Furthermore, the high energy of the lidar laser offers a much greater depth of penetration as compared to passive technologies, such as aerial photography, hyperspectral airborne surveys, or satellites. For lidar, viable laser returns can routinely be

retrieved from the seabed from up to two to three times the depth that can be observed by the human eye, and that maximum lidar depth range can exceed 60 m in the clear waters that surround coral reefs.

- Airborne blue-green lidar mapping of shallow benthic environments has several advantages over boat-based acoustic surveys. For example, navigational hazards associated with vessel operations near shore are not an issue; the lidar swath width is nearly independent of water depth; hybrid blue-green lidar with high pulse rates can collect almost seamless subaerial and submarine topobathymetric surveys; airborne lidar can also collect reflected intensity images useful in benthic class discrimination. Many prior lidar applications to benthic mapping have focused on coral reef tracts, as those rich environments are typically proximal to land and sit in clear shallow waters that are amenable to optical mapping techniques. The aggradation of coral reefs creates bottom roughness, resulting in topographic complexity ranging from centimeters to kilometers in spatial scale that influences and reflects many ecological variables. Blue-green airborne lidar sensing of benthic topographic complexity shows great promise as a proxy for habitat complexity, a fundamental ecological factor on coral reefs that is relevant to species diversity and richness, herbivore shelter, predation, recruitment, metabolic processes, hydrodynamics, and nutrient fluxes.
- Geomorphologists have traditionally based studies of coastal erosion and accretion, sediment transport and budgets, and flood hazards on repeated topographic profiling and shoreline mapping. In recent decades, new approaches have arisen for coast and shoreline mapping, including the use of high-resolution satellite imagery, all-terrain kinematic GPS vehicles, and airborne lidar surveys. Airborne lidar surveys are an efficient and powerful approach to shoreline mapping and change detection because lidar-based shorelines are referenced to the statistically established tidal datum surface and thereby avoid problems with the interpretation of the wet-dry beach line. Airborne lidar tailored to coastal applications can provide detailed cross-environment seamless information on both near shore bathymetry and beach topography along broad swaths that span the land-water interface. Further, lidar mapping allows analysis of beach and dune microtopography, and repeat surveys allow volumetric change analysis and the quantification of local sediment budgets.

Customer service benefits (external) to the public from improved USGS products and services

Performance: Minor	**Timeliness: Moderate**	**Experience: Moderate**	**$ Benefits: Unknown**

- Various management objectives, for example, the inventory of resources, tracking change, and identifying regions for protection, rely on accurate and repeated characterizations of benthic communities and morphology.
- During the coming decades, coastlines will respond to widely predicted sea level rise, and detailed coastal topographic information is a key variable in understanding the likely impacts of this global natural hazard (U.S. Climate Change Science Program, 2009). Vulnerability maps that depict regions prone to flooding as sea level rises are essential to planners and managers responsible for mitigating the associated risks and costs to human communities and ecosystems. Lidar mapping plays a central role in evaluating the vulnerability of low-lying coastal regions to inundation caused by relative sea-level rise. Most maps of potential inundation along coastlines have been based on outdated coarse elevation data and accordingly amount to only crude representations that may serve to mislead decisionmakers. The high vertical accuracy and spatial resolution of elevation data derived from lidar leads to improved identification and delineation of vulnerable lands.

Other benefits from USGS use of enhanced elevation data for this functional activity

Public/Social: Major	**Environmental: Major**	**Strategic/Political: Major**

- Hurricanes are another serious coastal hazard along the Atlantic and Gulf coasts of the United States, and airborne lidar mapping of beaches and dunes has been used extensively during the past decade in studies of barrier island vulnerability to severe storms. During hurricane landfall, if the storm-induced mean water level overtops the crest of the primary dune, the entire beach system will be submerged, resulting in exposure to processes that can cause extreme coastal change, including wholesale dune removal, island breaching, and inlet formation. Recognizing the importance of dunes in predicting barrier island response to hurricane impact, coastal geologists have devised approaches to use lidar surveys in identifying the crest of the seawardmost sand dune, the feature that defines the landward boundary of the beach system. Hurricane storm surge also threatens coastal communities and watersheds; for example, the landfall of Hurricane Katrina near the Mississippi-Louisiana border at the Gulf coast caused the largest natural disaster in U.S. history, with the loss of more than 1,800 lives and $81 billion in property damages. The use of the data assimilation techniques that combine various dissimilar lidar datasets and thereby create a uniform 3-m elevation grid throughout coastal regions

affected by storm surge allow rapid map creation, resulting in more rapid recovery efforts and emergency response.

- The benefits of elevation data meeting the characteristics specified for coastal applications include providing data that does not currently exist for some locations, decreasing reliance on costly field surveys (which result in less dense data than lidar surveys), and more accurately delineating areas subject to the effects of sea level rise.

Reference Cited

U.S. Global Change Research Program, 2009, Coastal sensitivity to sea-level rise—A focus on the mid-Atlantic region: U.S. Global Change Research Program Synthesis and Assessment Product 4.1, 298 p. (Also available at http://www.climatescience.gov/Library/sap/sap4-1/final-report/sap4-1-final-report-all.pdf.)

Flood Risk Management

Mission-Critical Requirements

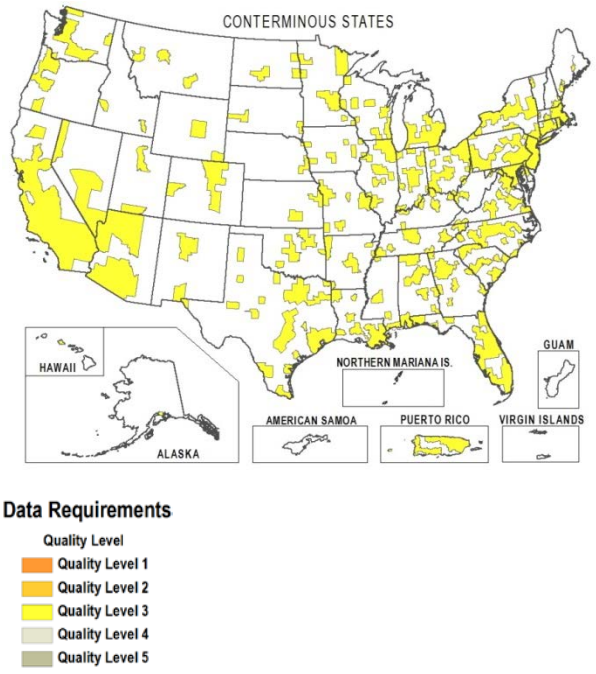
Because floods are the leading cause of natural-disaster losses, the USGS is actively involved in the development of flood inundation mapping across the Nation pursuant to its major science strategy goal of reducing the vulnerability of the people and areas most at risk from natural hazards. QL3 lidar plus bathymetry is required for priority areas for flood risk mapping.

Update frequency: 4–5 years.

Business Use: Flood Risk Management, BU#14.

Estimated program budget supported by elevation data: $12.6 million per year.

Quantifiable Benefits of Enhanced Elevation Data: Based on published estimation processes, the flood damage reduction benefits can be estimated at $10 million per year. Enhanced elevation data will produce more accurate flood extents and flood predictions (when NWS instruments are collocated at streamgages) to provide early warning information to emergency management officials and to the public for mitigation planning and evacuating businesses and residents.



The responsibilities of the USGS for near-real-time flood extent and depth predictions are significantly different from FEMA's responsibilities that are focused on long-range mitigation actions (for example, flood insurance). The USGS partnered with the NWS to produce flood inundation maps for the Advanced Hydrologic Prediction Service (AHPS).

Digital geospatial flood-inundation maps that show flood water extent and depth on the land surface are a powerful new tool for flood response and mitigation. Because floods are the leading cause of losses from natural disasters, the USGS is actively involved in the development of flood inundation mapping across the Nation pursuant to its major science strategy goal of reducing the vulnerability of the people and areas most at risk from natural hazards.

Static flood-inundation map libraries consist of maps that have been created in advance of a flood that are ready to be served through the Internet. Each library consists of a set of flood-extent and depth maps developed for predetermined stream stage intervals—typically either 0.5 or 1 ft. A user can view real-time or forecast stage data from a USGS streamgage or NWS flood forecast point and quickly access the map corresponding to the stage data. For clarification, flood inundation maps are being developed at streamgage locations where the NWS has co-located forecast points.

Operational benefits (internal) to USGS of enhanced elevation data for this functional activity

Time/Cost Savings: Major	Mission Compliance: Major	$ Benefits: Cannot estimate

- To develop the map libraries, it is necessary to compile ground elevation data to be used in hydraulic stream models for the study reach including the channel and contiguous floodplain up to the elevation of maximum expected flood level. To be useful, the stage intervals should be no coarser than 1 ft. According to NWS and USGS guidelines, this resolution requires a base-map (DEM derived from lidar) accuracy of the equivalent of 2-ft contour intervals or finer. To account for channel configuration, bathymetric data are also required.
- QL3 lidar for surface elevations would support a national program. However, in addition to land-surface elevations (and water surface elevations), bathymetric data are also a required input, as stream channel cross-sections, into the hydraulic modeling. Currently, the USGS acquires bathymetry using doppler acoustic instruments and this elevation data must then be tied to the surface. If airborne lidar could accomplish the need for bathymetry more cost effectively than the doppler acoustic units, then this option should be explored further.
- Flood inundation maps generally cover small geographic areas. However, several Eastern States are now realizing the benefit of statewide lidar programs and are choosing QL3 data.

Customer service benefits (external) to the public from improved USGS products and services

Performance: Major	Timeliness: Major	Experience: Major	$ Benefits: $10 million per year

- Static and real-time flood inundation maps, produced from lidar-derived elevation products, provide critical, up-to-date information to emergency managers, homeland security agencies, local government officials, and to the public to assist people in making important mitigation decisions during floods. These data will also be valuable input to determine building damage assessments before and after flooding occurs.
- The Day curve (Day, 1970) is a tool that estimates the benefits from flood damage reduction in terms of advanced hours of flood warning (the longer the warning time, the greater the damage reduction). The maximum reduction benefit of 33 percent occurs when advance warning is given 48 hours and earlier. Since NWS flood forecast points (and the associated inundation mapping) provide predicted flood level data 5 days out, this criterion is met. However, to achieve maximum flood damage reduction benefits, inundation mapping must be available for the forecast point. Therefore, the estimate is that the benefit attributable to inundation mapping is 10 percent because inundation maps are currently only available for 10 percent of all flood forecast points. A 10 percent reduction in the estimated $1.25 million per year in flood loses per forecast point with inundation mapping is therefore $125,000 per year. It is estimated that the USGS will generate 80 to 85 of these flood map libraries each year, resulting in $10 million per year in benefits.

Other benefits from USGS use of enhanced elevation data for this functional activity

Public/Social: Major	Environmental: None	Strategic/Political: Moderate

- Many other applications will be used by the hydrographic and hydrologic user communities with lidar-derived elevation data. Examples of additional applications could include cartographic mapping, recreational, fluvial erosion, and levee construction or deconstruction.

Reference Cited

Day, H.J., 1970, Flood warning benefit evaluation—Susquehanna River Basin (urban residences): Weather Bureau ESSA Technical Memorandum WBTM Hydro-10, 42 p.

Mapping, Monitoring, and Assessment of Biological Carbon Stocks

Mission-Critical Requirements

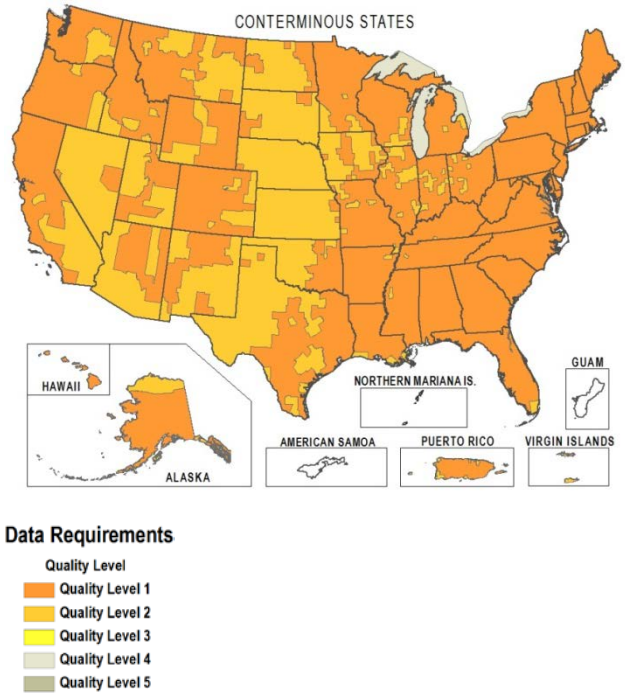
QL1 lidar data of forested counties and QL2 data of nonforested counties are required for quantitative characterization of vegetation structural attributes in support of the USGS mission to assess, monitor, and map land biomass and biological carbon stocks nationwide.

Update frequency: 6–10 years.

Business Use: Natural Resources Conservation, BU#1.

Estimated program budget supported by elevation data: USGS program budgets for biological research and monitoring, biological carbon sequestration, geographic analysis and monitoring total $177 million per year.

Quantifiable Benefits of Enhanced Elevation Data: Estimated at $13 million per year



Improved understanding and prediction of the global carbon cycle is one of the six major goals of the USGS global change science strategy. The strategy specifies near-term actions (1–5 years) to "initiate periodic national comprehensive carbon resource assessments of potential carbon sequestration and carbon storage vulnerability in terrestrial ecosystems…" and long-term actions (5-10 years) to "periodically update and refine assessments of carbon sequestration and loss.." and to "publish national maps of carbon stocks and fluxes… ." These activities contribute to meeting DOI and USGS responsibilities for assessing and monitoring biological carbon stocks and carbon sequestration potential in U.S. land areas as mandated by the Energy Independence and Security Act of 2007 (EISA). The major variables in estimates of forest carbon emissions include rates of deforestation, afforestation, restoration, changes in carbon stocks (biomass and soils) as the result of the land-use changes, and changes in carbon stocks within forests. Uncertainty about biomass density (for example, grams of carbon per square meter) as well as rates of deforestation contribute greatly to the range of current carbon flux estimates for land systems. Despite its position as the leading Federal agency for operational land remote sensing, the USGS currently has limited operational capability for spatially consistent, accurate mapping of biological carbon stocks to support the national assessment and related land monitoring, and currently depends on a limited array of disparate, external data sources. A strategy for repeat lidar observations as part of a national enhanced elevation program provides the most practical approach for USGS to develop and apply such a capability.

The methods for estimation and mapping of biological carbon stocks with enhanced elevation data are based on the quantitative characterization of vegetation structural parameters. Collecting these data accurately over large areas is feasible only by lidar remote sensing. Such lidar-dependent capabilities may be further enhanced through sensor fusion approaches with Landsat and other sensor types (for example, synthetic aperture radar, hyperspectral imaging). Defining and implementing a national enhanced elevation data acquisition strategy that includes lidar observations and that is strategically coordinated with the USGS Landsat Program is essential to overcome current constraints on USGS capabilities to perform its land science mission on a truly national scale.

In addition to enabling new capabilities for mapping biological carbon stocks, vegetation structure information from a national enhanced elevation data program would benefit other activities within the USGS mission areas on climate and land use change; ecosystems; and energy, minerals and environmental health. The major, overarching types of activities pertain to USGS responsibilities for national-scale mapping, monitoring, and analysis of:

- land use and land cover, including vegetation types
- ecosystem condition, sustainability, and restoration

- wildlife habitat condition and vulnerability
- wildfire risk

The spatial extents of the data quality requirements were developed with consideration to vegetation characteristics of the land cover within counties. The required lidar point density was the principal factor that determined the assignment of a QL to a given land cover category. The highest data quality level (QL1) is recommended for counties in which forest vegetation constitutes 20 percent or more of the county land area. In forest lands, QL1 is required for adequate performance in detecting the dispersion of tree heights in dense, complex canopies. QL2 is sufficient for counties with more than 80 percent nonforest vegetation, where the lower spatial complexity of the dominant cover types presents fewer obstacles to accurate characterization of the vegetation structure and underlying surface. Additional research is required to clarify the tradeoffs between data acquisition during leaf-on and leaf-off conditions.

Operational benefits (internal) to the USGS of enhanced elevation data for this functional activity

Time/Cost Savings: Major	Mission Compliance: Major	$ Benefits: Undetermined

- The USGS does not currently have an operational program for mapping biological carbon stocks, so the immediate operational benefits of national enhanced elevation data are undetermined. If the USGS establishes such a program in the future, then the prospective, operational benefits would be manifested as cost-savings from increased efficiencies and productivity. For example, in a single day, a 3-person USGS crew collects an average total of 400 tree-cover estimates and height point measurements spread across four sites within a 5-mile drive from one to the next. By contrast, millions of lidar data points can be collected over that same day to yield spatially explicit and distributed measurements at intervals of less than a meter over the entire study area (for example, 600 square miles). Such broad spatial coverage is not possible without lidar.

Customer service benefits (external) to the public from improved USGS products and services

Performance: Minor	Timeliness: Major	Experience: Major	$ Benefits: $13 million per year

- Lidar-derived data from a national enhanced elevation data program would enable dramatic improvements to the USGS capability to provide the public with objective, science-based, and timely information on the distribution of biological carbon stocks in U.S. land areas, and how and why they change over time. Public access to such information is critical to inform public discourse and guide effective policy development and decisionmaking on carbon-related issues by Federal, State, and local governments. Significant improvements in the availability and quality of enhanced elevation data would greatly improve the certainty of carbon estimates and corresponding societal benefits. Although the exact benefits associated with various levels of accuracy are difficult to quantify in monetary terms, the monetary value of some public benefits enabled by lidar-derived data can be estimated if the fact that lidar-derived enhanced elevation data on a national scale would enable the USGS to achieve improved accuracy in its science products, such as delivering estimates of national biological carbon stocks for different ecosystems required under the EISA mandate, were quantified. An analysis comparing lidar-based and conventional methodologies for estimating carbon stocks in Alaskan boreal forest reported costs of $1.36 per forested acre for conventional methods and $0.25 per forested acre using lidar. The lidar-based method also reduced sampling error by two orders of magnitude. Based on this comparison, the use of lidar would provide a 544 percent improvement in efficiency over conventional methods for estimating carbon biomass. In the absence of other specific estimates and recognizing the associated uncertainty in applying these boreal forest estimates to all 797 million acres of U.S. forested land, this comparison suggests that use of lidar could avert $885 million dollars in costs relative to conventional estimation methods, a vital investment and cost-saving for scientists and land managers who require in-situ measured vegetation data. In-situ measurements, such as the USFS inventory, are often repeated every 10 years. This translates to a cost savings of approximately $88.5 million per year for multiple studies and uses, while making USGS scientific investigations more accurate and serving as a foundational dataset for monitoring needs for DOI and other land management agencies and stakeholders. Under the guidance of the USGS global change science strategy and the DOI strategic plan for 2011–2016, the USGS is proceeding with the national carbon sequestration assessment, with carbon monitoring as a key objective. As an approximation, considering the areas and ideal quality of data needed, and assuming the optimal methods, the benefit of lidar to USGS as a contribution for in-situ biomass carbon measurement for improving carbon assessment could be approximately $13 million annually (assuming a national sampling rate of 15 percent for lidar acquisition and data processing).

Other benefits from USGS use of enhanced elevation data for this functional activity

Public/Social: Moderate	Environmental: Moderate	Strategic/Political: Moderate

- Improvements in USGS capabilities to produce more reliable, certain, and timely measurements of the distribution and dynamics of biological carbon stocks could bring major benefits in areas that extend beyond the fundamental USGS mission and that support the broader scope of U.S. national interests in global carbon monitoring. Such benefits would be realized through enhanced USGS support for current and potential U.S. contributions to international cooperative activities such as the Group on Earth Observation forest carbon tracking task and the United Nations program on reducing emissions for deforestation in developing countries.

Mapping, Monitoring, and Assessment of Habitat

Mission-Critical Requirements

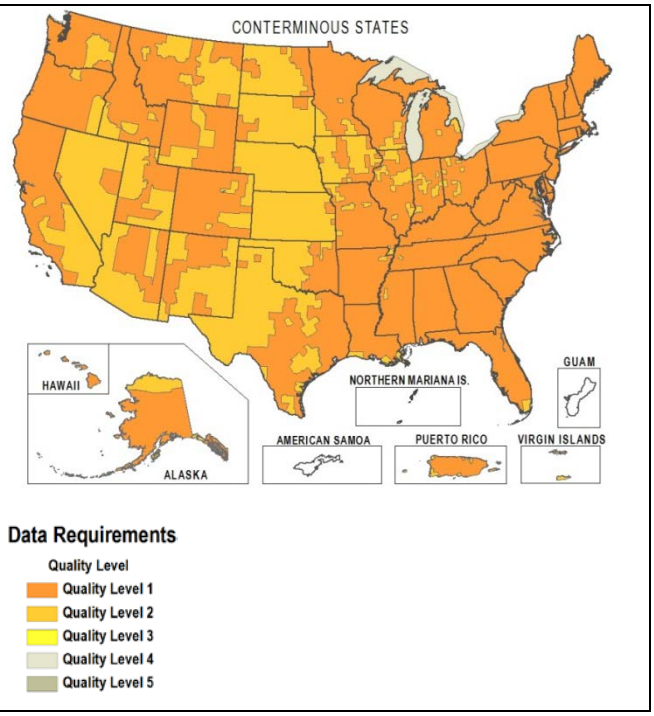
QL1 lidar data of forested counties and QL2 data of nonforested counties are required for quantitative characterization of terrain and vegetation structural attributes in support of the USGS mission to assess, monitor, and map wildlife habitat conditions nationwide.

Update frequency: 6–10 years.

Business Use: Wildlife and Habitat Management, BU#7.

Estimated program budget supported by elevation data: USGS program budgets for biological research and monitoring, geographic analysis and monitoring total $177 million per year.

Quantifiable Benefits of Enhanced Elevation Data: Undetermined.



The methods for mapping, monitoring, and assessing wildlife habitat with enhanced elevation data are generally based on the quantitative characterization of vegetation structural parameters and underlying surface topography. Collecting these parameters accurately over large areas is not feasible without the detailed height information (3D point clouds) obtainable by lidar remote sensing. Such lidar-dependent capabilities may be further enhanced through sensor fusion approaches with Landsat and other sensor types (for example, synthetic aperture radar and hyperspectral). Defining and implementing a national enhanced elevation data acquisition strategy that includes lidar observations and that is strategically coordinated with the USGS Landsat Program is therefore essential to overcome current constraints on USGS capabilities to carry out its habitat-related mission on a truly national scale.

New knowledge and information on the status and vulnerability of wildlife habitats in U.S. land areas is a major objective of the USGS science mission areas of ecosystems and of climate and land use change. It has long been recognized by ecologists that vegetative structure, particularly vertical structure, is a key factor affecting habitat selection by wildlife. In general, the diversity and density of wildlife species has been shown to be a function of both habitat patchiness and vegetation stand structure as quantified through foliage height diversity metrics, among other stand metrics. Most empirical models developed that relate wildlife occurrences, densities, and diversity to vegetation tend to have better predictive ability when using stand-level metrics such as stem densities, canopy closure, and canopy heights (and how they vary across space and time) than using broad cover types only (for example, DeGraaf and others, 1998). Vegetation structural information also describes habitat conditions in aquatic systems by enabling accurate modeling of surface water flow and stream temperatures (as affected by canopy shading). Information on surface topography and channel geomorphology is important for identification and

characterization of ephemeral surface water storage features that influence hydrology and climate and provide critical habitat for aquatic and other species.

Models of habitat condition are typically developed by characterizing site features at the scale of an individual study plot or stand (for example, 0.25 hectare). The challenge is to observe those features over broader spatial scales to enable high-confidence, spatially explicit assessments of habitat. To do so requires the use of remote sensing techniques. Lidar, alone but perhaps most effectively in combination with Landsat and other moderate- to high-resolution, multispectral or hyperspectral satellite systems provide opportunities for broad-scale, spatially continuous assessment of wildlife habitat that would not otherwise be feasible. Such mapping provides an improved basis for identifying habitats in need of conservation or restoration and enhances the reliability and effectiveness of decision support systems for adaptive management. Additional research is required to clarify the tradeoffs between lidar leaf-on and leaf-off acquisitions for this functional activity.

The spatial extents of data quality requirements were developed by reference to 22 major land cover categories and associated vegetation cover characteristics identified by the European Space Agency's GlobCover global land cover product. The point density requirement was the principal factor that determined the assignment of a QL to a given land cover class within each U.S. county. The highest data quality level (QL1) is recommended for counties in which forest vegetation constitutes 20 percent or more of the total land area. The assignment of QL1 to forest land areas is dictated by both the need to maximize pulse penetration to the ground under dense forest canopy (for accurate DTM generation) and the need for adequate performance in detecting the dispersion of tree heights in a complex canopy. A lower quality level (typically QL2) is adequate for counties with more than 80 percent nonforest vegetation, where a higher percentage of pulses are likely to penetrate vegetation canopy or vegetation canopy is typically absent.

Operational benefits (internal) to USGS of enhanced elevation data for this functional activity

Time/Cost Savings: Major	**Mission Compliance: Major**	**$ Benefits: Undetermined**

- The operational benefits to the USGS of enhanced elevation data that meet its mission-critical data requirements for mapping, monitoring, and assessment of habitat are manifested as cost-savings from increased efficiencies and productivity for existing research and monitoring activities, and new, added value realized through enhanced capabilities for collecting accurate data and information at the national scale, which improve the ability of USGS to perform its mission effectively. Many of these benefits are distributed among the broad array of natural resource-related activities in the USGS science mission areas rather than concentrated in one or a few bureau-wide activities. In addition, it is difficult to quantify the benefits of improved habitat and associated ecological values in economic terms. Therefore, the total monetary value of USGS operational benefits is problematic and remains undetermined. Substantial operational benefits are nevertheless expected, as suggested by the following qualitative example of mapping vegetation structure for habitat characterization and water flow modeling.
- In a single day, a three-person USGS crew collects an average total of 400 tree-cover estimates and height point measurements spread across four sites within a 5-mile drive from one to the next. In contrast, millions of lidar data points can be collected over that same day to yield spatially explicit and distributed measurements at sub-meter intervals over the entire study area (for example, 600 square miles). This level of coverage is simply not possible without lidar.

Customer service benefits (external) to the public from improved USGS products and services

Performance: Minor	**Timeliness: Major**	**Experience: Major**	**$ Benefits: Undetermined**

- Lidar-derived data from a national enhanced elevation data program would enable dramatic improvements to the USGS capability to provide the public with objective, science-based, and timely information on the distribution and condition of wildlife habitat nationwide, and how and why they change over time. Public access to such Information is critical to inform public discourse and guide effective policy development and decisionmaking on habitat-related issues by Federal, State, and local governments. An intangible public benefit such as this, while possessing tremendous importance to society, cannot be readily quantified in monetary terms.

Other benefits from USGS use of enhanced elevation data for this functional activity

Public/Social: Moderate	Environmental: Major	Strategic/Political: Moderate

- Improvements in USGS capabilities to produce reliable and timely data and information on the status and trends of wildlife habitat would bring major benefits in areas that extend beyond the fundamental USGS mission and that support the broader scope of U.S. national interests in the management of global natural resources. Such benefits would be realized through enhanced current and potential USGS support for to an array of international cooperative activities, including but not limited to the Global Earth Observation System of Systems (GEOSS) themes on biodiversity and ecosystems.

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