FEMA's Risk Mapping, Assessment, and Planning (Risk MAP)

National Digital Elevation Acquisition and Utilization Plan for Floodplain Mapping

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Homeland Security

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Preface

The mission of the Federal Emergency Management Agency (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.

Within the Department of Homeland Security, FEMA manages the National Flood Insurance Program (NFIP), the cornerstone of the national strategy for preparing American communities for flood hazards. Flood hazard mapping is a key component of the NFIP and FEMA is leading the effort to modernize flood hazard data and maps.

The vision for Risk MAP is to, through collaboration with State, local, and Tribal entities, deliver quality data that increases public awareness and leads to mitigation actions that reduce risk to life and property. To achieve this vision, FEMA will transform its traditional flood identification and mapping efforts into a more integrated process of accurately identifying, assessing, communicating, planning, and mitigating flood related risks. Risk MAP will address gaps in flood hazard data to form a solid foundation for risk assessment, floodplain management, and provide State, local, and Tribal entities with information needed to mitigate flood related risks.

As FEMA developed the strategy for implementing Risk MAP, evaluating the Agency approach to obtaining the elevation data needed to support flood risk analyses was an important issue. This report outlines the FEMA elevation strategy for Risk MAP.

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Executive Summary

The Federal Emergency Management Agency (FEMA) is implementing the Risk Mapping, Assessment, and Planning (Risk MAP) Program. The purpose of Risk MAP is to continue to improve flood hazard information for the National Flood Insurance Program (NFIP) and increase national awareness and understanding of flood risk to support Federal, State, and local actions to reduce risk. The flood maps are used to determine appropriate risk-based premium rates for the NFIP; to complete flood hazard determinations required of the Nation's lending institutions; and to develop appropriate disaster response plans for Federal, State, and local emergency management personnel.

Risk MAP combines flood hazard mapping, risk assessment tools, and mitigation planning into one seamless program. This improved integration of program components will allow FEMA to leverage the current digital flood map inventory and further enhance the usability and value of flood hazard data and mapping. The *Risk MAP Multi-Year Plan for Fiscal Years 2010 – 2014*, dated March 16, 2009, details FEMA's strategy for an integrated program that will invest in improving the scientific basis of the flood hazard maps, encourage beneficial partnerships, and foster innovative uses of flood hazard and risk assessment data to maximize flood loss reduction.

FEMA has been directed by the Appropriations Committee to develop a National Digital Elevation Acquisition and Utilization plan for floodplain map updates. This plan presents FEMA's national elevation strategy for Risk MAP.

The cornerstone of the Risk MAP Program is improving the accuracy and currency of the flood hazard data. And, incorporation of accurate elevation data is an important element in improving the quality of flood maps The Risk MAP program has developed an updated approach to revising flood hazard data. This approach includes minimum elevation data standards for all engineering updates and varies the level of precision and detail of the elevation data and engineering analyses based on the flood risks.

Based on the budget proposed for Risk MAP in the President's budget, FEMA will invest in the acquisition of updated elevation data to the extent that these data are essential to supporting the NFIP mission. The products will be new, accurate elevation data processed specifically to support flood hazard analyses. FEMA's Risk MAP strategy relies on validating that a substantial portion of existing flood hazard information is still current. When updated flood hazard information is needed, FEMA will acquire new elevation data to support these updated flood hazard analyses. When acquiring new elevation data, FEMA will try to identify elevation data partnerships that directly fulfill FEMA's elevation needs. With this approach, FEMA anticipates collecting updated elevation data for 26 percent of the contiguous United States and reaching the goal of verifying that 80 percent of the flood hazard data is current. This approach is a targeted national elevation strategy for Risk MAP, not a national strategy for elevation data collection designed to serve multiple stakeholders.

FEMA will work with potential partners to maximize the utility of the elevation data collected. In many cases, Federal, State, and local partners may provide the additional resources needed to produce a finished, high quality, general purpose elevation data set. FEMA will work to take advantage of every opportunity to do this. Even where a partnership is not assembled in advance of the Risk MAP elevation project, the data produced may serve a broader audience that will use the raw data to create finished data products suitable for their applications. FEMA will work closely with other Federal agencies and industries to ensure that new elevation mapping technologies are tested and integrated into the program operations so that leading edge technology is leveraged, while not slowing down the Risk MAP program.

FEMA plans to partner with the United States Geological Survey (USGS) to support the distribution, maintenance, and archiving of elevation data produced for Risk MAP. USGS has the mission to steward mapping information for the benefit of the nation, and is the logical partner to produce a national elevation data product that maximizes the value of the elevation data acquired for Risk MAP.

The Appropriations Committee further directed FEMA to coordinate this plan with other Federal agencies and States. The collective opinion of representatives from the agencies with which FEMA collaborated is that an elevation acquisition program driven primarily by FEMA's requirements for floodplain map updates would be inadequate for many other applications. The representatives from the other agencies and States preferred that a comprehensive national approach be taken that meets more of the national needs for elevation data.

Other Federal agencies and State agencies have significant needs for elevation data. For example, the National Oceanic and Atmospheric Administration (NOAA) uses elevation data to map the official shoreline and to analyze rises in sea level. This data is also used for other coastal zone management applications. The Natural Resources Conservation Service uses elevation data for soils mapping, conservation planning, and other services for landowners. State and local governments also have significant needs for elevation data as part of most government functions. Similarly, elevation data is useful for other applications within FEMA, like hurricane evacuation planning and estimating flood damages for flood insurance and disaster assistance. In the Department of Homeland Security, the accurate description of urban features using Light Detection and Ranging (LIDAR) is recognized as important for atmospheric modeling in the urban environment. The United States Border Patrol has analytical needs for terrain modeling to support the design of detection systems by computing view-shed, predicting high traffic areas, and identifying potential trails and smuggling staging areas.

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Legislative Language

The Report Language that accompanies the Fiscal Year 2010 Department of Homeland Security Appropriations Act (P.L. 111-83) states:

> FLOOD MAP MODERNIZATION FUND
> The conference agreement provides $220,000,000 for the Flood Map Modernization program as proposed by both the House and Senate. In fiscal year 2010, FEMA will continue to focus these funds on reviewing, updating, and maintaining maps to accurately reflect flood hazards. The goal shall be to review and, where necessary, to update and maintain data, methodologies, models, and maps that have been modernized, and to issue map updates no later than five years past the modernized dates of the maps. To support this goal, FEMA is directed to provide no less than 20 percent of the funds provided under this heading for map updates and maintenance conducted by Cooperating Technical Partners that provide a 25 percent cash match and have a strong record of working effectively with FEMA on floodplain mapping activities. With the fiscal year 2011 budget request, FEMA shall submit to the Committees a status report on the progress made towards the five-year Risk Mapping, Assessment, and Planning strategy. When allocating map modernization funds, FEMA is encouraged to prioritize as criteria the number of stream and coastal miles within the State, the Mississippi River Delta region, and the participation of the State in leveraging non-Federal contributions. FEMA is directed to develop a National Digital Elevation Acquisition and Utilization plan for the purposes of supporting flood plain map updates. FEMA shall collaborate with the United States Geological Survey, the National Oceanic and Atmospheric Administration, the National Aeronautics and Space Administration, and States that have experience in acquiring and incorporating high resolution elevation data in the flood plain map updates. FEMA shall submit this plan to the Committees within six months after the date of enactment of this Act.

Introduction

Purpose

This plan responds to the request from the Appropriations Committee that FEMA develop a National Digital Elevation Acquisition and Utilization plan. This request was included in the committee report for the Department of Homeland Security Appropriation Act for the Fiscal Year ending September 30, 2010. The objective is to outline FEMA's approach to elevation data for Risk MAP.

Overview

In order to achieve the Risk MAP vision of quality data that increases public awareness and leads to action to reduce risk to life and property, a significant amount of new ground elevation data is needed to support updated engineering assessments of flood hazards and risk. Investments in quality flood hazard data are critical to maintaining the scientific basis for the NFIP flood hazard data. FEMA has developed a plan for acquiring elevation data to support Risk MAP. The Risk MAP elevation approach is a significant, targeted investment to meet the goals laid out in the Risk MAP Multi-Year Plan.

As directed, FEMA collaborated with other Federal agencies and States in the development of this plan. FEMA worked with the National Digital Elevation Program (NDEP), the State of North Carolina, and the State of Oregon. For more details regarding these efforts, see "Appendix A: Collaboration with Other Organizations."

At a meeting on January 7, 2010, NDEP representatives from Federal and State agencies expressed a preference for a comprehensive national alternative to a Risk MAP-specific elevation program.

Under U.S. Geological Survey (USGS) leadership, FEMA and other NDEP member agencies are jointly funding a national enhanced elevation study to develop and refine requirements for a national program. Enhanced elevation data refers to measurements of the terrain, built features, vegetation and other landscape characteristics. The study will identify implementation alternatives and associated benefits and costs for a national program that meets priority Federal, State, and other national business needs. This study is expected to be completed by the end of the calendar year.

Background

Flooding is the most costly natural hazard in the United States. Congress created the NFIP to reduce the loss of life and property due to flooding. Participation in the NFIP requires that minimum local floodplain management standards be enforced in return for the availability of Federal flood insurance that provides the U.S. Treasury, communities, and individuals financial protection from flood risk. Accurate maps depicting flood hazard areas are critical to the fair and effective implementation of the NFIP, enabling enforcement of floodplain management requirements in high hazard areas, and identifying property owners at highest risk who are required to purchase flood insurance as part of federally backed mortgages. Federal, State, local, and tribal entities, land developers, insurance companies, lending institutions, other businesses, and individuals all use FEMA flood maps to understand existing flood hazards and make sound decisions on land use and construction standards. Inaccurate maps create substantial difficulties by undermining confidence in the NFIP, leaving some individuals and organizations unaware of their risks, and imposing unnecessary costs on others whose risk is overstated.

Risk MAP

The Risk MAP Multi-Year Plan (FY 2010-2014) outlines a FEMA initiative that continues to improve the NFIP flood maps and integrates the map update process with other FEMA programs to increase the resilience of communities. Execution of this plan will significantly improve the integrated flood risk management approach by weaving county-level flood hazard data into watershed-based risk assessments that serve as the basis for local multi-hazard mitigation plans and targeted risk communication activities.

In Risk MAP, the digital map inventory will be enhanced with a rigorous quantitative basis for all new analyses and always provide the projected elevation of flood waters. Risk MAP products will also provide a more complete risk profile, showing flood hazards for more potential flood events. These science-based products will be provided to communities to help convey flood risk so that they can take actions to protect themselves and their property and build resiliency. Reliable flood hazard data form the foundation of credible flood risk assessments, and these assessments serve a critical role as communities engage in the mitigation planning process. Risk assessments systematically analyze the nature and extent of the people and property in a community or watershed that are potentially affected by flood hazards. These assessments allow FEMA to quantify potential physical, social and economic losses. Targeted risk communication activities include prioritizing flood map updates for the highest risk areas and highlighting areas where mitigation activities are most needed based on the results of the watershed risk assessments.

Ultimately, Risk MAP will produce accurate flood hazard data, integrated watershed flood risk assessments, and stronger hazard mitigation plans. FEMA's Risk MAP approach will support local risk assessment and planning activities while addressing the

flood hazard data update needs, thus enabling citizens to increase their awareness of flood risks and ensure sound planning to mitigate these risks.

Although Risk MAP is fundamentally designed for flood hazards, the program establishes a framework for multi-hazard risk analysis, communications, and mitigation strategies. Strategies such as prioritization of program investments based on risk and need, delivery of multi-hazard risk assessments, and mitigation planning can be applied to multiple perils such as earthquakes, wildland fires, hurricane winds, tornados, and other hazards. Likewise, elevation data collected for Risk MAP can improve the understanding of many other perils.

More details on the Risk MAP strategy and goals are provided in the Risk MAP Multi-Year Plan at www.fema.gov/plan/prevent/fhm/rm_main.shtm.

Risk MAP Elevation Data Acquisition Plan
(Define Requirements, Inventory, Acquire)

The cornerstone of the Risk MAP Program is improving the accuracy and currency of the flood hazard data. This will require new engineering analyses for many areas. As noted in the National Research Council (NRC) report entitled *Mapping the Zone*, accurate elevation data is critical to the overall accuracy of these analyses and resulting flood hazard data. For additional information on the NRC report, see Appendix B. The Risk MAP program has developed an updated approach to revising flood hazard data. This approach includes minimum elevation data standards for all engineering updates and varies the level of precision and detail of the elevation data and engineering analyses based on the flood risks. This is consistent with the findings of the NRC report for maximizing the cost benefit of flood hazard data updates.

Based on program experience and the NRC findings, FEMA expects LIDAR will be the primary technology used for elevation data for Risk MAP. Some of the key components of the FEMA specifications and plans for collection and processing are specific to LIDAR technology, but may be generalized for situations where other technologies are more appropriate.

The current vertical datum and supporting geodetic data in use in the United States makes determining the accuracy of heights and using LIDAR for mapping heights in Alaska and on islands more difficult and less accurate than it is elsewhere in the country. NOAA has begun creating a new vertical datum that, when completed, will address these issues and make elevation measurements, including those using LIDAR, more accurate and less expensive throughout the United States.

While FEMA coastal flood hazard analyses require offshore bathymetric data, and riverine analyses require elevation for the submerged topography in the river channel, these data are not addresses in this plan. This plan focuses on the collection of land elevation data.

Risk MAP Planning Approach

Fiscal Year (FY) 2010 Risk MAP projects are specifically targeted towards areas with the highest flood risk, identified needs for flood hazard data updates, and recent, accurate digital elevation data. Also, in FY 2010, FEMA plans to initiate digital elevation data acquisition projects to support flood hazard data updates in FY 2011. This approach will allow FEMA to avoid delays related to new elevation data collection. Throughout Risk MAP, the elevation data needed for engineering work will be acquired in the year before it is needed. In planning for Risk MAP, FEMA expects to produce new or updated flood hazard data for a substantial portion of the country, based on available resources. Wherever Risk MAP undertakes a flood hazard data update and recent, accurate digital elevation data does not exist, FEMA will acquire new digital elevation data.

FEMA's goal in the Risk MAP Multi-Year Plan is to verify that 80 percent of the flood hazard information reflects current conditions. Currently, including projects planned to be completed during the next year, about 50 percent of FEMA's flood hazard information has been deemed to be valid. Under Risk MAP, FEMA will fully assess the flood map inventory for changes that indicate the depicted hazards do not reflect current conditions. Changes to physical conditions, climatological conditions, and engineering methodologies occur as the result of development, longer hydrologic records, and scientific and technological advances. When sufficient changes have been identified for a particular location in any of the above-referenced areas, a flood hazard data update need is identified. Risk MAP will perform enough new engineering analyses in areas where needs are identified to ensure that 80 percent of the inventory is validated.

Where FEMA performs new engineering analyses and the existing elevation data do not meet FEMA specifications, FEMA will acquire new elevation data. With this approach, FEMA anticipates collecting updated elevation data for about 26 percent of the contiguous United States depending on how much of the existing flood hazard data is determined to need updating. For additional information on current elevation data acquisition activities, see Appendix C.

In the geospatial data lifecycle, the requirements for the data must be defined first, and then an inventory of available data must be completed and assessed to determine to what degree the requirements can be met with existing data. FEMA has established the systematic needs assessment process described above to identify the need for flood hazard data updates. Similarly, FEMA is working with the USGS and State officials to develop an inventory of existing elevation data suitable for Risk MAP projects.

Risk MAP Technical Approach

FEMA will use several levels of elevation data specifications based on the flood risk and complexity for the area and the topography. FEMA is implementing this approach in FY10 as part of the overall Risk MAP solution developed to achieve the goals laid out in the Risk MAP Multi-Year Plan. This will allow FEMA to reduce the overall cost of elevation data compared to a program that uses the same level of specification in all areas. This approach is consistent with the overall program strategy that varies the investment in additional precision based on the level of risk. This approach has been used by FEMA for many years and was found by the NRC to produce the highest benefit to cost ratio.

The appropriate elevation data precision for floodplain mapping is related to flood risk, the complexity of the modeling, and to the flatness of the terrain for the area to be mapped. More detailed engineering methods with higher precision are typically used in higher risk areas and therefore more precise elevation data is appropriate. The requirements for elevation data are also related to the flatness or steepness of the terrain, since small vertical errors translate into much larger horizontal errors where the land is very flat. FEMA tentatively plans to use four different levels of elevation data specifications to optimize the balance between the cost of elevation data and the requirements for floodplain mapping. FEMA may choose to create more or fewer

classifications, depending on the difference in price between classifications and the impact on the finished flood hazard products. FEMA has issued a request for information to the industry to obtain more information regarding strategies to cost-effectively meet Risk MAP requirements. FEMA is working with technical experts from its production contractors to determine specific elevation data requirements for different types of flood studies. As the technology continues to mature, the price premium for higher densities and accuracies may diminish to the point where the lower-density / lower-precision specifications become obsolete. See Appendix D for draft elevation specifications for Risk MAP.

Nationally, there are a wide variety of other requirements for updated digital elevation data. The second FEMA specification level has a lower vertical precision requirement than most other LIDAR users currently accept. However, this precision is comparable to the highest precision specifications that FEMA has used historically. The third and fourth FEMA precision classifications may not be attractive to most potential partners or other users of the data, but they represent a clear improvement over the data typically available for flood mapping in these areas and will effectively meet FEMA's requirements for floodplain mapping. FEMA anticipates that in many cases, partnerships will be formed to produce elevation and derived products that meet a large number of different user requirements and substantially exceed the specification that FEMA would use when funding the project alone.

The elevation data requirements for floodplain mapping are concentrated in the floodplain and immediate vicinity. The accuracy of ground elevations away from the floodplain have little impact on the quality of the flood hazard data produced. It is only within the floodplain that FEMA needs newer, more accurate information. However, most efficient methods of ground elevation data collection are performed by airplane and the most efficient collection strategy is to fly long, straight, parallel lines to cover the entire area of interest. A flight plan that only collects data over irregularly shaped floodplain areas and avoids data collection in the areas in between is often inefficient.

For initial acquisition and processing of new elevation data, FEMA plans to identify the geographic areas where it has flood hazard data update needs and then group them into logical collection blocks. These collections will be primarily in the Continental United States (CONUS) that currently have modernized flood maps, but there will be gaps in the coverage where the existing flood hazard data is adequate. Where LIDAR is used, the data collected will be processed to integrate measurements from separate flight lines into a cohesive set of elevation measurements. This data set will be adjusted using calibration data and ground check points so the measurements are accurately referenced to the earth. This data set will then be checked for accuracy using independent ground surveys in open areas to verify the fundamental accuracy of the dataset.

This collection and initial processing of the data set is only a portion of the total cost of LIDAR data acquisition. Post-processing, editing and producing derived elevation products from the initial data set are also significant costs. A key strategy to control the overall cost for FEMA is to perform post-processing, editing, and production of derived

elevation products only in the area of the data that FEMA really needs for Risk MAP. The area in or nearby the floodplain on which FEMA will perform additional processing will be 7 to 15 percent of the total area. This processing and the derived elevation products will be specific to FEMA's needs for flood hazard analyses. FEMA will archive all of the raw data collected and make it available to the USGS and the public, but most applications of these data will require additional processing of the raw information.

Depending on the intended use of the elevation data, the types of derived elevation products created are typically different. Based on the intended use, there are a number of decisions that must be made during this post-processing and editing phase. For example, derived elevation products for cartographic and general purpose mapping typically do not include the geometry of the land below the surface of perennial streams and lakes. A smooth water surface elevation is created instead. Similarly, road beds where a culvert allows water to pass underneath are kept in general purpose derived elevation data products and the culvert is ignored. For floodplain mapping, data for the submerged lands is generally required and the water flow permitted by the culverts is represented in the derived elevation products by a gap in the road surface or details on the interior geometry of the hydraulic structure. Because of these and other differences between the floodplain mapping requirements and general purpose mapping requirements, the derived products created through the post-processing that FEMA performs on the floodplain areas is likely not suitable for other users in this form.

Partnerships

FEMA has historically tried to optimized partnership opportunities in the acquisition of elevation data and will continue to do so during Risk MAP. Specifically:

- FEMA participates in the NDEP;
- FEMA maintains service level agreements with the USGS for coordination and stewardship of elevation data; and
- FEMA has policies in place for FEMA staff and contractors to seek out partnership opportunities.

FEMA anticipates that, in many cases during Risk MAP, partnerships will be formed to produce elevation and derived products that meet a large number of different user requirements and substantially exceed the specifications FEMA would use when funding the project alone. FEMA will work to upgrade the basic FEMA specifications using partner funding whenever possible. Because FEMA's approach to elevation data acquisition is specific to the requirements for floodplain mapping, it may be difficult to find substantial partnership opportunities that reduce FEMA's cost. Most potential partners will want to invest their resources in better coverage, higher precision, more post-processing, editing and derived products. While these partnerships may not offset Risk MAP costs, they will produce significant benefits for both FEMA and other users of the elevation data.

FEMA will also work closely with other Federal agencies and industry experts to ensure that new elevation mapping technologies are tested and integrated into program operations so that Risk MAP continues to leverage leading edge technology. Elevation mapping technology continues to evolve rapidly and improvements to LIDAR technology and potential replacement technologies are likely to provide significant additional benefits in the future.

Resources Required for Risk MAP Elevation Data Acquisition

Based on the budget proposed for Risk MAP in the President's budget, FEMA is planning to invest about $20 million annually of the funding allocated in elevation data to achieve the goals laid out in the Risk MAP Multi-Year Plan. FEMA's refinement of the technical approach for Risk MAP and the NRC "Mapping the Zone" report have influenced this evolution in approach. FEMA expects to be able to validate a substantial portion of existing flood hazard information is still current and identify elevation data partnerships that directly fulfill FEMA elevation needs. Based on these assumptions, FEMA anticipates that a $20 million annual investment over the course of the five year Risk MAP plan will be adequate to produce updated elevation data for 26 percent of the conterminous United States and reach the goal of 80 percent of the flood hazard data verified as current. The approach is a targeted national elevation strategy for floodplain map updates.

Risk MAP Elevation Data Utilization Plan
(Access, Use, Maintain, Archive)

The utilization plan for elevation data comprises the data access, data use, maintenance, and archive phases of the data lifecycle. FEMA will maintain the authoritative archive of the derived elevation data products that directly support the flood hazard analysis and will support access, use and maintenance related to flood hazard mapping. FEMA will also ensure that the minimum requirements are met for the maintenance and distribution of all the elevation data products produced by Risk MAP. FEMA will partner with the USGS to support data access, use, maintenance and archiving for general purpose mapping as the steward for framework elevation data.

FEMA maintains an archive of all the supporting data and engineering analyses that are the scientific basis of NFIP flood maps. FEMA's mapping mission is to identify flood hazards and assess flood risk, not to produce general purpose national elevation data and products. FEMA has a responsibility to handle data produced through Risk MAP prudently to avoid wasting resources spent on NFIP mapping and ensure the data is available for other purposes. FEMA will meet these responsibilities by making sure that elevation data produced by Risk MAP is available to other users. The costs associated with the basic management of Risk MAP elevation data are a component of the overall Risk MAP information technology budget.

FEMA is transitioning from a paper-based system to a digital library containing all engineering models, supplemental mapping sources, project narratives, and other project documentation. FEMA will continue this approach by archiving the specific elevation surface used for the flood hazard analyses and mapping. This will allow FEMA to provide authoritative information about the basis of the flood hazards depicted on the FEMA maps. These FEMA-specific derived elevation data products have relatively limited utility except for water resources applications. The derived elevation products for flood hazard mapping reflect specific choices about how to represent the hydrologic systems that are frequently different from what other users want. FEMA will also make sure that the other elevation products created by Risk MAP are available to potential users. FEMA will make these data available to anyone. Managing the data in a digital library will provide better and faster public access. However, FEMA's archive and distribution system is oriented towards meeting the needs of NFIP stakeholders and does not serve other users of elevation data (or many other types of data) as effectively.

FEMA will make the native format LIDAR data and all other general purpose elevation products generated by FEMA Risk MAP projects available to the USGS for distribution through their standard data management operations. This model allows the general purpose elevation products produced through FEMA projects to be integrated with the USGS national elevation holdings, based on the USGS program capacity to process new data into the system. There is a risk that the volume of new elevation data produced by Risk MAP will exceed the available USGS program capacity to maintain, archive and distribute these data. This approach leverages FEMA's work, providing additional

benefits and improvements in the quality of national elevation data resources and extending the availability of FEMA data to the widest audience. FEMA and the USGS have existing agreements to make orthoimagery and elevation data from the FEMA archive available through the USGS. FEMA and the USGS will build on these existing agreements to create a robust partnership for providing access, maintenance and archiving of the data.

USGS management of elevation data produced by Risk MAP is logical because:

- The USGS is the Office of Management and Budget (OMB) lead agency for the coordination and management of the terrestrial elevation data theme, under OMB Circular A-16;
- Elevation data comprise a core layer of the USGS National Map; and
- USGS is the steward or provider of many other framework national data sets.

USGS management of Risk MAP elevation data would result in significantly better access to the data by a much broader community of users. This approach would also be more cost effective than FEMA attempting to replicate the access, management and archiving capabilities of the USGS. USGS has the mission and capability to unlock the value of these data as a national resource by:

- Integrating the data into the collection of existing national geospatial datasets;
- Facilitating access to these data;
- Archiving the data; and
- Providing for the long term maintenance of data.

Conclusion

Risk MAP will be making a major investment in updated elevation data. The Risk MAP elevation strategy will produce significant new elevation data, but will not comprise a national approach that meets multiple stakeholder needs. Instead, Risk MAP will target areas with specific flood map update needs. A Risk MAP national approach for floodplain map updates will result in improved flood hazard and flood risk products, and produce significant benefits for other elevation data users. The consensus of the agency representatives that worked with FEMA on this plan was that a national strategy would be preferable to a Risk MAP national elevation approach.

Appendix A - Collaboration with Other Organizations

There are extensive requirements for Federal agencies to work cooperatively across the government on mapping projects to avoid duplication and waste and maximize the value of national investments. FEMA invests substantial effort to align mapping efforts with other Federal agencies. One of the principle ways FEMA does this is through participation in the National Digital Elevation Program (NDEP). This is a voluntary interagency working group comprising most of the significant elevation data producers in the Federal Government and State participation through National States Geographic Information Council and the Association of American State Geologists.

NDEP has been working for a number of years to align and leverage mapping efforts to produce updated elevation data. Because the overall Federal investments in updated elevation data have been small relative to the overall need, NDEP's progress toward updated national elevation data has been modest.

Congress requested that FEMA collaborate on the development of this plan with:

- The U.S. Geological Survey;
- The National Oceanic and Atmospheric Administration;
- The National Aeronautics and Space Administration; and
- States that have experience in acquiring and incorporating high resolution elevation data in floodplain map updates.

In addition to collaborating with the organizations named in the Congressional Request, FEMA coordinated this plan with NDEP. NDEP includes all the Federal agencies named in the Congressional request for a National Digital Elevation Acquisition and Utilization plan. On January 6th through 8th, 2010, the NDEP held a steering committee meeting. The entire day on January 7th was devoted to discussing the content of this plan. In addition to the Federal agencies listed above, the participants in this meeting were:

- The U.S. Army Corps of Engineers;
- The U.S. Census Bureau;
- The National Geospatial-Intelligence Agency ;
- The U.S. Department of Agriculture (USDA) Natural Resources Conservation Service;
- The USDA Farm Service Agency;
- The Office of Surface Mining, Reclamation and Enforcement;
- Association of American State Geologists (represented by Pennsylvania);
- The State of North Carolina; and
- The State of Oregon.

Pennsylvania, North Carolina, and Oregon have significant experience with collecting elevation data for floodplain map updates.

Appendix B - National Research Council (NRC) Reports

The National Academies of Sciences' NRC has issued two reports over the past few years with significant findings pertaining to National Flood Insurance Program (NFIP) Flood Hazard Mapping. The first report, *Elevation Data for Floodplain Mapping* (National Research Council, 2007) was focused on whether the right technologies were being used for the planimetric base maps and the elevation data for NFIP flood mapping. The report concluded that new digital maps were adequate for defining the high hazard flood areas, but the accuracy of the available land elevation data limited the ability of the updated flood hazard data products to fully depict the risk in three dimensions. The report concluded that Light Detection and Ranging (LIDAR) was the right technology for floodplain mapping and observed that floodplain mapping and the Nation in general would benefit significantly from national updated elevation data. FEMA's approach was already consistent with the recommendation of this report. The primary technology used when new elevation was produced for floodplain map updates was LIDAR. However, the strategy for the Flood Map Modernization Program, which was underway at the time, did not include systematic national updates of flood hazard analyses and therefore a national update of elevation data was not appropriate as part of this effort.

One of the most difficult scientific questions for FEMA to answer is which flood mapping improvements really affect NFIP map users, versus what improvements increase cost and/or complexity but do not really impact the results. As a result, FEMA requested that the NRC undertake a comprehensive study to assess the most cost-effective improvements to the input data and methodologies used for flood hazard mapping and make recommendations based on their findings. Stakeholder feedback and analyses by FEMA staff indicate that additional investments in updating flood hazard data are needed to meet national needs. Mapping flood hazards is a complex effort. Rather than mapping a physical feature that can be seen or measured, flood maps depict the result of engineering computer models. A model is a simplified mathematical representation of a complex real world system. Maps are simplifications of a large and complex world. Therefore, flood hazard maps are an abstraction of an abstraction incorporating complex analysis and synthesizing a large number of data elements. Despite this complexity, this type of analysis is very reliable and used regularly in the design and construction of dams, levees, roads, bridges and housing subdivisions. Because the modeling and mapping processes require dozens of assumptions and data inputs, there are an almost unlimited number of potential improvements that could be made to the maps. However, many of these "improvements" will have a very small or negligible impact on the precision or accuracy of the flood hazard maps.

The NRC study committee worked for about two years and produced the report entitled *Mapping the Zone* (National Research Council, 2009). This report concludes that accurate land elevation data is the single biggest factor in improving the quality of the flood hazard maps. The report also concluded that accurate elevation data was cost beneficial both in the areas with high flood risk and low flood risk and that the maximum cost benefit was achieved by varying the complexity and precision of the analysis based on the flood risk in the area being analyzed. The findings of this report reinforced the conclusion that the Risk MAP Program needs to continue to invest in updating the nation's flood hazard data and sharpen the focus on using accurate land elevation data for those updates.

Appendix C - Elevation Data Acquisition Status

There are several different commercial technologies available for mapping ground elevations. Over the past ten years, Light Detection and Ranging (LIDAR) technology has become commercially successful and now dominates the market. As the technology has matured and the cost has been reduced, a number of States have undertaken statewide LIDAR programs. States that have nearly complete recent elevation data coverage are:

- North Carolina;
- Louisiana;
- New Jersey ;
- Maryland;
- Delaware;
- Pennsylvania;
- Ohio; and
- Iowa.

Several other States have substantial initiatives underway, including:

- Florida;
- Texas;
- New York;
- Oregon;
- Minnesota;
- South Carolina; and
- Mississippi.

These statewide efforts cover approximately 20 percent of the land area of the continental United States. At the current rate, it may take 40 to 50 years to complete a national elevation data update.

LIDAR is a transformative technology in a number of ways. Historically, one of the biggest problems with mapping the ground from an aircraft has been seeing the ground through the trees, other vegetation, and manmade structures obscuring the ground. The LIDAR sensor sends a pulse of laser light to measure the ground. In many cases, even when there is substantial tree cover, vegetation, or other obstructions, a portion of the light penetrates through small gaps in the leaves, hits the ground, and is reflected back to the sensor, producing a measurement. Because of this, LIDAR produces measurements of the ground in areas that other technologies cannot measure. In addition, the laser pulse typically reflects off of objects above the ground, producing several other measurements of the tree canopy and understory. So, where traditional methods have produced a single measurement for a location, LIDAR frequently produces several measurements. Where the LIDAR is sufficiently dense, these multiple measurements can be portrayed as a three-dimensional cloud of point measurements showing trees, buildings, light poles, towers, and sometimes overhead wires. Older elevation mapping methods relied on

significant human intervention to select the points to be measured. This usually meant that fewer points were measured and these measurements focused on the obvious physical features of the landscape. The collection of LIDAR measurements is automated, although there is some manual editing involved in data finishing. As a result, LIDAR systems typically measure thousands or even millions of points where previous methods would measure only a few. This results in the following benefits:

- LIDAR obtains accurate ground measurements in places that could not previously be easily mapped
- LIDAR provides measurements of the ground and also measurement of features above the ground
- LIDAR provides extremely dense and detailed measurements

The applications of these new capabilities are not fully understood. However, users have demonstrated the ability to generate detailed three-dimensional city models, and significantly more precise vegetative structure measurements.

The NDEP agencies have worked together, with input from State officials, to coordinate new elevation data collections for most of the past decade. The participating organizations are: the U.S. Geological Survey (USGS), U.S. Department of Agriculture (USDA)-Natural Resources Conservation Service, USDA-Forest Service, Bureau of Land Management (BLM), National Oceanic and Atmospheric Administration, Census, National Geospatial-Intelligence Agency, U.S. Army Corps of Engineers, FEMA, and National States Geographic Information Council. NDEP agencies have been involved in most of the statewide programs mentioned above. However, the Federal spending on new elevation data collection is fairly small relative to the need; when it is not part of a State or local partnership effort, it is generally project driven. It is difficult to find enough overlap between the area of interest, schedule, and specifications between member agencies on these project-specific collections. The total annual spending on elevation data across the NDEP Federal members is less than $20 million.

Appendix D - Federal Elevation Requirements

The requirements for Light Detection and Ranging (LIDAR) data can vary significantly depending on the intended use of the derived products. This section presents representative requirements for several Agencies and mission areas.

Most of the general requirements are fairly similar across different applications. The recent LIDAR Standards and Guidelines published by the U.S. Geological Survey provide the most recent example of these requirements.

The data collection parameters that typically vary are:

- The density of measurements Nominal Post Spacing (NPS); and
- The typical vertical precision of the measurements. This is usually stated as the Root Mean Square Error (RMSE).

The NPS is typically higher than the density of measurements that will be included in most finished products derived from the native format LIDAR data. Because some measurements do not hit the target that is being measured, they are excluded from the derived products. For example, when mapping ground elevations, measurements that do not penetrate the trees or other vegetation are excluded from the derived "bare earth" products.

RMSE is a statistical method to quantify the typical variance of a set of sample measurements from their "true" value. Two thirds of all measurements should fall within one RMSE of "true".

Both of these parameters typically affect the cost of the data collection and the types of work that can be performed using the data collected.

There are also sometimes specific ground conditions required for data collection. For many coastal applications, the data must be collected within 6 hours of low tide to ensure that as much of the inter-tidal area is exposed. This is referred to as tide-coordinated data collection.

The chart on the following page summarizes some typical LIDAR requirements.

LIDAR Application	NPS (meters)	RMSE (cm)	Comments
FEMA Risk MAP – flood hazard mapping in flat, high risk areas	1	20	
FEMA Risk MAP – flood hazard mapping in rolling to hilly terrain, high risk.	2-3	40	
FEMA Risk MAP – flood hazard mapping in moderate risk areas	5	70	40 cm RMSE required in open, unvegetated areas.
FEMA Risk MAP – flood hazard mapping in very low risk areas	10	100	
USGS Base LIDAR Specification	1-2	15	
NOAA – sea level rise, shoreline delineation and other applications related to water level in the flattest areas	1	9	Shoreline delineation requires tide-controlled collection. International Hydrographic Organization standards specify horizontal accuracy requirements for shoreline, so the vertical accuracy required depends on the land slope.
NOAA – nearshore bathymetric mapping	2	15	Also needs to meet International Hydrographic Organization standards for charting purposes.
BLM – Site Design and Site Characterization, Shrubland Characterization, Habitat Assessments, and Assessment, Inventory, Monitoring	5-8	9-12	NPS and vertical RMSE values stated are based on current technology and should not be considered hard and firm Bureau of Land Management requirements. The Bureau's technology requirements will always be based on the current capabilities available from industry.