Dewberry

FINAL REPORT

Evaluation of Alternatives in Obtaining Structural Elevation Data

Part I — Assessment of Elevation Strategies

Part II — Providing Structural Elevation Data

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PURPOSE

Insurance agents and write-your-own (WYO) companies have long affirmed that the requirement for Elevation Certificates (ECs) is a major impediment in selling flood insurance. In 2000, FEMA held a forum for parties interested in developing an *e*Rating system for flood insurance policies. The purpose of the meeting was to exchange ideas on the best strategy to achieve FEMA's goals for an *e*Rating system and to discuss alternatives for overcoming the difficulties and high cost of implementing such a system. FEMA had not developed a requirement for an *e*Rating system but simply sought input from industry, other government agencies, and academia on the best strategy to develop such a system. After careful consideration of the issues raised at the *e*Rating forum, FEMA decided not to pursue developing an eRating system for flood insurance but rather, concluded that it must (1) examine whether it is appropriate, feasible, and legally possible for the government to provide elevation information on individual structures for use in rating structures, and (2) determine if it is technically feasible and cost effective to do so.

The purpose of this study is to determine if it is appropriate, feasible, and legally possible for FEMA to obtain the elevation data on individual structures and to make this elevation information available to properly rate the structures for flood risks and flood insurance premiums so that ECs costing hundreds of dollars each would not be needed in most cases for insurance rating. The study examines the legal issues involved in collecting and making elevation information available and assesses five approaches for obtaining structure elevation information. The cost effectiveness of these various approaches is evaluated and a recommendation is provided for implementation of an elevation registry. This study will allow FEMA to determine if providing individual structure elevation data best serves the National Flood Insurance Program's (NFIP) needs.

Initially, the Dewberry team submitted a report on legal issues, prepared by FEMA Law Associates and the EOP Foundation, which summarized research and analysis on legal issues relevant to a determination by the Federal Emergency Management Agency (FEMA) of whether it can develop an elevation registry ("registry") of structural elevation data for National Flood Insurance Program (NFIP) purposes. The Dewberry team sought to identify and evaluate the significance of potential legal obstacles to developing this registry primarily in three areas: (1) the Privacy Act of 1974 and other privacy issues; (2) potential exposure to liability for inaccurate elevation information; and (3) potential ownership rights that third parties may have to elevation data. As indicated in APPENDIX A of this report, we identified no legal issues that would preclude FEMA from establishing and maintaining a registry and making it available to insurance companies and agents writing NFIP policies, or even to the general public. Creation of the proposed registry is an activity well within the authority granted by the National Flood Insurance Act. An elevation registry as described in the Statement of Work, and in subsequent meetings with FEMA, would not violate federal or state privacy law or policy or significantly expand the liability exposure of participants in the NFIP.

Part I of this Final Report summarizes Dewberry's research and analysis of five (5) elevation strategies/alternatives considered for acquiring data for an elevation registry, explains how data were gathered and evaluated for utility in populating this registry, and assesses whether it is technically feasible and appropriate to utilize any or all of the five elevation strategies proposed by Dewberry to develop an elevation registry of structures.

The five elevation strategies evaluated in Part I of this Final Report are as follows:

- Strategy A: Maximize use of existing Elevation Certificates
- Strategy B: Maximize use of airborne remote sensing (photogrammetry, LIDAR and IFSAR)
- Strategy C: Evaluate use of mobile photogrammetric vans
- Strategy D: Maximize cost-effectiveness of future Elevation Certificates
- Strategy E: Leverage alternative data sources for an elevation

The purpose of Part I of this Final Report is to document the accuracy standards and the evaluation of each strategy, and to develop conclusions and recommendations regarding the utility of these strategies for populating an elevation registry.

The purpose of Part II of this Final Report is to document the process for arriving at the recommended strategy or strategies for obtaining structure elevation data.

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PART I — ASSESSMENT OF ELEVATION STRATEGIES

BACKGROUND

The National Flood Insurance Act of 1968 created the National Flood Insurance Program (NFIP). The NFIP is a cooperative venture involving the federal government, state and local governments and the private insurance industry. The federal government sets insurance rates, provides the necessary risk studies to communities, and establishes floodplain management criteria guiding construction in the floodplain. Communities must adopt and enforce floodplain management standards for new and substantially improved structures. Flood insurance is only available in those communities that enact and enforce these measures. Private insurance companies, under an arrangement known as the Write Your Own (WYO) program, sell and service federal flood insurance policies in their own name and withhold part of the premium for their efforts. The government also sells flood insurance directly through its servicing contractor and retains the risk for all flood insurance policies. Within the Department of Homeland Security (DHS), the Mitigation Division, a component of FEMA, administers the NFIP. The regulations governing the NFIP appear in Title 44 of the *Code of Federal Regulations* and in manuals, procedures and other documents.

The provision of insurance, the regulation of the floodplain, and the enforcement of the mandatory purchase requirements depend on three things:

- *Flood hazard identification and risk assessment* -- certain key information about the nature and extent of the flood risk in a given area
- *Floodplain management* -- the elevation of the structure
- *Insurance rating* -- structural characteristics such as the number of floors and occupancy type

Flood Hazard Identification and Risk Assessment: FEMA provides flood-zone information in the form of a Flood Insurance Study (FIS) and Flood Insurance Rate Map (FIRM). The FIRM shows the flood risk in a given jurisdiction and serves as the guiding document for communities in the regulation of floodplain construction and for lenders in enforcing the mandatory purchase requirements. The primary flood risk characteristics shown on the FIRMs are the Special Flood Hazard Areas (SFHAs) or areas inundated by a one-percent annual probability flood and the elevation relative to the mean sea level to which the floodwaters will rise. (A discussion of accuracy standards is in APPENDIX B, and a discussion of mean sea level and vertical datums is contained in APPENDIX C). Whereas Base Flood Elevations (BFEs) are also shown on FIRMs, communities and surveyors usually get this information from a community's flood insurance study profile.

The FIRM also serves insurance companies and agents as the source of needed risk information for writing and rating applications for flood insurance under the NFIP. Agents must have the flood zone and BFE to rate a flood insurance policy. For most Post-FIRM structures within the SFHA, the agent gets the flood zone and BFE from the Elevation Certificate (EC). In other cases, the agent must get the flood-zone and BFE from the community's FIRM and FIS. Locating a property on the paper copy of the FIRM has historically been a problem for agents, a problem that has not diminished substantially over the years.

Flood zone determination companies and some WYO companies have digitized much of the information on the FIRMs and now provide this information to some agents. Zone information is far from universally available from the WYO companies, and agents may not want to pay the fee that flood zone determination companies charge for the service. The primary clients of the flood zone determination companies are federally regulated lenders who need the information to comply with the mandatory flood insurance purchase requirements of the National Flood Insurance Reform Act of 1994. Lenders are able to pass along the fee for the service to borrowers as part of a mortgage loan's closing costs. However, insurance agents may hesitate to do the same with their customers because charging for this service could jeopardize their competitive position.

In 2002, FEMA made all effective maps available in raster scan version through the Map Service Center. Digital map files, flood insurance studies and flood profiles are now available on FEMA's website and on CD. This greatly improves accessibility for agents by eliminating the need to maintain paper copies of the maps and providing data which an agent or others can use to calculate the BFE.

Floodplain Management: FEMA cannot provide flood insurance unless a community adopts and enforces a floodplain management ordinance that meets or exceeds the minimum requirements of the NFIP. Elevation information is needed to guide floodplain construction and to rate insurance applications. The community must ensure that the lowest floor elevation of a new structure, built in the SFHA after the date of the current effective FIRM, is at or above the BFE shown on the FIRM. To encourage community participation in the NFIP and the purchase of flood insurance, Congress subsidized the insurance premiums for buildings constructed before the issuance of a FIRM or before 1975, whichever is later. The NFIP does not require an EC to rate these buildings though, in the case of better-situated Pre-FIRM properties, actuarial rates may be lower.

The NFIP, as adopted and enforced by each participating community, requires the community to obtain the elevation of the lowest floor, which includes the basement, of all new and substantially improved buildings, and to maintain a record of such information [44 CFR 60.3(b)(5) and 60.3(e)(2)]. The local floodplain administrator must determine which level is the "as built" lowest floor to verify whether the building complies with the community's floodplain management regulations. "As built" means that construction of the building is complete and the building is ready for occupancy.

For new construction and substantially improved building in the floodplain, there are a series of surveys and inspections to verify that construction takes place according to plan and that it meets floodplain management requirements. FEMA's EC is an important tool that communities can use to document the level of flood protection for various building components and the "as built" lowest floor elevation. All communities must obtain and retain elevation information but they are not required to document that information on a FEMA EC. Communities participating in the NFIP's Community Rating System (CRS), which account for 66 percent of the policies, must obtain and retain this information on a FEMA EC (currently FEMA Form 81-31, July 2000). Communities often archive the elevation data they maintain and hence it is not readily accessible. The passage of time may have compromised the reliability of older elevation information.

Insurance Rating: All applicants for flood insurance on Post-FIRM structures within the SFHA must provide the lowest floor elevation on a property in the form of an EC completed by a licensed engineer or surveyor. For these buildings, flood insurance rates take into account a number of different factors including the flood risk zone shown on the FIRM, the elevation of the lowest floor above or below the BFE, the type of building, the number of floors, and the existence of a basement or enclosure.

The NFIP uses elevation information to determine rates for flood insurance coverage. The EC shows the structure's elevation relative to the mean sea level. Insurance agents writing a flood insurance policy use this information to determine a structure's lowest floor elevation and calculate the difference between the BFE and the lowest floor elevation to determine the proper rate for insurance coverage. Approximately 40 percent of the policies sold require an EC. The cost for the certificate is usually more than $300.

The insurance agent obtains the relevant structural characteristics from the insured. For example, the property owner can supply information about the number of floors, occupancy type, date of construction, etc. to the agent. The NFIP's *Flood Insurance Manual* provides detailed guidance for the agent's use in rating flood insurance policies, which the agent uses to determine the type of building. Building types include those with no basement, an unfinished basement, a finished basement, mobile homes on foundations, and elevated buildings. The agent also classifies the building's occupancy type as single-family dwelling, two to four family dwelling, other residential building, or a non-residential building. The agent determines if the structure is used for commercial or residential purposes, records the value of the structure, its owners and, as appropriate, the elevation.

ACCURACY OF ELEVATION CERTIFICATES

This section explains why it is important for structural elevation data to be accurate, especially for structures in or near the SFHA. Flood insurance premiums, for a post-FIRM structure (built after publication of a FIRM) and showing the structure's location to be within a SFHA, are largely based on the difference in elevations between the BFE and the top of the bottom floor of the structure. If the structure's top of bottom floor elevation is above the BFE, insurance premiums are much lower than when the top of bottom floor is below the BFE. For example, using NFIP flood insurance premiums as of May 1, 2004, for a post-FIRM building in the SFHA of a non-CRS community, annual premiums shown below are for $150,000 in building coverage and $75,000 in contents coverage for a one-story building with no basement and a $500 deductible:

- When the top of bottom floor is 2 ft above the BFE: $418
- When the top of bottom floor is 1 ft above the BFE: $595
- When the top of bottom floor equals the BFE: $892
- When the top of bottom floor is 1 ft below the BFE: $3,201
- When the top of bottom floor is 2 ft below the BFE: $4,040

From this example, it is obvious that elevation errors could have a major effect on actuarial rates charged for post-FIRM buildings, whereas the "subsidized" rate charged for pre-FIRM buildings (constructed prior to publication of a FIRM) would be $1,471, regardless of the top of bottom floor elevation. If the building is outside the SFHA in areas of low or moderate flood risk (shown as B, C, or X zones on a FIRM) and with no significant history of flooding, its premium for a Preferred Risk Policy (PRP) would be $264 (with $60,000 in contents coverage), regardless of the top of bottom floor elevation.

Higher accuracy top of bottom floor elevation data also reduces risks in actuarial ratings. For this study FEMA assumes that ground-surveyed ECs are accurate to 0.5 ft at the 95% confidence level. For example, if an EC surveyor certifies a top of bottom floor elevation to be 1 ft higher than the BFE, FEMA can assume (with 95% confidence) that the actual top of bottom floor elevation is between 0.5 ft and 1.5 ft above the BFE, the structure has a relatively low risk of flooding and insurance premiums would be at a relatively low rate ($595 in the above example). However, if a less-accurate "approximate" aerial survey process were used to determine the top of bottom floor elevation, accurate to 2 ft at the 95% confidence level for example, then a top of bottom floor elevation determined to be 1 ft higher than the BFE might actually be between 1 ft below the BFE and 3 ft above the BFE at the 95% confidence level. Then, FEMA would have less confidence that the structure has a low risk of flooding and would need to charge a higher "judgment rating" premium (somewhere between $595 and $3,201) to account for increased risk of flooding, even though the top of bottom floor elevation is probably on the "safer side" of the BFE.

Executive Order 12906 requires all Federal agencies collecting or producing geospatial data to comply with standards adopted through the Federal Geographic Data Committee (FGDC) which requires accuracy to be reported in ground distances at the 95% confidence level. As stated in FGDC-STD-007.1-1998, Geospatial Positioning Accuracy Standards, Part 1: Reporting Methodology, the Federal Geographic Data Committee (FGDC) defines geospatial positioning accuracy in terms of *local accuracy* and *network accuracy*, described in APPENDIX B.

To understand *local accuracy*, one needs to understand the concept of *relative accuracy*, as applied to a 95% confidence level. The most common ground surveys are referenced to local survey monuments or benchmarks, including temporary benchmarks such as elevation reference marks (ERMs), often selected for their proximity or convenient location rather than for their accuracy or stability.

To understand *network accuracy*, one needs to understand the concept of *absolute accuracy*, as applied to a 95% confidence level. Such control surveys are referenced to a rigorous geodetic control network of survey monuments that are both accurate and stable. FGDC-STD-007.1-1998 states: "Geodetic control surveys are usually performed to establish a basic control network (framework) from which supplemental surveying and mapping work, covered in other parts of this document, are performed. Geodetic network surveys are distinguished by use of redundant, interconnected, permanently monumented control points that comprise the framework for the National Spatial Reference System (NSRS) or are often incorporated into the NSRS. These surveys must be performed to far more rigorous accuracy and quality assurance standards than control surveys for general engineering, construction, or topographic mapping. Geodetic network surveys included in the NSRS must be performed to meet automated data recording, submission, project review, and least squares adjustment requirements established by the National Geodetic Survey (NGS). The lead agency is the Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service, NGS; the responsible FGDC unit is the Federal Geodetic Control Subcommittee (FGCS)."

In addition to understanding distinctions between the various accuracy standards explained in APPENDIX B, it is also important to understand distinctions between ellipsoid heights (from GPS surveys that follow the rules of geometry) and orthometric heights (from differential leveling surveys that follow the rules of gravity). The term "elevation" is normally meant to infer orthometric heights. These distinctions, and other factors necessary in the generation of "accurate" elevation data, are discussed in APPENDIX C.

As referenced in Table B.4 of APPENDIX B, accuracies in this study will refer to vertical errors at the 95% confidence level and equivalent contour interval (CI), as follows:

- ECs, whether surveyed by GPS or conventional means, are assumed to be accurate to 0.5 ft at the 95% confidence level. This means that 5% of the ECs will have errors larger than 0.5 ft when compared against a standard of higher accuracy such as geodetic surveys that satisfy NGS 2-cm or 5-cm standards.
- If alternative ECs are equivalent to 1' contours, as with the highest accuracy LIDAR surveys, this means that 95% of EC elevations checked should be accurate within 0.6 ft when compared against a standard of higher accuracy.
- If alternative ECs are equivalent to 2' contours (as with the most common LIDAR or high accuracy photogrammetric surveys), this means that 95% of EC elevations checked should be accurate within 1.2 ft when compared against a standard of higher accuracy.
- If alternative ECs are equivalent to 5' contours (as with mid-accuracy photogrammetric surveys), this means that 95% of EC elevations checked should be accurate within 3.0 ft when compared against a standard of higher accuracy.
- If alternative ECs are equivalent to 10' contours (as with IFSAR or USGS DEMs produced from 10' contours), this means that 95% of EC elevations checked should be accurate within 6.0 ft when compared against a standard of higher accuracy.

A "standard of higher accuracy" is assumed to be at least three times more accurate than the product being evaluated, e.g., geodetic surveys accurate to 5-cm (≈2") at the 95% confidence level are suitable for checking the accuracy of another product to determine if it is accurate to 6" at the 95% confidence level.

As explained later in this report, FEMA considers elevations to have zero value for an elevation registry when elevation errors are 4 ft or worse at the 95% confidence level.

LESSONS LEARNED IN NATIONWIDE SURVEYS

This section describes early GPS survey projects that provided lessons learned for subsequent surveys performed by Dewberry, URS, and G&O. Occasionally, Dewberry has been asked to review ECs produced by other firms that were unaware of these lessons learned. Regardless, the major problem remains today for most EC surveys nationwide — that local surveys are still performed relative to the most convenient and accessible benchmarks, regardless of accuracy and stability, rather then using more rigorous (and expensive) procedures to guarantee some reasonable level of *network accuracy*.

For decades, Dewberry surveyed ECs with conventional survey procedures; it has been using combinations of GPS and conventional survey procedures since 1993. Dewberry has also been hired to determine the most likely reasons for errors in elevation surveys performed by others, once a client determined that errors had occurred. This section summarizes lessons learned during the past decade. The following studies provided valuable input into shaping Dewberry's current GPS elevation survey procedures.

- In 1993-1994, Dewberry performed GPS surveys of thousands of homes flooded in Georgia, Alabama, Florida, and Texas. For those surveys, FEMA only needed GPS to determine the latitude and longitude of the flooded homes. At that time, GPS elevation survey procedures had not yet been published. For elevations, FEMA asked only for "windshield survey estimates" of the depth of interior flooding as well as the area of each building's footprint, plus costs to repair (estimated by a Certified Flood Adjustor looking only at external conditions without leaving the car).

- In early 1995, Dewberry was tasked by FEMA to survey 1,300 structures in Louisville and Jefferson County, KY, to demonstrate the viability of generating low cost and expedient ECs and to provide homeowners with credible, personalized flood risk information on which to determine their need for flood insurance. This project, which became known as the "GPS shootout," compared the capabilities of a relatively unsophisticated *GPS Backpack* solution with those of a highly sophisticated *GPS TruckMAP* solution, both using "stand-off" survey procedures that did not require surveyors to walk on private property.

- In 1995, Dewberry, with support of ISO/CRS specialists, performed No-Cert GPS surveys of 1,468 structures. Dewberry developed Standards and Specifications for GPS "No Cert" Reference Level Surveys to be conducted in eight states (NJ, NC, SC, FL, LA, TX, CA, and WA), using procedures validated by the National Geodetic Survey (NGS). Demonstrations were conducted to validate the accuracy of the procedures to be used.

- In 1996, Charlotte and Mecklenburg County, NC, concluded that the mass production of accurate elevation surveys was the key to proactive floodplain management in their community. They hired Dewberry to survey approximately 2,190 floodprone buildings throughout the county and to develop a GIS database designed for proactive floodplain management. This database has since grown to over 3,000 structures, and all structural elevation data is freely available to the public on-line.

- ECs and databases were similarly prepared for Boone, NC; Roanoke, VA; and Prince George's County, MD.

- In 1998, as part of a Price-Waterhouse study of the economic effects of actuarially based premiums, Dewberry surveyed 7,628 pre-FIRM houses in 23 communities nationwide. By then, GPS elevation survey procedures were established and published by NGS for achieving 5-cm vertical accuracy.

<u>Local and temporary bench marks are not always accurate</u>. When asking the Director of Public Works (DPW) in Albany, Georgia to recommend a survey monument to be used as the GPS base station, he asked, "Do you want a high one or a low one?" Dewberry replied that we wanted the most accurate one. The DPW replied that he didn't know which monument was actually the most accurate, but he knew that if one (high) monument was used as the reference station, elevations would be about one foot higher than if a different (low) monument was used. Because Dewberry didn't need accurate elevations for this particular project, this discrepancy did not need to be resolved. This was Dewberry's introduction to the fact that local surveyors often know which monuments are high or low, but may not know which one is more accurate; furthermore, it could be perfectly legal for a surveyor to choose a high monument, when surveying an EC, and this could artificially cause a house to appear to be less floodprone.

In Jefferson County, KY, the County Surveyor provided a list of temporary benchmarks (TBMs) in the vicinity of the Southern Ditch which posed a threat of flooding to the majority of the 1,300 houses surveyed. These TBM descriptions were typical of FEMA's Elevation Reference Marks (ERMs), e.g., railroad spikes in power poles and trees (that grow), and chisel marks on bridge abutments, for example. While recognizing that none of these were suitable for accurate vertical surveys, Dewberry checked two telephone poles with railroad spikes for which elevations were provided. One had two, and the other had three railroad spikes at different elevations on the referenced power poles, visible from different directions. Depending on the surveyor's care and angle of approach, he/she could have selected a railroad spike several feet higher or lower than the one intended. Also, none of the benchmarks on this list referenced the vertical datum used. Unfortunately, this is typical of local benchmarks used for surveys of many ECs, where surveyors traditionally select the most convenient benchmarks, rather than those of higher accuracy at greater distances which are more expensive to survey.

Surveyors may not be able to detect the presence of basements from the street. Of the 62 most difficult houses surveyed in Jefferson County, KY, the lowest floor elevations surveyed independently by two different methods all agreed within 1 inch, except for one house (3140 Sunny Lane) where two significantly different survey reference points were selected in large part because of the desire to minimize intrusion on private property. A neighbor had indicated to one survey team that the house next door had no basement under the northern half of the split-level home; this team classified the house as building diagram number 3 and surveyed the ground level entrance door to the southern half of the house. The other team detected the presence of basement windows in the northern section, classified the house as building diagram number 4, and surveyed the bottom of siding of the northern section with an offset of 8 feet to the basement floor. The elevation difference was over 5 feet between these two split levels.

Failure to detect the presence of basements could cause lowest floor elevations to be in error by a full story (9 feet when including floor joists and flooring materials). Because of the high visibility failure at 3140 Sunny Lane in Jefferson County, KY, all surveys conducted by Dewberry since 1995 have included brief intrusions onto private property, if only to detect the presence or absence of basement windows and/or walk-out basement doors. (Uncertainty in the height of floor joists is the main reason why surveyors prefer to survey the top of the foundation and then subtract 8 feet -- the standard height of construction forms used to pour concrete foundations -- to determine the elevation of basement floors.)

ERMs shown on FIRMs may not be reliable or may not be recoverable. To achieve high absolute accuracy from GPS surveys, it is important to first validate the accuracy of all monuments to be used as GPS base stations. Dewberry recommends that four of the best monuments surrounding a project area be checked relative to each other and validated, prior to actual surveys of structures. If the relative elevations of these four monuments are consistent within 1 inch, then any of them could be used as a GPS base station without causing significant errors in surveys derived therefrom. Dewberry attempted to survey the elevation of ERM 45, on Jefferson County's FIRM panel 170, which is nearest to the majority of the houses surveyed during this project, but this ERM could not be located after 2 hours of searching.

ERMs from FIRM panels were found to be unreliable in all 8 states included in the No-Cert GPS Survey. They often were obsolete, having been destroyed because of construction or buried under concrete years ago. Most ERMs could not be recovered, and when they were recovered, they were often found to be inaccurate. For example, RM61 in Carteret County, NC, was documented as 10.41 ft on the FIRM, when its elevation was actually 5.78 ft per the NGS Data

Sheet and confirmed by Dewberry's surveys as having an elevation of 5.78 ft. This was a significant error of nearly 5 feet. Other ERMs typically had errors of 6 to 18 inches.

Note that FEMA no longer shows ERMs on its FIRMs but rather, on newer FIRMs, includes only NGS benchmarks of First or Second Order Vertical and a stability classification ranking of A, B, or C as defined by NGS. Local vertical monuments also may be shown on the FIRM with the appropriate designations. Local monuments shall be placed on the FIRM only if the community has requested that they be included, and if the monuments meet the NGS inclusion criteria. Additional information on qualifying criteria is as follows:

- They must be surveyed per NGS-58 guidelines for Secondary Base 5-centimeter monuments relative to existing NSRS monuments.
- They must have stability classifications of A, B, or C.
- Global Positioning System (GPS) files and station descriptions must have been previously submitted and accepted by the NGS for inclusion in the NSRS.

Survey monuments must be verified before beginning a survey project. Before starting the surveys in Louisville and Jefferson County, KY, the elevations of four control points, recommended for use by the County Surveyor, were checked for accuracy. Three of the four were consistent within 1 inch, but control point BF26-01 was found to be in error by 30 feet; its published elevation was 494.97 ft. but its correct elevation was 464.97 ft.

During the No-Cert GPS Survey study, Dewberry's GPS teams invariably arrived in a community and had to "start from scratch" using NGS monuments to determine survey control. Local benchmarks were generally found to be inaccurate, also with errors of 6 to 18 inches, even in areas where subsidence was not a problem.

In Charlotte-Mecklenburg County, NC, Dewberry's surveyors spent the first two weeks attempting to sort out the discrepancies found between the various survey monuments and benchmarks required as GPS base stations. Many discrepancies were over 12 inches, whereas Dewberry's standard was one inch. Dewberry required all surveys to be performed relative to accurate, reliable and stable benchmarks documented in the National Spatial Reference System and internally consistent within one inch; but it took two weeks to resolve control discrepancies throughout the county.

To avoid multi-path errors, GPS elevations must be validated. To prevent potential GPS multipath errors, NGS-58 states that single elevation points should be surveyed twice, on successive days with distinctly different satellite geometry. Alternatively, pairs of inter-visible points can be surveyed the same day, using conventional survey procedures to survey a "backsight" and validate the elevation differences between the two points; if they agree within a few centimeters, then no multipath errors occurred.

Subsidence can be a problem. In Louisiana and Texas, subsidence was a problem in several communities. In some cases, several days were spent by 2-person survey crews trying to resolve 12 inch discrepancies in elevations of control points that should have been accurate to a fraction of an inch, but which were apparently sinking at different rates as a result of subsidence.

Accurately located structures must be compared to accurately located floodplain boundaries to make in/out determinations. The left side of Figure 1 shows a segment of FIRM panel 25 of 50 in Omaha. The SFHA to the east includes two tree-lined streets that closely parallel the creek. The pre-FIRM houses on these two streets are clearly in the SFHA. However, the right side of the figure shows that an automated determination would plot the houses outside the SFHA -- not because they were actually outside the SFHA, but because the entire paper FIRM, from which the Q3 Flood Data was produced, lacks absolute horizontal accuracy. The GPS points with absolute accuracy (network accuracy) could not be accurately registered to the less accurate base map that has relative accuracy (local accuracy) only. Similar problems occur with elevation surveys where ECs may have good local accuracy relative to the nearest benchmarks, but lack good network accuracy relative to the geodetic datum which should form the vertical basis for all Flood Insurance Studies.

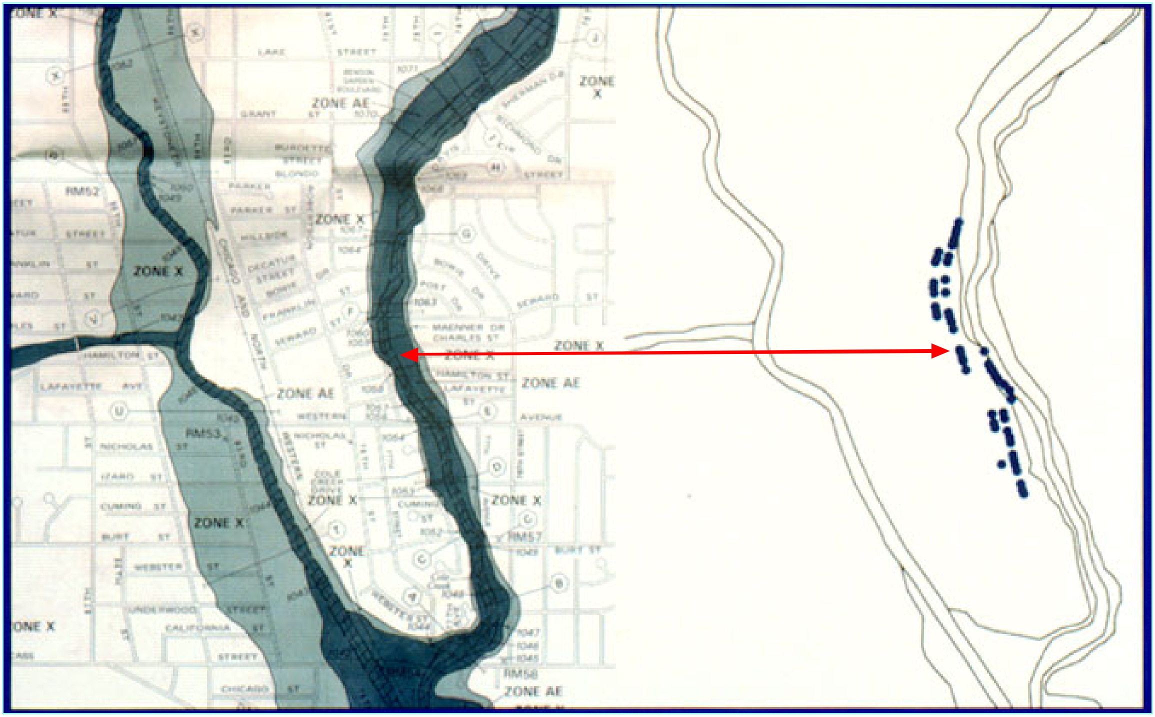


Figure 1 — Example of Poor Absolute Accuracy

STRATEGY ASSESSMENTS

FEMA's intent in creating the elevation registry is to expedite and simplify the rating and issuance of flood insurance policies by insurance agents, WYO companies, and the FEMA contractors issuing FEMA flood insurance policies directly and, when possible, avoid the need for new ECs to be surveyed. If FEMA decides to establish an elevation registry, it would probably be a subset of the NextGen data warehouse, with firewalls to prevent Privacy Act violations. The data will be available to WYO companies and agents in a format capable of linking to their existing computer systems. Further, for purposes of rating and writing policies, FEMA intends that agents and companies be able to rely on elevation data in the registry, and policies properly written and rated consistent with elevation data in the registry will be deemed correct until the registry information is changed.

The registry, at minimum, will provide to insurance agents and companies improved and simplified access to a key element of evaluating flood risk: <u>elevation of the structure as compared to the BFE as determined in that area</u>. As noted in Dewberry's *Report on Legal Issues* at APPENDIX A, Registry data will likely also be available and accessible to homeowners, potential homeowners, communities, lenders, and any private companies requesting access to this data. While the registry is not designed for this purpose, homeowners or prospective homeowners might seek to use the data to evaluate flood risk of their homes, or of properties prior to purchase. Communities might use this data in studies of flood prone areas or as part of a building permit process.

For communities that maintain their own ECs online, the registry might simply provide a link to the community web site. FEMA should consider granting CRS credits for providing this information to the public.

From the Dewberry team's legal analysis at APPENDIX A, we understand that elevation information required for use in determining premiums for an actuarially sound flood insurance program need not be as accurate as information required for evaluating the true flood risk of individual structures. An actuarially sound program can average out modest positive and negative errors in elevations of individual buildings, whereas those same errors could hide true flood risk for the owner of a particular structure. Whereas FEMA can accept some uncertainty in approximate, uncertified elevations of existing structures for insurance rating purposes and use *judgment rating* procedures to increase flood insurance premiums accordingly, communities and home owners need elevation data with absolute accuracy, providing certified assurance that new construction does not result in floodprone structures intended to be built at higher elevations. Communities would be advised not to rely on an elevation registry of approximate top of bottom floor elevations for evaluating a permit or for determining compliance of an existing structure that is being substantially improved or was substantially damaged. A new EC would have to be obtained to determine the "as built" information on the structure. In the case of new construction, an EC would not even exist.

Elevation information used for floodplain management purposes must be as accurate as possible for any proposed construction in the floodplain. This elevation information includes the BFE, any topographic information, and the proposed building elevations of all new and substantially improved structures that are provided to the community as part of the application for a development permit. It also includes “as built” elevation information the community must obtain once the structure is completed before it can issue a certificate of occupancy or compliance. Information in a registry cannot properly be used as a substitute for “as built” information because it is generally not available at the time the building is completed and may not be of the required level of accuracy. To ensure that potential users of the registry are aware of its limitations, the registry should include a prominent notice stating that it may be used in lieu of ECs in rating or writing flood insurance policies but that the approximate elevation information may not be sufficiently accurate for other purposes, particularly in determining whether to purchase a structure in the flood plain or to permit new construction or renovation in the floodplain.

Relying on elevation data that is costly to obtain led FEMA to examine whether it is legally possible, appropriate and feasible to obtain and make available the elevation information necessary to rate a flood insurance policy. FEMA's goal is to make elevation information more accessible to foster the development of an *e*Rating system that supports the actuarial rating of a flood insurance policy.

For this study, FEMA originally identified two strategies to obtain elevation information to *e*Rate flood insurance policies, which FEMA wanted thoroughly examined. (1) The first strategy called for a means to efficiently gather into a single, accessible database all available ECs for structures in the floodplain and to continually update this database as additional or better structure elevation information becomes available; this strategy is designed to capture the elevation data needed to rate a flood insurance policy in a single database. (2) The second strategy called for exploring new mapping technologies and approaches, combined with other property data, to gather elevation data. For example, Light Detection and Ranging (LIDAR) and Interferometric Synthetic Aperture Radar (IFSAR) can provide information on the lowest adjacent grade near a structure from which it is possible to determine the ground elevation and estimate the structure's lowest floor elevation, using foundation types or some other parameter, measured from that ground elevation. From FEMA's two strategies, Dewberry proposed five strategies to be evaluated for populating an elevation registry once it was determined that there were no major legal impediments for doing so. These strategies are evaluated in the following sections.

Strategy A — Maximize use of existing Elevation Certificates

Strategy A is based on gathering all available ECs for flood prone structures and capturing the elevation information, needed to rate a flood insurance policy, into an accessible elevation registry that would be maintained and updated as new information becomes available. Owner names would be deleted from the elevation registry because of Privacy Act considerations. Since ECs are required to rate a policy when the structure meets certain conditions (e.g., date of construction, flood hazard zone, etc.) and to obtain a LOMA or LOMR-F, EC information is vital for the elevation registry.

Strategy A will be applicable to structures for which ECs have been developed and where they are most readily available, preferably in electronic format. Strategy A alone will not result in a structural elevation database for all structures in and near the SFHA. In most communities, ECs have only been produced where required for selected structures.

Several previous studies have identified the potential need to evaluate existing ECs for completeness and accuracy. The other strategies assessed in this study will shed light on this issue through the comparison of ECs with other data sources.

ECs include structure-specific information about the elevation of various features of that structure. Depending on the type of structure, as depicted in standard building diagrams, the information in Table 1 is currently required by FEMA and by insurance agents to rate policies for flood risks.

Table 1 — Elevation Certificate Information

General Information	Elevation Information
Address	Base Flood Elevation (BFE)
Flood zone	Lowest adjacent grade (LAG)
Building use*	Highest adjacent grade (HAG)*
Building diagram number	Top of bottom floor (TBF)
Latitude/longitude (optional)*	Top of next higher floor (TNHF)*
Source of latitude/longitude*	Bottom of lowest horizontal structural member (LHSM)
Horizontal datum*	Top of slab of attached garage*
Source of elevation information	Lowest elevation of machinery and/or equipment servicing the building*
Vertical datum	

* Note: Older ECs may not contain these items.

ECs also typically include other information such as FIRM panel number and date. ECs that are already in a computer database format will be the least costly to convert to an elevation registry. Ideally, all pertinent elevation information has been captured from the ECs and the data would be able to be imported directly into the registry.

Sources of Elevation Certificates

In order to populate an elevation registry, the logical starting point is to determine where existing elevation data exists, to determine the data format(s), to assess the data suitability to the needs of the registry, and to assess the ease with which the data could be obtained and imported. Seven potential data sources were evaluated: (1) databases of the Insurance Services Office, Inc. (ISO), (2) FEMA's LOMA 2000 database, (3) ECs available to Dewberry and URS Corporation, (4) ECs available to FEMA Regions and state NFIP coordinators, (5) ECs available at selected local communities where large numbers of digital or hardcopy ECs are available, (6) ECs available from the U.S. Army Corps of Engineers, and (7) FEMA's Policies in Force database.

In order to document the existence of ECs that might be available from various sources, Dewberry developed an Existing Data Review Form to use as an aid when contacting agencies that have ECs. The form was designed to be used to document the findings of the available ECs and/or elevation databases in the various FEMA regions and states. With few exceptions, Dewberry learned that such elevation information is only available at the community level, except for data already being collected by ISO. For the most part, Dewberry did not contact individual communities as part of this study. The exception was that we contacted communities whose ECs we needed to augment with additional data to determine if ancillary data could be made available for geocoding addresses.

A.1 Insurance Services Office, Inc. (ISO)

Under this contract ISO was tasked to inventory the ECs and/or elevation databases that they have access to. This includes the ECs submitted annually by Community Rating System (CRS) communities. All CRS communities are required to maintain ECs for all buildings built in the SFHA after the date of their application to the CRS. The community must make copies of the ECs available to all inquirers, and FEMA publishes a listing of the phone number of the point of contact for the ECs for each CRS community. Additional CRS credits are given for maintenance of ECs for older buildings and for maintenance of ECs in an electronic format. FEMA estimates that 63% of the flood insurance policies are in CRS communities. Approximately 25% of the CRS communities receive credits for maintaining their ECs in a computer format. They submit these data annually to ISO which collects them on behalf of FEMA.

Additionally, ISO participated in a 1995 study on the retrieval and conversion of ECs to a database format. At the time, significant difficulties were encountered in creating a database from information documented on more than 7 different FEMA EC forms and provided in hardcopy format of varying quality, completeness, and legibility. However, there remain a significant number of ECs in this database.

ISO reported the EC holdings in Table 2.

Table 2 — Summary of ISO Elevation Certificate Holdings

Source	Format	Number of CRS communities	Number of Elevation Certificates
1995 conversion project	Access database	315	33,865
CRS program	Diskettes	90	17,751
		(Non-CRS) 50	1,367
Total		**404**	**52,983**

Dewberry subsequently asked ISO to provide existing ECs and/or elevation databases for Pinellas County, FL; Beaufort County, SC; Jefferson County, CO; and Harris County, TX to support Strategies B and C. Several issues were found with the data that are noted later in this chapter. A complete listing of ISO's data sets can be found in APPENDIX D.

A.2 LOMA 2000 Database

LOMA 2000 is a software application used by all of FEMA's Mapping Coordination Contractors (MCCs). LOMA 2000 automates the writing of Letters of Map Amendment (LOMAs) and Letters of Map Revision based on Fill (LOMR-Fs) and their attachments. Approximately 20,000 LOMAs and LOMR-Fs are processed annually by the MCCs. For most, if not all, LOMAs and LOMR-Fs, an EC and additional information, e.g., lowest elevation on the parcel is required. Owners typically request that their house be administratively removed from the SFHA because the lowest grade adjacent to the structure is higher than the BFE on the FIRM. LOMA 2000 has been in use since 1999 and contains approximately 163,000 records with EC information. Historic Letters of Map Change (LOMCs) have been entered into LOMA 2000; however, pertinent information is missing in the database for these older records.

The LOMA 2000 data dictionary includes the elements, listed in Table 3, that could be relevant to an elevation registry, as well as many other elements that are non-relevant. It should be noted that the lowest floor elevation (LFE) often is not the same as the top of bottom floor elevation because the LFE may include the lowest insurable elevation, to include crawl space, floor of attached garage, or lowest elevation of machinery.

Table 3 — Relevant Data from LOMA 2000 Database

General Information	Horizontal Location Data	Elevation Data
Community code	Latitude	BFE
State code	Longitude	BFE source
Street address	Lat/Long source	LAG (elevation)
City	Lat/Long datum	LAG source
Zip code	Old zone	Lowest floor (elevation)
County	New zone	Lowest floor source
Lot		Elevation datum
Block		
Section		
Panel		
Panel date		
LOMA		
LOMR_F		
CLOMA		
CLOMR_F		

Dewberry alone currently has approximately 130,000 addresses in the LOMA 2000 database. Depending on the age of the ECs, they may or may not include latitude and longitude. Approximately 80,000 records in Dewberry's LOMA 2000 database include latitude and longitude, Baker has approximately 12,000 files, with 4,200 geocoded. PBS&J has approximately 21,000 records, with 7,400 geocoded. All of the MCCs use commercial geocoding packages to estimate the latitude and longitude of LOMA 2000 addresses if they have not been provided on the EC. Only 124 entries in LOMA 2000 list latitude and longitude as having been derived by GPS survey.

The elevation data in the LOMA 2000 database was obtained from many different documents including various editions of the FEMA Elevation Certificate. Therefore, the data will only be as good as the knowledge of the persons completing and interpreting the form before entering it in the database. For insurance rating, FEMA considers data in LOMA 2000 to be less reliable than data on an EC submitted with a LOMA application. Whereas the ECs submitted with a LOMA application may be highly accurate, the elevation data in the LOMA 2000 database is believed to be less accurate. Moreover, the latitude and longitude errors that may exist within LOMA 2000 from the use of commercial geocoding packages may be several hundred feet in any direction, as documented in A.9 below. Of note, the FEMA DFIRM Database design team considered adding point locations of LOMCs as a layer in the DFIRM Database, using LOMA 2000 as the source. However, because of the known geocoding variances, it was decided that a relational table listing LOMC cases by panel was a more prudent option than including approximate structure locations. The LAG elevations in the LOMA 2000 database do have value for the elevation registry.

A.3 Dewberry and URS

Dewberry and URS each searched their archives to determine the availability of existing EC data that they had produced. The complete results are at APPENDIX E. A summary is provided below.

Dewberry

Dewberry has produced thousands of GPS ECs as part of the 1995 No Cert study; the 1999 *Study of the Economic Effects of Charging Actuarially Based Premium Rates for Pre-FIRM Structures*; for pro-active communities such as Charlotte-Mecklenburg, NC; and as part of post-disaster surveys of damaged structures.

As indicated in Table 4, Dewberry was able to assemble a combined Access database of 16,381 GPS ECs. The Dewberry ECs included a mix of residential, commercial, and public structures; were collected by GPS survey; include latitude/longitude, LAG, and BFE; include structure details such as building diagram number or building description; and most contain elevations for top of bottom floor or top of reference floor.

Some of the earliest surveys, including the No Cert surveys in 1995 and post-flood surveys in 1993-94, were not retrievable in digital format and/or lacked suitable information for an elevation registry. The hardcopy deliverables were provided to FEMA. The 1993-94 post-flood surveys in Georgia, Alabama, Florida, and Texas did not include any actual elevations, but depths of interior flooding to the nearest whole foot, based on "windshield surveys" from the car.

Dewberry also obtained structure information from the City of Austin, TX, to be used for a demonstration by FIA at the 2000 National Flood Conference of the feasibility of automating flood policy writing. The data provided by the City of Austin included addresses, structure type, latitude/longitude and first floor elevation for 863 structures in and near the floodplain of Waller Creek. The city has collected this type of information for an EC database. Additionally, the city maintains an address centroid database of 272,127 addresses for the entire city (not including first floor elevation).

Table 4 — Dewberry's Elevation Certificates

Source	Geographic Area	Date	Structure Category	Format	Number of Elevation Certificates
HMTAP	West Virginia	1996	Damaged structures	Database	1,129
Actuarial Study	Throughout U.S.	1997	Pre-FIRM structures in SFHA	Database	8,083
HMTAP	North Topsail, NC	1997	Damaged structures	Database	2,046
Charlotte-Mecklenburg County, NC	Mecklenburg County, NC	1997	All structures in SFHA	Database	2,197 (Add'l ECs done by county since)
HMTAP	Horry County, SC	2000	Damaged structures	Database	207
HMTAP	Coastal counties of Maryland	2000	Damaged structures	Database	84
Boone, NC	Boone, NC	2001	Selected structures in SFHA	Database	378
Project Impact Roanoke Valley Alleghany Regional Commission	Roanoke, Roanoke County, Vinton, & Salem, VA	2001	Selected structures in SFHA	Database	1,495 (Add'l ECs done by PDC since)
Prince George's County, MD	Prince George's County, MD	2002 & 2003	Selected structures in SFHA	Database	762
Subtotal				**Database**	**16, 381**
No-Cert GPS Survey Study	Florida, New Jersey, North Carolina, & South Carolina	1995	Post-FIRM structures in SFHA	Hardcopy	1,368
Post-Flood Surveys	Georgia, Alabama, Florida, and Texas	1993-1994	Damaged structures	Hardcopy (not true ECs)	7,963 No absolute elevations
Total					**25,712**

URS

Under various HMTAP task orders managed by URS, contractors such as Dewberry, Greenhorne & O'Mara (G&O), GRI (now Baker), and SKW have surveyed thousands of additional ECs, as summarized in Table 5. The data in these ECs were collected using conventional and GPS surveys. All are available in hardcopy format and some may be available in digital format. These surveys normally include the pertinent EC items.

Table 5 — URS' Elevation Certificates

Source	Geographic Area	Date	Structure Category	Format	Number of Elevation Certificates
HMTAP TO012	Sonoma County, CA Russian River	1995	Damaged structures	Hardcopy	450
HMTAP TO032	Lexington, VA & surrounding counties	1995	Damaged structures	Hardcopy	750
HMTAP TO048	Wyoming, Bedford, & Lycoming Counties, PA	1996	Damaged structures	Hardcopy	1,050
HMTAP TO079	Hoisington, KS	2001	Damaged structures	Hardcopy	20
HMTAP TO081	Wyoming County, WV	1996	Damaged structures	Hardcopy (see Dewberry’s listing for database)	175
HMTAP TO082	West Virginia	1996	Damaged structures	Hardcopy (see Dewberry’s listing for database)	1,060
HMTAP TO113	North Topsail, NC	1996	Damaged structures	Hardcopy (see Dewberry’s listing for database)	1,000
HMTAP TO122	Shenandoah County, VA	1996	Damaged structures	Hardcopy	46

Source	Geographic Area	Date	Structure Category	Format	Number of Elevation Certificates
HMTAP TO126	Danville & South Boston, VA	1996	Damaged structures	Hardcopy	14
HMTAP TO129	Barbour & Harrison Counties, WV	1996	Damaged structures	Hardcopy	172
HMTAP TO130	West Virginia	1996	Damaged structures	Hardcopy	240
HMTAP TO131	Hampshire County, WV	1996	Damaged structures	Hardcopy	80
HMTAP TO139	Page & Warren Counties, WV	1997	Damaged structures	Hardcopy	17
HMTAP TO142	West Virginia	1997	Damaged structures	Hardcopy	330
HMTAP TO144	Shenandoah & Rockingham Counties, VA	1997	Damaged structures	Hardcopy	10
HMTAP TO373	Horry County, SC	2000	Damaged structures	Hardcopy (see Dewberry's listing for database)	220
TOTAL					**5,634**

Additional information about the URS data sets can be found in APPENDIX E.

A.4 FEMA Regions and State NFIP Coordinators

For this study, Regional engineers and State NFIP Coordinators nationwide were telephoned by Dewberry, URS and G&O to determine the availability of ECs at the regions and states. Without exception, the regions and state NFIP coordinators indicated that individual community NFIP coordinators would need to be queried to determine what was available at community level, because the regions and state coordinators do not maintain ECs. It was beyond the scope of this study to contact all individual community NFIP coordinators, but some state coordinators provided information about communities known to have large numbers of ECs. A few of these communities were contacted as noted below.

A.5 Local Communities

Several local communities believed to have large holdings of ECs were contacted regarding available data. Some of them have ECs online for public outreach; to avoid duplication of effort, FEMA's elevation registry should (as a minimum) provide a link to such sites.

Several communities with larger numbers of electronic ECs are noted below. Additionally, a few local communities provided other GIS data or support that enabled Dewberry to make use of the ECs for use in evaluating Strategies B through D. These are also noted below.

Monterey County, CA. Monterey County maintains a database containing the information from Sections A-F of the new (2000) EC form. The database is sent to FEMA during every verification cycle for the Community Rating System (contained on CD). The builder collects most of the data; however, some data are verified by the County. Currently the database contains 383 records. This is consistent with ISO's EC database records for this community (374). The community is also receiving full CRS credit for maintaining ECs in a computer format.

Sacramento County, CA. Sacramento County maintains a database that contains all the EC data for structures built in the floodplain within the last few years. The database is directly linked to an EC template that can be printed. Approximately 90% of the data was collected by county surveyors specifically for this purpose. Additional data is kept for local flooding regulatory elevations such as high-water marks, etc. Currently the database contains approximately 200 records out of approximately 3000 structures. ISO reports that this community is not receiving full credit for maintaining ECs in a computer format and reports 0 database records for this community.

Santa Barbara County, CA. Santa Barbara County keeps hardcopies of ECs filed by parcel. In addition, the County maintains an internally developed Access database that duplicates all of the EC information. All structures (pre- and post-FIRM) are kept in the database, which numbers approximately 1000 entries. It is required that all elevation data be obtained by a licensed land surveyor, and are tied into USGS benchmarks. ISO reports that this community is not receiving any CRS credit for maintaining ECs in a computer format and reports 0 database records for this community.

Maricopa County, AZ. Maricopa County currently maintains a database of all EC data. This database is linked to their geographic information system (GIS) using ArcView. A database query can be used to complete and printout ECs for any parcel. They are in the process of linking this information to their internet site so that it will be available to the public. All of their ECs are in the database. The number of structures currently numbers 662. ISO reports 932 database records for this community. The community is also receiving full CRS credit for maintaining ECs in a computer format.

Simi Valley, CA. The City of Simi Valley maintains EC data for all residential structures in the form of a database that contains all of the same information. Elevation data for larger structures (commercial, industrial, etc.) are kept on file in hardcopy form. ISO reports that this community is receiving full CRS credit for maintaining ECs in a computer format and reports 13 database records for this community.

Charlotte and Mecklenburg County, NC. The Charlotte-Mecklenburg (NC) Storm Water Services provided over 3,000 ECs used by Dewberry for evaluation of low-resolution LIDAR data produced of Mecklenburg County as part of the North Carolina Floodplain Mapping Program. A GIS database with building footprints, plus the raw LIDAR dataset, was also provided by the community. Note that Dewberry also lists 2,197 EC records for this community; the remaining ECs were surveyed by other firms. This is one of those communities that maintain ECs online for public information and outreach.

Prince George's County, MD. Prince George's County, MD provided ECs used by Dewberry for evaluation of mid-resolution LIDAR data and oblique Pictometry images. Note that Dewberry also lists 136 EC records for this community.

Beaufort County, SC. Beaufort County, SC provided GIS data used by Dewberry for evaluation of high-resolution LIDAR data also provided by the county.

Jefferson County, CO. The Jefferson County Planning and Zoning Department provided Dewberry with 25 ECs as well as accurate geographic coordinates for each structure.

Pinellas County, FL. The GIS Coordinator for Pinellas County, FL provided a GIS file (Pinellas_co_parcels_roads.dxf) used by Dewberry to georeference ECs.

A.6 U.S. Army Corps of Engineers (USACE)

The Philadelphia District of USACE used contractors to survey thousands of floodprone houses for the Susquehanna River Flood Warning and Response System (FWRS) in Pennsylvania. They used a quasi-photogrammetric method whereby photogrammetric spot heights were established of the terrain surrounding the corners of each house visible in stereo, and then surveyors were hired to measure the vertical offset up or down from these spot heights in order to determine the top of bottom floor elevation, top of next higher floor elevation, and lowest adjacent grade elevation of each house. The specifications for photogrammetric spot heights called for vertical accuracy of 0.5 ft (6 inches) at the 90% confidence level, with spot height accuracies equivalent to 2' contours. They have approximately 1,200 structures with street addresses and elevation data, plus an additional 1,400 structures with elevation data and only partial or incomplete addresses.

A. 7 Policies in Force Database

FEMA's Policies in Force database contains some 3 million records, 80,000 of which have elevation data. The Policy database includes the following information as shown in the example from CSC's BureauNet (sometimes called FIANet) in Table 6 below. Note that latitude and longitude are not available for many records.

Table 6 — Example File from Policies in Force Database

Company No: 23779	Pol Nbr: 5400518089	Pol Status: Expired more than 94 days	
Pol Eff Dt: 08/12/2001	Pol Exp Dt: 08/12/2002	Org Nb Dt : 08/12/2000	
End Eff Dt: 08/12/2001	Org Con Dt: 01/01/1996	As of Date: 01/31/2003	
Community : 370246	CRS Class : 0	Probation : 0	
First Name: RICHARD			
Last Name : EDDINS			
Address 1 :			
Address 2 : 204 DULCIMER LN			
City : ZEBULON	State: NC	Zip Code : 27597 2876	
Addr Key : NC2145LN2043425			
			WYO Rate Data
Program : Regular	Rate Meth : Manual	Rollover : New Policy	Exp Const : 0
Condo Ind : Non-Condo	Condo Unit: 1	Prem Pay I:	Bldg Basic:
Occupancy : Single Family	Building : One Floor	Bsmt/Encl : None	Bldg Addtl:
Post Firm : Y	Flood Zone: AE	Loc Cont :	Cont Basic:
Crse Const: N	State Own : N	Dis Assist: 0	Cont Addtl:
Pol Term : 1	Small Bus : N	Ins To Val:	ICC Prem : 0
			Comm Prob : 0

Premium : 209	Pol Fee : 30	NFIP Expc : 50	Deduct Pct:
Bldg Covg : 900	Cont Covg : 50	Rep ICCCov: 200	
NFIP ICC $: 6	Bldg Deduc: 500	Cont Deduc: 500	
Base Flood: 232.5	Low Floor : 244.4	Elev Diff : 12	
Diagram # : 8	Low Adj Gr: 235.3	Fld Proof : N	
Obstruct : 10	Elev Cert : 3	Post V Crt: N	
Longitude : .000000	Latitude : .000000		
GEO Result: N	GEO Census:		

A.8 Limitations of Existing Elevation Certificates

As noted above, ISO provided Dewberry with a spreadsheet of EC data for CRS communities within four counties: Pinellas County, FL; Beaufort County, SC; Jefferson County, CO; and Harris County, TX. In working with these data and through evaluation of other available ECs, several limitations have been identified. These are issues that will make the creation of a consistent, up to date, and accurate elevation registry challenging.

Data are not centralized. Most ECs are maintained at the local level. This means that obtaining the information that would be needed for an elevation registry will require significant effort to identify and obtain. Additionally, most communities that maintain their ECs in a hard copy format reported that substantial effort would be required to collect and submit ECs.

Most ECs are not digital. Most communities do not maintain their ECs in an electronic format. Those databases that do exist tend to contain only newer structures and/or newer LOMAs and LOMR-Fs. The older records that are stored on paper in scattered locations may be much more difficult and potentially cost-prohibitive to retrieve. A 1995 study by ISO on the retrieval and conversion of ECs to a database format resulted in over 30,000 records that were provided to FEMA and to the CRS communities that originally supplied the information. At the time, significant difficulties were encountered in creating a database from information documented on seven different FEMA EC forms and provided in hardcopy format of varying quality, completeness, and legibility. These issues would still exist with ECs not currently in a digital format.

Many EC database records are missing information or appear to contain questionable information. Related to the issue of older EC forms noted above is the fact that certain pertinent pieces of information for an elevation registry may not have been included in older forms. Highest Adjacent Grade (HAG) is an example of an item currently required but not included on older EC forms.

Many of the ECs that were retrieved for use in evaluating Strategies B and C lacked relevant elevation data.

Pinellas County, Florida (1,524 records)
Of the 1,524 Pinellas County records, 1,361 (89.3%) had lowest floor elevations in A-zones, 27 (1.8%) had lowest floor elevations in V-zones, 136 (8.9%) had no lowest floor elevations, and 581 (38.1%) had no LAG information. Of the 1,524 records, 1,306 had elevations less than 25 feet (most were between 5 and 15 feet); but 55 had elevations over 100 feet, with two over 500 feet and one over 800 feet. Thus, 55 (4.2%) of the 1,306 elevations were probably in error, especially since there were no elevations between 25 feet and 100 feet. Of these 55 erroneous elevations, 17 listed NGVD as the vertical datum, whereas

the remaining 38 had the datum field blank in the database. Thus, of the 1,524 records in Pinellas County, 191 records (12.5%) either had no lowest floor elevation data or the elevations were grossly in error, and 581 (38.1%) had no LAG elevations.

There were about 400 records that were duplicates for fewer than 200 homes, normally resurveyed on different dates, with different elevations. In one interesting example (see Table 7), the lowest floor elevations for the same house vary between 1.4 and 11 feet, LAG elevations vary between 6.5 and 10.4 feet, and BFEs vary between 10 and 12 feet. The lowest floor elevation change from 11 feet to 1.4 feet may also be caused by illegal construction below an elevated structure.

Table 7 — Same House with Four Different Elevation Certificates

House Number	Street Prefix	Street Name	Street Suffix	EC Date	Zone	BFE	LAG	Lowest Floor A-zone	Lowest Floor V-zone
4200	S	54th	Ave	7/11/91	A12	10	blank	10	blank
4200	S	54th	Ave	2/19/92	A12	11	10.4	11	blank
4200	S	54th	Ave	11/25/92	A12	10	6.5	blank	blank
4200	S	54th	Ave	3/05/93	V15	12	blank	blank	1.4

Based on prior experience, it is common to survey LAG and lowest floor elevations that differ by a foot or more when surveyors base their surveys on different elevation reference marks (ERMs) that are unstable, inaccurate, and not accurately surveyed with GPS relative to the National Spatial Reference System (NSRS) maintained by the National Geodetic Survey (NGS). Furthermore, as demonstrated in the above example, elevations are sometimes in error by 8-9 feet because of confusion by surveyors as to which floor is the lowest, a reason why changes were made to FEMA's new EC Form 81-31 in 2000.

Beaufort County, South Carolina (448 records)
Of the 448 records of Beaufort County, 122 (27.2%) had no lowest floor elevation, and 126 (28.1%) had no LAG elevation. Only 46 of 448 (10.3%) of the records had street addresses and lowest floor elevations for the same records. Others had street names that duplicated other records, but no house numbers to distinguish one building from the other; but they did have lot numbers.

Jefferson County, Colorado (10 records)
Of the ten records of Jefferson County, only three (30%) had lowest floor elevations, and none had LAGs.

Harris County, Texas (22 records).
Of the 22 Harris County records, 13 had LAG elevations and 21 had lowest floor elevations, but one of these elevations was (erroneously) 5,429 ft, whereas all other elevations in the county's dataset were less than 25 feet.

ISO, the source of the EC database information cited above, noted that "gaps" in the data exist and "vary greatly by community because in most cases the community is not only the source of the data but also the checker of data quality." ISO also provided additional rationale:

- “Communities transfer the EC information from hard copy to a data set, not ISO. If information is missing it is because the community failed to enter it.
- "ISO only randomly quality checks hard copy ECs. We do not compare the hardcopy and the data sets, as this is the communities’ responsibility.
- "No EC information is typically found for properties in the un-numbered A zones or AO zones, C or X zones because the FIRMs do not show elevation data. Gaps in EC data can subsequently result.
- "EC data quality also varies greatly by state."

No latitude/longitude. As expected, none of the street addresses found in the ISO database were georeferenced, i.e., none had latitude/longitude, UTM coordinates or State Plane northings/eastings. This means that an alternative means for determining geospatial coordinates would need to be identified so that the EC data could be used and maintained in an elevation registry. See section A.8 below for a further discussion of geocoding options.

Non-standard addresses. Of the 1,524 Pinellas County EC records, 371 (24.3%) had no street addresses; most of these had some form of lot number, but some listed only a name, e.g., "Tooke, O.J. UNREC" in the address column. Most of the 1,153 addressed records did have different columns for the property's house number, house suffix, street prefix, street name, street suffix, and apartment number, but many of the records had the street suffix merged with the street name.

Pinellas County’s database was designed in a way that made it very difficult to link the county's street addresses with those from the ECs. The Pinellas County database had all address information merged in a single column, and many of the addresses were very complex and not suited for "normal" address matching.

After reviewing the EC data from these four counties, Dewberry concluded that quality control review changes would be needed in the way community data are entered into a database such as that developed for the CRS program before it could be reliably used to populate an elevation registry.

A.9 Tools for Georeferencing existing Elevation Certificates

Latitude and longitude are required to georeference/geocode a structure in a GIS, but such geographic coordinates are an optional entry on FEMA Form 81-31, July, 2000. As a result, a very small percentage of ECs include this optional entry, except when Global Positioning System (GPS) procedures are used for the survey. Even when GPS procedures are used for the surveys, the latitude and longitude are not always provided since the entry is optional.

Without geographic coordinates, or comparable UTM or State Plane coordinates, street addresses alone are not adequate to accurately determine the location of a structure in a GIS. For this study, without accurate geocoding, existing ECs could not be used as "ground truth" to validate the accuracy of the alternative elevation strategies discussed below. For a potential elevation registry, the lack of accurate geocoding would impact the accuracy of revisions to the elevation registry when new DFIRMs or other changes would normally dictate the need for maintenance and updating of registry records.

GPS Surveys. The most accurate and direct way to establish latitude/longitude for an EC is to use GPS procedures which automatically yield geographic coordinates of all points surveyed. When using differential GPS procedures with survey-grade receivers, GPS is capable of producing centimeter-level accuracy; however, when using a single mapping-grade receiver, GPS produces positions with error on the order of 10 meters horizontally and 20 meters vertically. In surveying buildings, GPS antennas cannot be placed immediately adjacent to a building because the building itself would block many of the GPS satellite signals, and visible satellites would suffer from multipath errors -- causing errors in x/y/z coordinates so surveyed. For these reasons, differential GPS procedures are used to survey temporary benchmarks in front of each building to be surveyed (often PK nails driven into the street pavement), followed by conventional surveys from the PK nails to the survey reference points being surveyed on or near the building, e.g., bottom of front door, top of foundation, LAG or HAG point. Such high-accuracy GPS/conventional survey procedures were used for the ECs used as "ground truth" in Charlotte-Mecklenburg County, NC and Prince George's County, MD. For these two counties, each street address was directly linked to the surveyed latitude/longitude of the front door of each building.

Digital Orthophotos. An accurate but indirect way to establish latitude/longitude for an EC is to utilize digital orthophotos, combined with some other means for identifying which rooftop image on the orthophoto goes with each street address. In Harris County, TX, georeferencing of existing ECs was performed by the Harris County Flood Control District (HCFCD) which had a GIS database that linked street addresses to a vector polygon bounding each parcel/lot to which a street address is referenced. For each street address for which an EC was provided in Houston, Mike Walters (713-684-4173) at HCFCD established the parcel/lot polygon from the HCFCD's GIS database; overlaid each parcel/lot polygon on top of the city's digital orthophotos, manually selected the rooftop within that parcel/lot, and then selected the latitude/longitude of the rooftop centroid. When performed correctly, this is a perfectly acceptable way to geocode the centroid of a building from its street address.

As demonstrated in a Dewberry study for FEMA Region 5 in 1998 and this current study, documented below, it is relatively easy to determine the latitude and longitude of buildings from various forms of digital orthophotos commonly used and available nationwide, but it is very difficult to identify the correct street addresses for those buildings from commonly-used geocoding software programs.

GIS Polygons. A slightly less accurate way to georeference an EC, based on its street address, is to utilize tax parcel polygons from the community's GIS, but without refinement by digital orthophotos. The tax assessor and city planner are among the officials who typically utilize such a GIS that digitizes the parcel/lot perimeter boundary lines, as with the HCFCD database above. Such polygons are typically digitized by using Computer Aided Design and Drafting (CADD) coordinate geometry (COGO) procedures to enter the boundary survey information (line distances and angles) for each boundary line segment bounding a tax lot or parcel. However, rather than overlaying the parcel/lot polygon over a digital orthophoto to manually select the location of the building centroid, the GIS itself is used to automatically place a centroid at the center of the lot or some alternative means to estimate the location of the main building on the lot. Resulting geocoding errors are insignificant on small lots, but could be significant on large lots.

Several states, notably Maryland (http://www.op.state.md.us/data/mdview.htm) and New York (http://www.nysgis.state.ny.us/inventories/orps.htm) provide statewide parcel data to the public (for a fee), as do numerous local and county entities. However, if New York is representative, some entities may begin restricting access to this type of information due to increased security concerns.

Commercial Geocoding Services. A number of commercial companies offer georeferencing software and/or services to perform either or both of the following: (a) geocoding -- providing latitude/longitude values for a known list of street addresses, but excluding P.O. box addresses or rural route addresses, and (b) reverse geocoding -- providing street addresses for a known list of geographic coordinates. For establishment of an elevation registry, FEMA has need for both geocoding and reverse geocoding. As discussed above, the geocoding of ECs with known street addresses would be required for records derived from existing ECs. However, an elevation registry could also be populated by any of the aerial remote sensing techniques described in this study, for which geographic coordinates (latitude/longitude) are known but street addresses are unknown when surveyed from the air; this would require reverse geocoding.

Commercial geocoding solutions typically rely on street centerlines with address ranges or zip-code points that serve known address ranges. Linear interpolation of the target address between the low and high address ranges is used to identify *where along the block* and *on which side of the block* (odd or even) the address falls. If the address ranges of the street centerlines are larger than the real addresses, as is most often the case, a “clustering” effect can happen, with all of the addresses landing at the “low” address end of the block. Standard offsets or setbacks of the house from the street are usually included and can sometimes be varied. If an address cannot be found, a default location at a zip-code centroid is sometimes returned.

Accuracy of geocoding relies on the spatial accuracy and currency of the street centerlines and the accuracy and completeness of the street names and address ranges used. Rural route addresses, post office boxes, and lot and block numbers are addressing systems that do not lend themselves to geocoding.

Four leading commercial georeferencing services were evaluated by Dewberry to test the geocoding of a small sample set of 53 ECs in the City of Houston, TX. One of these four services readily admitted that procedures were approximate and could not distinguish between neighboring houses or houses across the street from each other. Table 8 summarizes some of the differences between the other three geocoding services for the same addresses; the names of these services will remain anonymous as results may vary widely in different communities, and none was clearly superior to the others. The complete results are at APPENDIX F with geocoded coordinates compared with "ground truth" coordinates provided by Harris County derived from parcels and rooftops identified on digital orthophotos (described above). All of the geocoding services delivered approximate positions, but yielded positioning errors of several hundred feet. Thus, none of the commercial services evaluated can be relied upon to distinguish between neighboring houses or houses across the street. Still, as with the LOMA 2000 database, such crude geopositioning is better than no geopositioning.

Table 8 — Comparison of Geocoding Services

Geocoding Service	**A**	**B**	**C**
Address matching	50 of 53	52 of 53	53 of 53
ΔN average (Northing)	129.80 ft	152.97 ft	178.79 ft
ΔE average (Easting)	362.97 ft	206.37 ft	212.68 ft
ΔN maximum (Northing)	1055.66 ft	1127.10 ft	894.98 ft
ΔE maximum (Easting)	7684.08 ft	1469.53 ft	767.13 ft
ΔN 95th percentile	360.13 ft	509.85 ft	428.63 ft
ΔE 95th percentile	449.52 ft	600.65 ft	533.35 ft
Horizontal errors at the 95% confidence level *	**575.99 ft**	**787.86 ft**	**684.24 ft**

* Because of systematic formulas that interpolate street addresses, there is no reason to assume that geocoding errors follow a normal distribution, therefore, the 95th percentile method is warranted and the

horizontal (radial) error at the 95% confidence level is assumed to equal the square root of [(ΔN 95th percentile)^2 + (ΔE 95th percentile)^2].

A.10 Conversion of paper Elevation Certificates to digital format

As noted previously, most communities do not maintain their ECs in an electronic format. These records tend to be stored in scattered locations and may be cost-prohibitive to retrieve. A 1995 study by ISO on the retrieval and conversion of ECs to a database format resulted in over 30,000 records that were provided to FEMA and to the CRS communities that originally supplied the information. At the time, significant difficulties were encountered in creating a database from information documented on more than 7 different FEMA EC forms and provided in hardcopy format of varying quality, completeness, and legibility. Scanning and Optical Character Recognition (OCR) software was tested by ISO on the conversion project and abandoned due to the poor quality of the scans.

Dewberry contacted S.A.I.D. Inc. regarding the feasibility and cost of scanning paper ECs and digitizing the pertinent data into a database. S.A.I.D. Inc. was contacted because they provide similar scanning services for FEMA's Engineering Study Data Packages and have provided data entry for other services. S.A.I.D. estimated $5 per EC for double-entry digitization (whereby two different personnel enter the data which is then compared for quality control purposes to detect differences/errors) and 300 dpi PDF files for each EC form. The assumptions used for this cost estimate are as follows:

- The ECs would be 2-sided forms or 2 pages.
- There would be a minimum of 50,000 ECs to be digitized.
- Within those 50,000 EC forms, there will be up to 7 types of EC forms. These forms will have varying amounts of data, similar in nature to the current FEMA Form 81-31.
- Up to 50% of the EC forms may be handwritten.
- The output will be a PDF multi-page image (2 pages) and an ASCII data file, including the image file name, to satisfy the format of the data dictionary for the elevation registry.
- The size of the 300 dpi PDF file for each EC form would be approximately 138 Kb.

Strategy B — Maximize use of Airborne Remote Sensing

B.1 Photogrammetry

<u>Conventional (Vertical) Photogrammetry</u>. Photogrammetry is that branch of surveying that deduces the physical three-dimensional measurements of objects from measurements on stereo photographs that photograph an area from two or more different perspectives. The 3rd dimension (elevation) is normally mapped as contours of equal elevation, or as spot heights for which the z-value (elevation) of each point is carefully measured. Spot heights are normally mapped at tops of mountains, bottoms of depressions, centers of road intersections, tops of dams or dikes, or other locations where there is a need for an accurate elevation value; but spot heights can also be mapped at LAG or HAG points (if these points are visible on both of the stereo photographs) or at the four corners of a building, for example.

Normally, vertical stereo photography is flown of entire communities with numerous adjacent/parallel flight lines. The area imaged with each photograph overlaps the adjoining photo (before and after) in the same flight line by about 60% and has 10-20% sidelap with photos from adjoining flight lines. With 60% forward overlap, all of the terrain area can be seen on at least two successive photos, and up to 30% of the terrain area can be seen on three successive photos.

The camera's focal length and the aircraft's flying height dictate the accuracy of elevation data surveyed photogrammetrically. When elevation data are acquired, mapping cameras with a standard 6" focal length are normally used, and flying heights are varied to satisfy requirements for a specified contour interval to be mapped. Subsequently, when mapped to National Map Accuracy Standards, spot heights measured from this stereo photography will have 90% of the elevations accurate to one-fourth of the contour interval or less, with no spot height elevation errors larger than one-half the contour interval. For example, to produce a map with 2 ft contours, it is common to acquire the aerial photography from an altitude of 4,000 ft above the mean elevation of the terrain being mapped; then, at least 90% of the spot height elevations should be accurate to 0.5 ft, and the remaining 10% of the spot height elevations should be accurate to 1.0 ft. Whereas the National Map Accuracy Standard expresses accuracies at the 90% confidence level, the new National Standard for Spatial Data Accuracy requires accuracies to be expressed at the 95% confidence level, as used throughout this report. The three-dimensional (3-D) coordinates (latitude, longitude, and elevation) of any point can be surveyed photogrammetrically if the point can be seen on two or more stereo photos. Some ground points cannot be seen in stereo when tall trees or buildings block the view to the ground from one or more perspectives.

For the purpose of this study, vertical aerial photography (aimed straight down) can accurately survey rooftops and many points on the ground including LAGs and HAGs, but basement windows cannot normally be seen in stereo because one photo might see a basement window, but the second photo will look straight down on the house, and the third photo will see the opposite side of the house -- thus no stereo images of the same basement window feature.

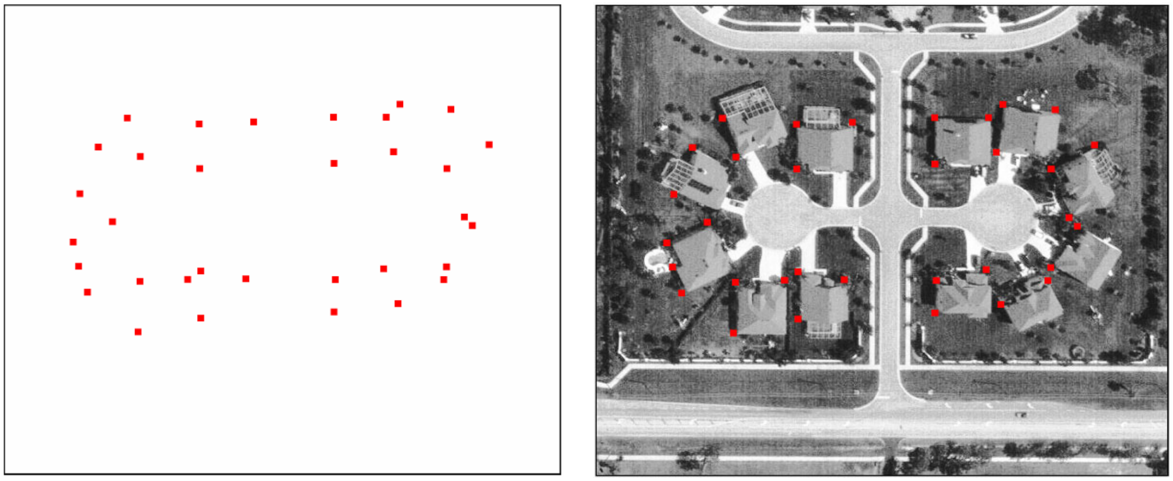
Conventional Photogrammetry with Measured Offsets.

As described at www.nap.usace.army.mil/GIS/fwrs.htm, the Philadelphia District of the U.S. Army Corps of Engineers (USACE) executed the structure inventory portion of the Susquehanna River Flood Warning and Response System (FWRS) in 2000. A part of the FWRS involved the Corps using a multi-technology method to survey the top of bottom floor elevations of thousands of floodprone houses along the Susquehanna River in Pennsylvania. The District hired a photogrammetric firm (BAE/ADR) to establish photogrammetric spot heights on the ground adjacent to the corners of each house (as many corners as could be seen in stereo). The Corps also hired a survey firm to measure the offset distances up/down from one of the surveyed spot heights (per structure) to indirectly compute the top of bottom floor elevation and other elevations relative to the spot heights. The specifications for the photogrammetry were that the spot heights should satisfy National Map Accuracy Standard for 2 ft photogrammetric contours.

Figure 2 (left) illustrates how spot heights (shown here as red dots) might initially appear when photogrammetric x/y/z coordinates are provided as spot heights. At this point, there is no basis for reference. Normally only two or three spot heights can be established on the ground adjacent to the corners of any building because, from one or two directions, the building itself blocks the view of one of the photographs needed to make stereo measurements on the ground. With only georeferenced points, it is difficult for the land surveyor to determine which house, and which corner of which house those coordinates (dots) pertain to. Figure 2 (right) illustrates how those same spot heights might be plotted on top of a digital orthophoto or other base map so that the surveyor can determine the spot height, for each building, most appropriate for use for measurement of vertical offsets.

Not all surveyors have GIS tools for overlaying such "dots" on top of orthophotos or other base maps. Similarly, for home owners, they too would not be able to easily determine which "dots" pertained to their house. However, most communities have GIS specialists who could easily perform such tasks on a community-wide basis. Furthermore, home owners may actually be able to recognize the pattern of dots relative to streets and homes in the area.

Figure 2 — Photogrammetric Spot Heights



To verify the accuracy of this method, Dewberry hired a survey firm to use GPS and conventional survey procedures to directly survey the top of bottom floor elevations of 40 of the same houses previously mapped by the Corps of Engineers. The comparisons of the expedient photogrammetric method vs. ground survey method are at APPENDIX G for the 40 houses selected at random. Assuming the GPS surveys were correct with all errors attributed to the photogrammetric surveys and/or offset measurements, the vertical accuracy of the top of bottom floor elevations by this method was 1.19 ft at the 95% confidence level. This exactly satisfied the mapping standard for 2 ft contour interval accuracy and proves that this is a viable method for obtaining accurate structural elevation data. A total of 31 of the 40 top of bottom floor elevations (77.5%) were accurate within 0.5 ft.

<u>Oblique Photogrammetry - Pictometry</u>.

Because Pictometry's oblique imagery will be new to most readers of this report, the company-provided information is included at APPENDIX H to explain the products and how they are acquired and used.

Figure 3 shows a sample Pictometry oblique image, photographed from an elevation of approximately 2,000 feet above the mean terrain.

Figure 4 provides samples of Pictometry imagery, zoomed-in from four different perspectives. When features are not in the shadows, the oblique views enable the GIS analyst to see and measure the bottom of doors, tops of foundations, presence of walk-out basements, or basement windows, for example. In fact, this is the only airborne remote sensing technology that is able to "see" such features needed to determine the elevation of the lowest floor. All other airborne remote sensing technologies are able to survey the rooftop and the LAG and HAG, for example, but only estimates or infers the lowest floor or top of bottom floor elevation. However, as can be seen from the four views at Figure 4, because of shadows and shrubbery, it is nearly impossible on this particular residence to see basement windows or flood vents from any of the four views.

Dewberry learned during this study that Pictometry's elevations are actually *relative* rather than *absolute*. For example, Pictometry can accurately measure the distance up from the ground (e.g., LAG point) to the top of foundation, and then subtract 8 feet to compute the top of bottom floor elevation of the basement, but if it doesn't know the absolute elevation of the ground, then the absolute elevation of the lowest floor will also be in error by the error in the ground elevation. The next three subsections describe Pictometry projects with different techniques for obtaining digital elevation data from which relative height differences were determined and tested by Dewberry.

2-View Pictometry with USGS DEM.

Pictometry had flown over 100 counties/communities by this method, but none where Dewberry had georeferenced ECs to serve as ground truth. However, Pictometry had flown over Prince George's County, MD, while flying Montgomery County, MD, Washington D.C., and Arlington County, VA and had acquired imagery of Prince George's County from two directions instead of four. Pictometry provided measurements of 29 buildings, using 2-view images, where Dewberry had georeferenced ECs to serve as ground truth. Of these 29, three houses could not be accurately surveyed for various reasons and their top of bottom floor elevations were left blank; they were obscured by trees or neighboring buildings on the two sides of the houses where photos were available and they did not have photos of the front and rear of these houses. Several other houses were measured with questionable accuracy because the analyst could not clearly see whether or not these houses had basement windows. Furthermore, Pictometry used USGS DEMs to determine the elevation of the ground, from which offset measurements were made to determine top of bottom floor elevations. See APPENDIX I. Of the houses measured, the average absolute error in the top of bottom floor elevation was 2.61 ft; the error at the 95% confidence level was 6.34 ft; and the largest error was -10.75 ft, caused by identifying a basement where none actually existed. While unimpressive in and of itself, Dewberry still considered this potentially encouraging for three reasons: (1) the 2.61 ft average elevation error was strongly influenced by several houses where the wrong assessment had been made regarding the presence or absence of basement windows, and the Pictometry analyst can annotate the database with a confidence level indicator, rating houses where he/she is highly confident that the house has a basement or doesn't have a basement, or various degrees of diminished confidence; (2) confidence levels should be increased if the normal 4-view images were available to view each building from all four sides rather than from only two sides as in PG County; and (3) because USGS DEMs (with potentially large elevation errors) had been used as the reference elevation for each building.

Figure 3 — Sample Pictometry Oblique Photo

Figure 4 — Sample 4-View Pictometry Images

2-View Pictometry with LIDAR DEM.

Dewberry subsequently provided Pictometry with a LIDAR dataset of Prince George's County, MD, and these same 29 buildings were re-measured. This time, the analyst provided top of bottom floor elevations for all 29 homes. The average (absolute) error in the top of bottom floor elevation was 2.53 ft; the top of bottom floor error at the 95% confidence level was 4.66 ft; and the largest top of bottom floor error was 5.63 ft, again influenced by the same factors (1) and (2) above, but without major errors from factor (3). See APPENDIX I

4-View Pictometry with Spot Heights

Finally, to eliminate factors (1) and (2), Dewberry decided to survey additional houses in Arlington County, VA for comparison with the 4-view Pictometry images previously available. Since LIDAR data was not available for this county, Dewberry provided Pictometry with the surveyed spot height elevations at three corners of 27 houses. This is essentially the most accurate DEM that could be provided, allowing Dewberry to isolate errors from Pictometry's measurement process from errors in the DEM. Each of these houses had dense tree cover on at least two sides.

For these 27 houses, the average error in the top of bottom floor elevation was 1.59 ft; the error at the 95% confidence level was 5.01 ft; and the maximum error was 5.85 ft. See APPENDIX I This time, many houses again had misidentified basements.

Pictometry Accuracy Summary

Table 9 summarizes the accuracies achieved in three different evaluations of Pictometry datasets compared with ECs.

Table 9 — Pictometry Accuracy Comparisons

Pictometry Dataset Evaluated	LAG errors 95% Conf.	Average absolute LAG errors	HAG errors 95% Conf.	Average absolute HAG errors	TBF errors 95% Conf.	Average absolute TBF errors
Prince George's County, MD w/USGS DEM	3.96 ft	1.65 ft	3.61 ft	1.54 ft	6.34 ft	2.61 ft *
Prince George's County, MD w/ LIDAR	3.99 ft	1.62 ft	3.83 ft	1.70 ft	4.66 ft	2.53 ft **
Arlington County, VA, w/surveyed spot heights	N/A	N/A	N/A	N/A	5.01 ft	1.59 ft

* Initially, only 26 of 29 homes were surveyed for top of bottom floor (TBF) elevations; three were not surveyed because existence of basements could not be determined

** Subsequently, all 29 homes were surveyed for top of bottom floor elevations. The same Pictometry images were used. LIDAR results would have been better if the analyst had not guessed on the questionable basements.

Photogrammetry Conclusions

The major photogrammetry conclusions are as follows:

- Conventional vertical photography can survey LAG and HAG elevations as well as spot heights of the terrain at multiple corners of a structure; but this technology cannot directly survey the lowest floor elevations because the bottom of front door or other survey "target points" are not normally visible on aerial photographs looking straight down at rooftops.
- When conventional photogrammetric spot heights are combined with on-site tape measurements from the ground to bottom of front door or top of foundation, for example, then the top of bottom floor elevations could be computed with errors comparable to the elevations interpolated from topographic contours, i.e., 90% of top of bottom floor elevations accurate within ½ the contour interval and the remaining 10% accurate within the

full contour interval. However, errors in measuring the offset distances could also be a factor. For the 40 Susquehanna structures, the vertical error at the 95% confidence level was 1.19 ft, equivalent to 2' contours, and 31 of 40 lowest floor elevations were accurate within 6 inches. However, it must be recognized that discrepancies were not necessarily due to errors in the photogrammetry but partly due to two different surveyors measuring vertical offsets by different methods, or selecting different points on the houses on which to base the lowest floor measurements.

- Oblique aerial photography, from Pictometry for example, cannot directly survey LAG and HAG elevations or spot heights, but can indirectly survey top of bottom floor elevations relative to elevations of surrounding terrain. However, in all three tests performed, there difficulties in detection of basements, causing top of bottom floor elevations to have average errors between 1.59 and 2.61 ft, and top of bottom floor errors at the 95% confidence level between 4.66 ft and 6.34 ft. For these reasons, Dewberry concludes that Pictometry imagery can not be reliably used to determine top of bottom floor elevations but, instead, has its best value for other applications, such as providing a "birds' eye" view of the property so an insurance agent or others can see the house to be insured, and/or to provide a means to check for unauthorized construction. The exception is in some areas where there are no basements, such as in many Florida counties; then Pictometry can provide more information without fear that a wrong assessment is made regarding the presence or absence of basements.

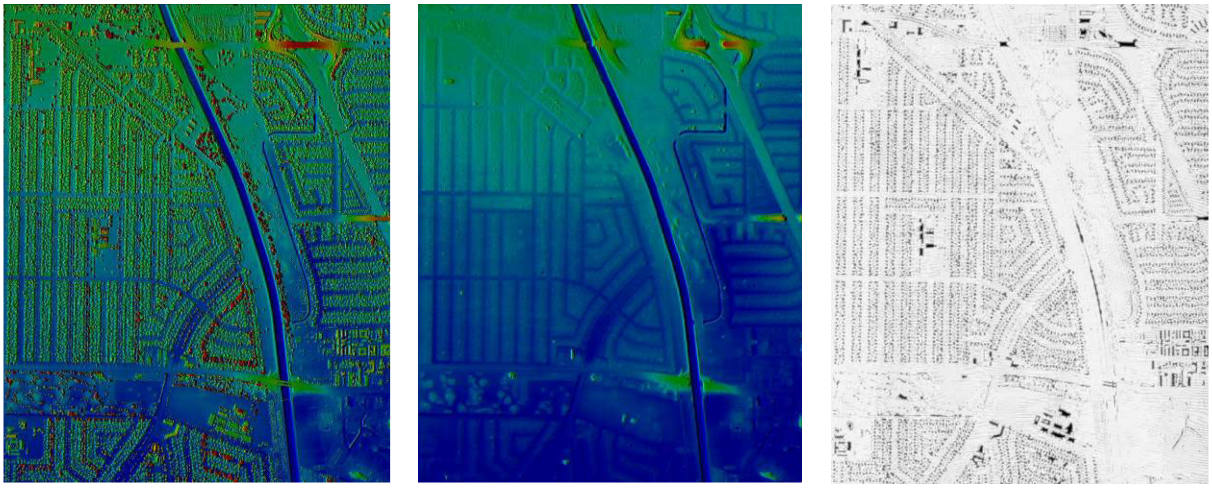
B.2 Light Detection and Ranging (LIDAR)

LIDAR collects thousands of spot heights every second of flight, currently with up to 100,000 laser pulses per second. LIDAR is most commonly flown of entire counties or communities to establish the elevation layer of their GIS. Each LIDAR pulse can receive multiple returns, yielding elevations (actually x/y/z coordinates) of features mapped. The first return for each pulse provides the elevation of the first thing hit by the pulse, to include treetops and rooftops. Some of the light from each laser pulse penetrates through or between the trees and hopefully hits the ground for use in establishing a bare-earth digital terrain model (DTM). With dense vegetation, LIDAR pulses might never penetrate the vegetation to reach the ground. Vegetated features are "soft" where there is a difference between the elevation of the first and last return. Other features, including bare earth, sand, concrete, rock, short grass, and building rooftops are "hard" where the elevations from the first and last returns are the same, i.e., where there is no LIDAR penetration of the feature.

To generate a bare-earth DTM, the LIDAR data is post-processed by computer algorithms to "remove" buildings and vegetation. Figure 5 provides an example of LIDAR processing. The left image shows LIDAR last-return elevations prior to post-processing. The center image shows the bare-earth DTM after post-processing for removal of buildings and vegetation and interpolation to fill in the missing spaces where elevation points were deliberately removed. The right image shows where there is no longer elevation data. There is no data in the black areas either because there were no LIDAR returns in the first place (in water) or because those returns were deliberately deleted during post-processing because they mapped trees, rooftops or other elevated features above the bare-earth DTM that was needed. Note the bridge decks that were deliberately "cut out" for hydro-enforcement of the streams and canal for hydraulic modeling purposes.

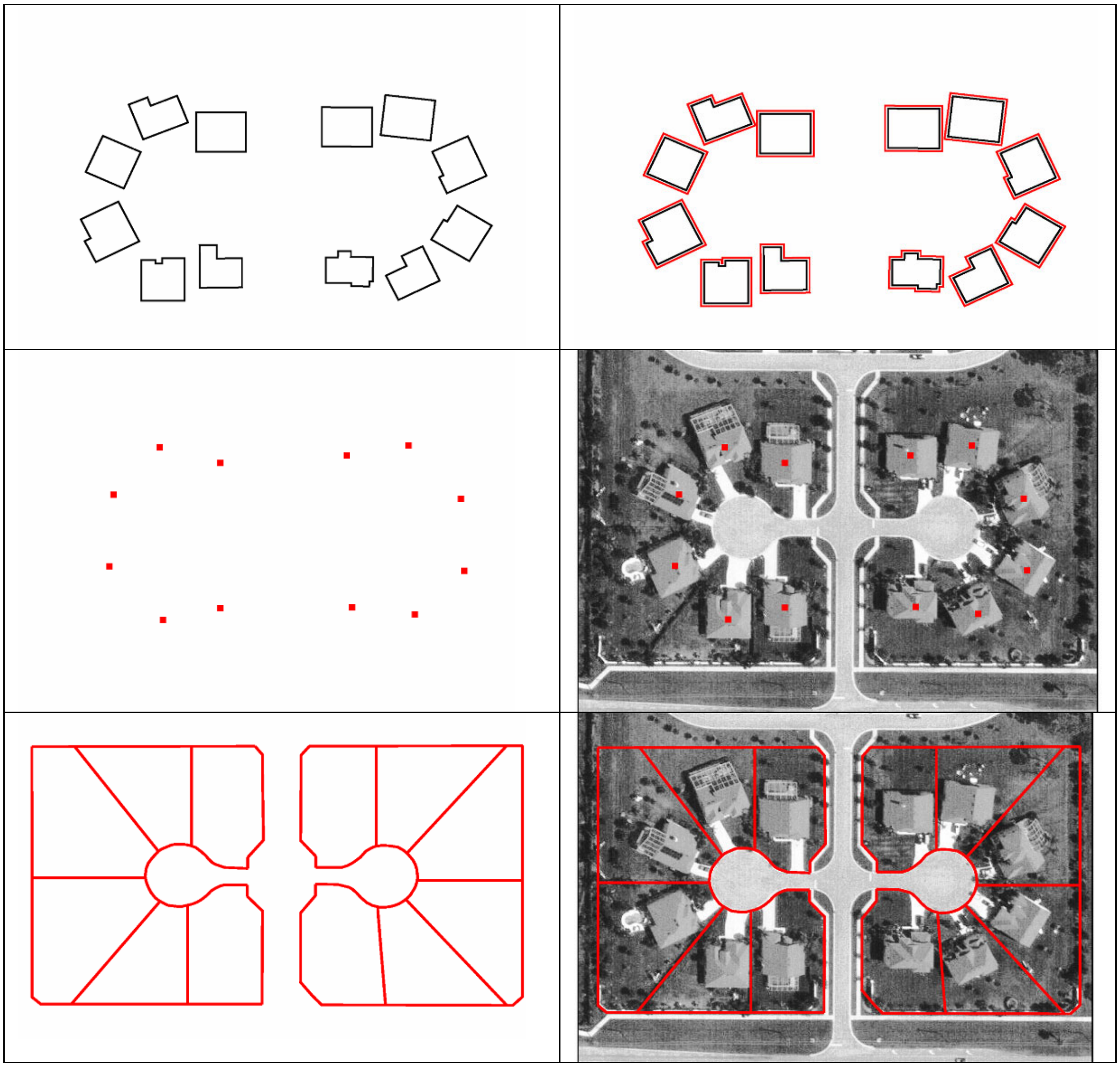
The reverse of the right image would show where LIDAR elevation points remain after removal of trees and buildings. As with the right image, a surveyor or home owner could probably navigate to specific streets just by recognizing the LIDAR dot pattern for the streets and buildings when using the LIDAR's bare-earth point file.

Figure 5 — LIDAR Surfaces Before and After Post-Processing



When LIDAR data is used to automatically determine the LAG and HAG of structures, or to estimate their lowest floor elevations, it is preferred to have a GIS file of structure footprints, as maintained by many communities. Such footprints are most commonly mapped photogrammetrically or with rooflines digitized from digital orthophotos. Figure 6 shows an example of building footprints (top left), and those same footprints with a surrounding buffer (top right), shown in red, that can be automatically generated by a GIS with any buffer width desired. Some community GIS files have these footprints georeferenced so that the street addresses are known for each building. Other community GIS files do not link their footprints to street addresses. For analyses of the various technology sub-options for both LIDAR and IFSAR, the base scenario assumption is that footprints are linked to street addresses; but separate calculations are also performed with the assumption that street addresses are not linked to footprints. With bare-earth DTMs, there is no need for a buffer zone because each footprint can directly "cut" the DTM to establish the LAG and HAG.

Figure 6 — Examples of Building Footprints and Buffer, Centroids, and Parcel Polygons



Some communities do not have footprints, but they do have building centroids linked to street addresses. The center left image at Figure 6 shows examples of such centroid points, and the center right image shows those centroids superimposed on top of digital orthophotos. Still other communities may have neither footprints nor centroids but instead have parcel polygons that are linked to street addresses as shown at the bottom left image at Figure 6 and superimposed on top of digital orthophotos at the bottom right image. The superimposition of footprints, centroids, or parcel polygons on top of digital orthophotos provides graphic orientation but not street addresses. Such addresses must be established in the GIS database. Of all these options, footprints are preferred because they can be overlaid on top of a bare-earth LIDAR TIN to "cookie cut" the LIDAR data to determine the LAG and HAG. In this report, the "with footprint" process will be abbreviated as the "w/FP" method. With either centroids or parcel polygons, there is less certainty in the computation of LAG and HAG elevations from LIDAR data because the location of LAG and HAG points must be estimated; however, when either centroids or parcel polygons are overlaid on top of digital orthophotos, it is a simple GIS task to generate footprints around the perimeters of visible rooftops.

When footprint files are not available, Dewberry uses Computational Consulting Service, Inc. (CCS) which has developed sophisticated algorithms to process the raw LIDAR "point cloud" dataset in order to detect building locations and search for the LAG and HAG. This "no footprint" process will be abbreviated as the "NoFP" method. When LIDAR data is widely spaced (e.g., 4-5 meter post spacing), CCS computer algorithms have a much harder time detecting building locations than when the post spacing is narrower. With 4-5 meter point spacing, it is possible to have only one LIDAR pulse hit a rooftop, making it impossible to determine the shape of the roof for estimating the shapes of the building footprints and their buffers. With wide post spacing, it is even possible that no LIDAR pulse hits a rooftop. One purpose of this research project is to determine how well narrower post spacings perform in helping these computer algorithms to estimate building footprints so that buffers can be accurately established. As described below, CCS processed four different LIDAR datasets and prepared the *LIDAR Automated Data Extraction Report* at APPENDIX J that describes procedures for extraction of buildings from LIDAR data, determination of main parameters of buildings from LIDAR data, and determination of additional parameters of buildings using 3D models created of those buildings.

LIDAR data of Charlotte/Mecklenburg County, NC. Raw LIDAR data of Mecklenburg County was provided by the Charlotte-Mecklenburg Storm Water Services. The LIDAR data was flown by EarthData in 2003 and had nominal post spacing of approximately 16 feet. This is considered to be a low resolution dataset because each house might have only one LIDAR pulse hit an entire rooftop, and some houses might even have no pulse hit an entire rooftop if the width of the house, for example, is less than 5 meters (16 feet).

Building footprint files were also provided by the County for some of the buildings. Dewberry chose a test area that included 2617 buildings with footprints. CCS' "NoFP" processing was performed which automatically identified 2270 of those 2617 buildings for which one-to-one GIS relationships were identified, missing 347 (13.3%) of the buildings; Dewberry considered this a success because of the low resolution dataset that might have no LIDAR pulse, or perhaps only one or two pulses hit many of the rooftops. Some of the one-to-one "misses" were actually cases where there were one-to-many or many-to-one relationships because of rows of townhouses, for example, with different rooftop elevations for different units, but for which multiple units may have only a single footprint.

Dewberry then determined that 217 of these 2160 buildings also had ECs for use as "ground truth" elevations, so these 217 buildings became the basis for comparison of CCS' automated "NoFP" method to be used when there are no footprints, and Dewberry's automated "w/FP" method to be used when there are footprints. Of these 217 ECs, 215 had LAG elevations, and 108 had HAG elevations (HAG elevations were not required on earlier versions of FEMA form 81-31). The spreadsheet that computes the overall statistics for LAG and HAG elevations, comparing CCS' "NoFP" method (without footprints) with Dewberry's "w/FP" method (with footprints) is at APPENDIX K — LIDAR Accuracy Analysis (Mecklenburg County, NC). The results are summarized in Table 10.

Table 10 — Mecklenburg County LIDAR Accuracy Comparison

Mecklenburg County, NC, LAG/HAG from LIDAR with 16 ft nominal post spacing	**"NoFP" LAG**	**"w/FP" LAG**	**"NoFP" HAG**	**"w/FP" HAG**
LIDAR average post spacing	16 ft			
Number of Houses	215		108	
Standard Deviation	1.91 ft	1.13 ft	1.84 ft	1.15 ft
Average (absolute) Error	1.22 ft	0.87 ft	1.11 ft	0.71 ft
Minimum Elevation Error	-9.39 ft	-4.64 ft	-5.75 ft	-5.75 ft
Maximum Elevation Error	9.47 ft	3.63 ft	9.44 ft	4.05 ft
95th Percentile Error	3.79 ft	2.82 ft	3.57 ft	2.09 ft
90th Percentile Error	2.55 ft	1.98 ft	2.28 ft	1.61 ft
85th Percentile Error	1.95 ft	1.43 ft	1.71 ft	1.16 ft

- For CCS' "NoFP" method (no footprints), the average LAG elevation error was 1.22 ft, but the LAG elevation error at the 95% confidence level was 3.79 ft. Similarly, the average HAG elevation error was 1.11 ft, but the HAG elevation error at the 95% confidence level was 3.57 ft. The spreadsheet at APPENDIX K shows some larger outlier errors that indicate potential systematic errors when the two methods both yield poor results.

- For Dewberry's "w/FP" method (with footprints), the average LAG elevation error was 0.87 ft, but the LAG elevation error at the 95% confidence level was 2.82 ft. Similarly, the average HAG elevation error was 0.71 ft, but the HAG elevation error at the 95% confidence level was 2.09 ft.

- For systematic errors, it is possible that the ECs or footprints include errors in horizontal position, that the LAG/HAG elevations on the ECs may include errors, or that Dewberry's attempts to establish one-to-one GIS relationships between ECs, building footprints, and LIDAR data failed for some records — all potentially causing the wrong elevations to be compared.

- It is interesting to note that errors at the 95% confidence level are nearly twice as large as errors at the 85% confidence level.

LIDAR data of Prince George's County, MD. LIDAR data of Prince George's County was acquired by Waggoner Engineering, Inc. in 2000 and had nominal post spacing of approximately 8 feet. This is considered to be a medium resolution dataset because each house should have several LIDAR pulses hit individual rooftops. See APPENDIX K — LIDAR Accuracy Analysis (Prince George's County, MD). The results, summarized at Table 11, are considerably better than Table 10, demonstrating the benefits of narrower post spacing for this purpose. By using 8 ft spacing instead of 16 ft, the LAG elevation errors at the 95% confidence level were reduced from 3.79 ft to 1.68 ft when using CCS' "NoFP" method (no footprints), and they were reduced from 2.82 ft to 2.02 ft when using Dewberry's "w/FP" method (with footprints).

Table 11 — Prince George's County LIDAR Accuracy Comparison

Pr. George's County, MD, LAG/HAG from LIDAR with 8 ft nominal post spacing	**"NoFP" LAG**	**"w/FP" LAG**	**"NoFP" HAG**	**"w/FP" HAG**
LIDAR average post spacing	8 ft	8 ft	8 ft	8 ft
Number of Houses	579	579	579	579
Standard Deviation	0.57 ft	0.61 ft	1.71 ft	0.60 ft
Average (absolute) Error	0.53 ft	0.80 ft	0.77 ft	0.65 ft
Minimum Elevation Error	-5.15 ft	-4.28 ft	-1.76 ft	-3.11 ft
Maximum Elevation Error	1.91 ft	2.51 ft	29.69 ft	4.91 ft
95th Percentile Error	1.68 ft	2.02 ft	2.40 ft	1.82 ft
90th Percentile Error	1.11 ft	1.54 ft	1.34 ft	1.44 ft
85th Percentile Error	0.82 ft	1.19 ft	0.91 ft	0.95 ft

LIDAR data of Harris County, TX. Raw LIDAR data of Harris County was provided by TerraPoint and had nominal post spacing of approximately 5 feet. This is a high resolution dataset that became available for evaluation during the progress of the study. However, this dataset was flown with an older sensor not optimized for foliage penetration, and there were considerable difficulties with the old ECs that lacked geographic coordinates. When the ECs were geocoded, they appeared to be far out of registration with the LIDAR data, causing CCS and Dewberry to be unsure of the validity of comparing the LIDAR data with EC data that appeared to be questionable at best and erroneous at worst. Furthermore, compounding this issue is the fact that Houston suffers from severe subsidence, and there was a distinct possibility that the land subsided significantly between the time when the ECs were surveyed (up to 20 years ago) and recent years when the LIDAR was flown. For these reasons, Dewberry abandoned any attempts to evaluate the Harris County LIDAR dataset. Fortunately, an alternative high resolution LIDAR dataset of Beaufort County, SC was already available.

LIDAR data of Beaufort County, SC. LIDAR data of Beaufort County was provided by the county's GIS coordinator. The LIDAR data was flown by Laser Mapping Specialists, Inc. (LMSI) and had nominal post spacing of approximately 4 feet. This is the highest resolution dataset evaluated in this study; each house should have many LIDAR pulses hit individual rooftops. See APPENDIX K — LIDAR Accuracy Analysis (Beaufort County, SC).

Table 12 — Beaufort County LIDAR Accuracy Comparison

Beaufort County, SC, LAG/HAG/TBF from LIDAR with 4 ft nominal post spacing	**"NoFP" LAG Elevations**	**"w/FP" LAG Elevations**	**"NoFP" HAG Elevations**	**"w/FP" HAG Elevations**	**"NoFP" TBF Elevations**
Average post spacing	4 ft	4 ft	4 ft	4 ft	4 ft
Number of Houses	27	38	27	38	27
Standard Deviation	0.43 ft	0.28 ft	0.39 ft	0.39 ft	0.78 ft
Average (abs) Error	0.42 ft	0.28 ft	0.37 ft	0.95 ft	2.93 ft
Minimum Error	-1.37 ft	-0.65 ft	-0.25 ft	0.23 ft	-0.19 ft
Maximum Error	0.27 ft	-0.55 ft	1.19 ft	1.73 ft	3.63 ft
95th Percentile Error	1.09 ft	0.59 ft	0.97 ft	1.60 ft	3.58 ft
90th Percentile Error	0.91 ft	0.54 ft	0.84 ft	1.50 ft	3.50 ft
85th Percentile Error	0.77 ft	0.51 ft	0.77 ft	1.40 ft	3.44 ft

The results summarized at Table 12 are considerably better than Table 11 for all of the statistics shown in these two tables, again demonstrating the benefits of narrower post spacing. By using 4 ft spacing instead of 8 ft, the LAG elevation errors at the 95% confidence level decrease from 1.68 ft to 1.09 ft when using the "NoFP" method and from 2.02 ft to 0.59 ft when using the "w/FP" method. Similarly, the HAG elevation errors at the 95% confidence level decrease from 2.40 ft to 0.97 ft when using the "NoFP" method, and decrease from 1.82 ft to 1.60 ft when using the "w/FP" method.

CCS's estimation of top of bottom floor elevations, using "NoFP" methodology, yielded errors of 3.58 ft at the 95% confidence level. This was the only dataset that yielded top of bottom floor elevations that could even be considered for the registry, and these results are this good in large part because the test houses in Beaufort County had no basements. If these houses had basements, the "NoFP" top of bottom floor elevation accuracies would probably have been poorer.

Overall, for estimation of LAG elevations, CCS' "NoFP" method yielded errors of approximately 1.09 ft at the 95% confidence level. Similarly, Dewberry's "w/FP" method yielded LAG elevation errors of 0.59 ft at the 95% confidence level. This equals the accuracy expected of data equivalent to 1 ft contours, although most LIDAR datasets are compiled to meet 2 ft contour interval standards. Throughout the remainder of this study, LIDAR data will be evaluated as though equivalent to 2 ft contours — in spite of the fact that this particular LIDAR dataset in Beaufort County is considerably more accurate than 2 ft.

LIDAR Conclusions.

At the 2004 International LIDAR Mapping Forum (ILMF), several presentations pointed out the fact that LIDAR firms in Europe and Japan routinely collect much higher resolution LIDAR data than in North America, with some countries now collecting data at extremely high resolution, i.e., up to 28 points per square meter, whereas in the U.S. there is normally one LIDAR point for several square meters. The reason for this difference is that LIDAR data is most commonly used for engineering design applications in Europe and Japan and is collected with helicopter-based sensors, whereas LIDAR data is most commonly used for mapping applications in North America and is collected with fixed wing aircraft designed for flying longer distances at higher altitudes.

Regardless of the type of aircraft used, LIDAR systems now being sold in the U.S. have extremely high pulse repetition rates, now up to 100,000 pulses per second. This alone will cause high resolution LIDAR datasets to become the norm rather than the exception in North America.

The results achieved in Beaufort County, SC make it reasonable for Dewberry to proceed with this study assuming that LAG and HAG elevations, when footprints are available to "cookie cut" the LIDAR TIN surface, can be derived with accuracies comparable to 2 foot contours, i.e., accurate to 1.20 ft or less at the 95% confidence level. When proceeding on this assumption, LIDAR datasets should have independent confirmation of the overall accuracy of the data.

In all cases, the availability of building footprints makes it possible to obtain the most accurate LAG/HAG elevations from existing LIDAR datasets.

B.3 Interferometric Synthetic Aperture Radar (IFSAR)

For a quick reference to Interferometric Synthetic Aperture Radar (IFSAR), the reader is referred to Intermap's web site at www.intermaptechnologies.com, *Product Handbook*.

IFSAR products have traditionally consisted of ortho-rectified radar images (ORI) and digital surface models (DSMs). An ORI is a grayscale image of the earth's surface that has been corrected to remove geometrical distortions that are a normal part of the imaging process. Although they are similar to black and white aerial photographs, ORIs differ because, instead of being made of visible light, the radar pulses the ground with "flashes" of radio waves which then return from imaged features to the antennas to give distance and intensity measurements. The key feature of ORI imagery is that it provides a means of viewing the earth's surface in a way that accentuates features far more than is possible with aerial photography. The radar looks to the side of the aircraft and casts "shadows" that enable the user to visually perceive the elevation information in the image. See Figure 7 for comparison of ORI imagery with traditional digital orthophotos.

IFSAR DSMs are derived from the return signals received by the two radar antennas on the aircraft. The signals bounce off the first surface they strike, making the DSM a representation of any object large enough to be resolved. This includes buildings, vegetation and roads, as well as natural terrain features. DSMs map the top reflective surfaces, i.e., treetops and rooftops.

IFSAR DSMs can be further processed to produce digital terrain models (DTMs) of the bare-earth terrain with buildings and trees removed. However, Intermap's *Product Handbook*, referenced above, identifies limitations of IFSAR DTMs, especially DTMs in built-up areas:

- Layover and foreshortening which tend to make objects (including buildings) look shorter than they really are.
- Shadowing which causes no returns on the back sides of buildings.
- Signal saturation where too much light is returned and image detail is lost -- most often a problem over urban areas because of the strong return from buildings.
- Multipath, where the radar signals bounce off of buildings and other objects before hitting the ground, making the ground appear lower than it really is. (Note: this affects LIDAR also).
- Edge effects, sometimes called "blooming," near buildings and forests where interpolation between true ground and elevated points creates intermediate elevations in transition zones up to 25 meters away from the elevated edge.
- Slope effects that degrade accuracy. The impact depends on the magnitude of the slope, whether the slope is positive or negative, aspect angle, and where it lies in the radar swath (look angle)

Figure 7 — Comparison of ORI and Orthophoto Images

1-foot resolution color orthophoto of a sample project area

1-meter resolution black-white ortho

2.5-meter resolution black-white ORI

IFSAR data of Jefferson County, CO. Intermap Technologies Inc. provided a sample IFSAR dataset of Jefferson County, CO that included both a DSM file and a DTM file for which buildings and trees were removed. In open areas, the DTM was expected to be approximately equivalent to 10 ft contours. Dewberry compared the DTM file (converted to TIN format) with 21 ECs surveyed in Jefferson County, CO specifically for this evaluation. The quality control survey firm was tasked to select approximately half the houses with trees, and half the houses relatively free of trees, and to provide geographic coordinates of the front doors of each house. For this evaluation, Dewberry drew circles around these geographic coordinates with radii of both 20 ft and 30 ft and then "cut" the TIN surface to determine the LAG and HAG values around these circles. The spreadsheet at APPENDIX L is summarized in Table 13. The LAG and HAG errors were consistent for either the 20' radius or 30' radius. Of the 21 houses, LAG/HAG errors were between 0' and 5' for nine houses, between 5' and 10' for five houses, between 10' and 15' for five houses, between 15' and 20' for one house, and approximately 25' for one house. The spreadsheet at APPENDIX L indicates whether each house had trees, some trees, or no trees. This data would indicate that the LAG/HAG elevations in this dataset are unsuitable for *e*Rating purposes. Any or all of the possible causes bulletized on the prior page could have contributed to these errors.

Table 13 — Jefferson County IFSAR Accuracy Comparison

Comparison with EC surveys in Denver area	**Within 20' Radius**		**Within 30' Radius**	
	LAG	**HAG**	**LAG**	**HAG**
Number of Houses	21	21	21	21
Standard Deviation (ft)	6.99	8.10	7.00	8.16
Average ± Error (ft)	+7.22	+6.70	+6.73	+7.17
Average (absolute) Error (ft)	8.15	8.44	7.81	8.85
Minimum Elevation Error (ft)	-7.63	-8.65	-7.76	-8.51
Maximum Elevation Error (ft)	+24.10	+26.56	+23.37	+27.31
95th Percentile Error (ft)	15.11	16.84	14.98	17.27
90th Percentile Error (ft)	15.08	15.79	14.45	16.38
85th Percentile Error (ft)	14.15	13.10	13.56	13.30

IFSAR Conclusions. After the above research was completed, Dewberry was informed that FEMA considered LAG and HAG elevations with errors equal to or larger than 4' at the 95% confidence level to have no value for populating an elevation registry. This negated the need for additional IFSAR research for this study. IFSAR elevations could still have value for a FEMA database used for other natural disasters, e.g., wildfire modeling, but not for *e*Rating of flood insurance. IFSAR remains a viable alternative for other applications, however. IFSAR was not designed or intended to provide accurate elevations around buildings, but remains the lowest cost alternative for providing elevations for broad areas of terrain that is relatively free of trees and other obstructions.

Strategy C — Evaluate use of Mobile Photogrammetric Vans

C.1 VISAT™ Photogrammetric Van

Dewberry contracted with Sanborn Mapping to evaluate the viability of data collected using Sanborn's VISAT (Video Inertial SATellite) technology from which to extract the necessary information to complete FEMA ECs. The objective of the study was to conduct a "prototype test" of van-based data collection systems configured with GPS and Inertial Navigation System technology to the EC data collection process. The VISAT van is shown at Figure 8.

Figure 8 — VISAT Van

This study utilizes data collected by Sanborn Mapping in Pinellas County, FL. A neighborhood area of seven streets was selected as the study area. The data extracted from the VISAT imagery included:

- Image and description of each house
- Latitude and longitude of the front door
- Top of bottom floor
- Elevation of lowest adjacent grade (LAG) as visible in the image
- Elevation of highest adjacent grade (HAG) as visible in the image
- Building address
- FEMA building type as best determined from the image

Pinellas County VISAT Data

The majority of the Pinellas County data set was acquired in the fall of 1998. The County had originally contracted with Sanborn to collect images at a 5-meter interval in both directions on all County-maintained roadways and alleys. Pertinent data to be extracted from the VISAT imagery and incorporated into the County's GIS included:

- Edges of roads and sidewalks
- Sidewalk width
- Storm manholes and catch basins
- Signs, including type and text
- Fire hydrants
- Guard rails

The project entailed approximately four months of field acquisition and an additional six months of data extraction. The yield was over 2,200 miles of collected imagery and well in excess of 30,000 point-features and 3,000 linear features extracted.

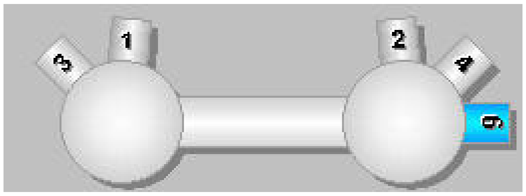
VISAT System Overview

The heart of Sanborn's VISAT technology consists of a rigid, inertial frame that carries an array of b/w digital cameras, a geodetic grade GPS receiver (or more precisely, the antenna), and an inertial measurement unit (IMU). The GPS and IMU data are used to observe the position and orientation of each camera as images are collected. The camera array is designed to provide stereoscopic coverage of up to a 220-degree swath in front of the vehicle.

Once acquired and georeferenced, the images are then used to extract three-dimensional coordinates and attributes using the same colinearity principles that apply to aerial photogrammetry. The VISAT Station software is used to navigate or "drive" spatially through the images and collect features and attributes into an SQL database.

The accuracy target for features extracted for Pinellas County was 40cm horizontal and 20cm vertical, RMSE, approximately equivalent to the vertical accuracy expected from 2 ft contours. Accuracy was assured by extracting known control targets within each mission and extracting the same features from multiple missions. Figure 9 illustrates the camera array configuration for the Pinellas County project (viewed from above the vehicle). This configuration was designed with the data extraction requirements and the technical limitations of storing images every five meters in mind. As shown also in Figure 8, cameras 1 and 2 point forward, camera 3 points forward and to the left, camera 4 points forward and to the right, and camera 6 points to the right (used for this project).

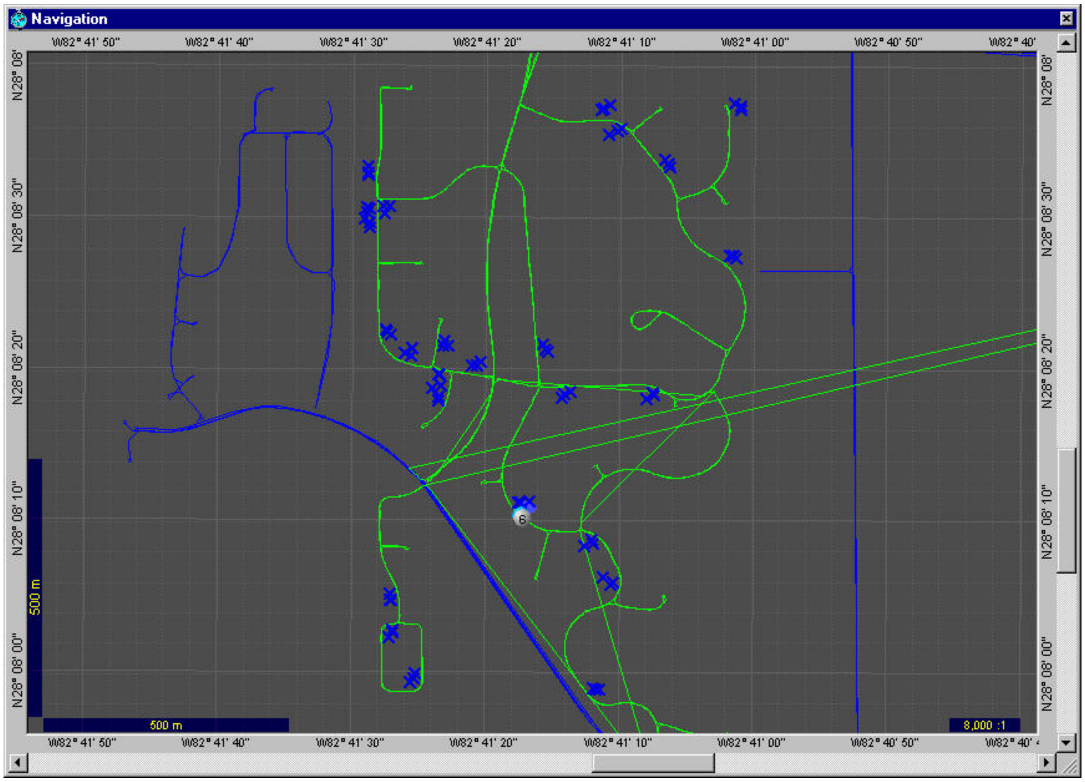
Figure 9 — VISAT Camera Array Configuration



Structure Elevation Study

For the purpose of this study, a neighborhood in Pinellas County was selected based primarily on the visibility of the buildings and addresses. Figure 10 provides an overview of the VISAT vehicle's route through the neighborhood. The small X's represent the measurements that were made on the candidate buildings. Each building was selected based on the visibility of the front door, adjacent grade, and address, and viewed with camera 6.

Figure 10 — VISAT Navigation Route and Display



Limitations to extracting the necessary data included:

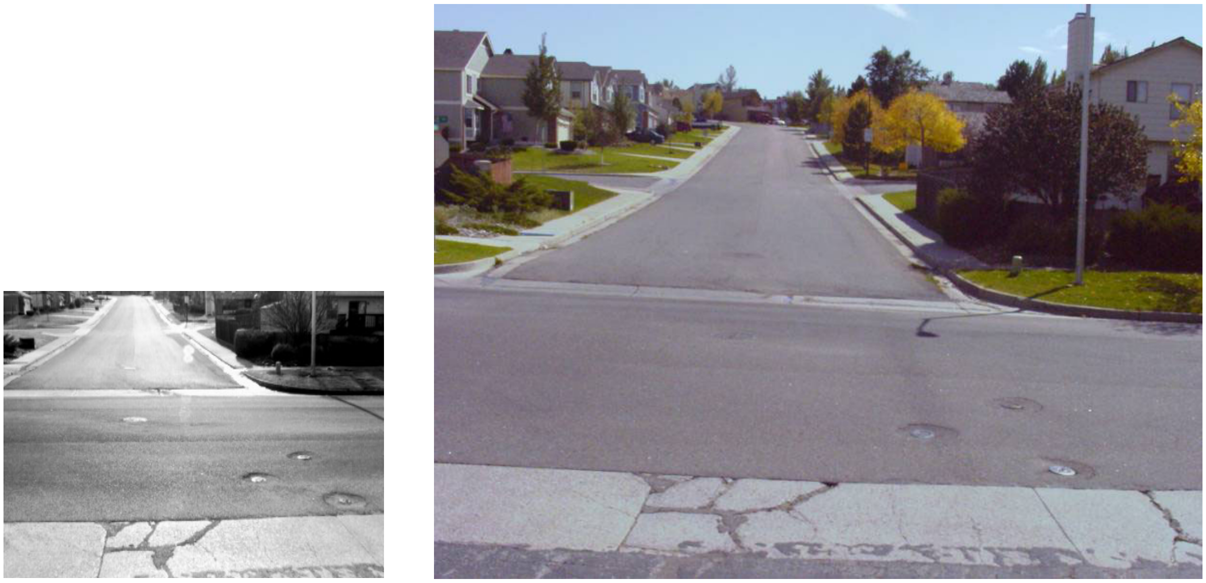
- Camera configuration. With reference to Figure 9, camera number 6 was used almost exclusively for all observations. In order to observe the same feature in a stereo pair, it was necessary to see the feature from camera 6 from two different image capture “epochs” (i.e. an epoch refers to an instance of image capture as the vehicle moves forward). Because images were captured only at an interval of 5 meters, each building was only visible in a maximum of two or three capture epochs. Unlike when capturing features in front of the vehicle, this camera configuration severely limits the available visible angles from which to observe features to the side of the vehicle.
- Vegetation. Owing to the location, many buildings are obscured with dense tropical vegetation in the front yards and along the streets. Attempting to see around the vegetation was limited by camera configuration.
- Image resolution. Several ideal houses were not selected for the study because the address was unreadable. This is directly a function of image resolution.

As a result of these limitations, only about 20% of the buildings were suitable for data extraction. It was necessary to navigate several blocks of the neighborhood, as depicted in Figure 10, in order to locate and survey 25 candidate buildings. The other obvious limiting factors of this approach include the inability to see or access the rear, and sometimes the sides, of the buildings and to positively identify the FEMA building type.

If the VISAT technology were to be deployed specifically for data capture to support FEMA ECs, an alternate camera configuration would aid capture rate and accuracy tremendously. Sanborn's suggestion would be to extend the inertial frame longitudinally along the vehicle facilitating the placement of a side-looking camera at both the front and the rear, i.e., rotating the camera rack by 90 degrees in order to take stereo photos to the side with cameras 1 and 2. This will allow a stereo observation at every capture epoch and provide additional viewing angles to see around vegetation and obstructions.

In addition, the VISAT technology has been improved since the Pinellas County project. Specifically, the original b/w cameras have been replaced with higher resolution color cameras. Figure 11 illustrates the dramatic difference in image quality. The higher resolution will facilitate higher accuracy observations, more positive feature identification, and the ability to observe the street address in all cases.

Figure 11 — VISAT Van Camera Comparison



VISAT Van Current Image
COHU Analog Camera
640 x 240
(interpolated to 640 x 480)
256 Level of Gray

VISAT Van Proposed New Camera
Sony Progressive Scan Digital Camera
1280 x 960
256 Colors
(YUV 4:2:2)

APPENDIX M provides the accuracy assessment statistics, comparing the VISAT-derived elevations of 27 houses in Pinellas County with GPS-surveyed elevations. The VISAT-derived elevations were tested to have vertical accuracy of approximately 1.5 ft at the 95% confidence level. The checkpoint surveys indicated top of bottom floor elevations were accurate to 1.54 feet at the 95% confidence level; LAG elevations were accurate to 1.34 feet at the 95% confidence level; and HAG elevations were accurate to 1.59 feet at the 95% confidence level. However, each of these houses had a concrete pad in the back yard for the air conditioner that was not seen from the street and/or could not have been mapped in stereo. Although these pad elevations were only slightly lower than the top of bottom floor, they could not have been mapped even if they were significantly lower.

For visible features, their surveyed accuracies were quite acceptable; however, the inability to see (in stereo) the majority of the target points to be surveyed presents the major challenge for this technology. An alternate camera configuration coupled with the improved camera technology will overcome some of the limitations encountered during this study.

<u>Pricing</u>

Following are Sanborn's pricing scenarios for the VISAT technology.

- Commission a VISAT campaign………………..….$5000.00 mobilization fee
  …………………………………………..$100.00 per mile of image capture
  note: it is usually recommended that all streets be driven in both directions

- Extraction per house from data………………….$20.00 - 40.00 per building
  note: price assumes a minimum of 100 houses per image campaign

C.2 SideSwipe™ Vehicle Mounted Side Scan LIDAR

LIDAR vans are just now becoming available commercially. Mosaic Mapping's SideSwipe™ is described at APPENDIX N. Such LIDAR vans operate with a low power laser scanner and also take digital images. LIDAR vans drive streets at normal traffic speed, normally scanning to only the right side of the van. The LIDAR point density on the ground is very high resolution, sometimes enabling street signs to be read from LIDAR intensity images. The only such commercial system is currently operating overseas and data is not yet available for evaluation by Dewberry.

Because LIDAR requires only a single laser pulse to measure any point (as opposed to two different views required with photogrammetric vans), LIDAR vans should be better able to map the elevations on front porches, decks, patios, etc. when viewed from only a single angle. Dewberry presumes that the imagery would normally enable the correct identification of basement windows; however, the LIDAR van would be unable to detect walk-out basement doors visible only from the back yard. Without a field test, Dewberry is unable to determine how well a LIDAR van could determine street addresses, or accurately determine the lowest floor elevations, LAGs and HAGs, or elevation of lowest machinery. It is probably the best technology for determining the elevation of lowest horizontal structural members in V-zones. Dewberry is confident that this technology should have fewer limitations than the VISAT van described above, but benefits can only be estimated at this time.

C.3 Mobile Remote Sensing Van Conclusions

Assuming houses are not far above or far below street level, either a LIDAR van or a photogrammetric van has the capability to survey accurate elevations of features that can be seen from the street, but neither can map features (or identify features such as walk-out basement doors or air conditioner pads) that are not visible from the street. The photogrammetric van has an additional disadvantage in that photogrammetry requires any feature mapped to be visible in stereo (from two different perspectives). The VISAT dataset of Pinellas County was already available, and it had not been configured for mapping features to the side of the van. Turning the camera rack sideways so that cameras 1 and 2 (Figure 9) would take simultaneous stereo images to the side (rather than forward) would help to alleviate this limitation. Also, Sanborn already has plans to upgrade the VISAT cameras so they have a wider field of view.

Strategy D — Maximize Cost-Effectiveness of Future ECs

D.1 Future Web-Based Elevation Certificates

To maximize the cost-effectiveness of future ECs, Dewberry recommends that FEMA develop a web-based system for surveyors to use when producing new ECs, building upon current functionality of the NFIP/CRS Elevation Certificate software. APPENDIX P explains Dewberry's concepts for web-based ECs in greater detail. This web site would have eight major features/advantages:

1. It would prompt surveyors to assist them in entering correct data into various fields on the ECs.
2. It would include some quality control tools to automatically "flag" incorrect entries that need to be corrected by the surveyor.
3. It would ensure that all mandatory data items are completed (to include latitude and longitude which ought to be mandatory rather than optional).
4. It would be designed to eliminate or minimize the kinds of quality control problems evident in existing databases mentioned above.
5. It would or could validate the name and license number of the professional surveyor, engineer or architect authorized by law to certify elevation information. (This could get tricky if a newly-registered professional is not yet in the database used by FEMA to query the lists of authorized personnel in each state.)
6. It would prepare a .pdf file of the final EC to be printed by the surveyor for his/her seal and signature for submission of a hardcopy EC to the person who paid for the survey.
7. It would automatically populate the elevation registry with information from the appropriate data fields on the EC, but deliberately exclude the name of the owner because of Privacy Act considerations.
8. This web site could also be used by communities to digitize and enter their existing hardcopy ECs into the elevation registry.

D.2 Legal Considerations for Web-Based Elevation Certificates

In determining the legality of establishing a web-based procedure that (1) helps the surveyor prepare the EC correctly and (2) automatically enters the data into the elevation registry, Dewberry again consulted with FEMA Law Associates, PLLC, and received the legal opinion at APPENDIX O which concludes that such a web site would be legal and helpful. FEMA Law Associates recommended that the foreword to the web site should state that the site will help the surveyor prepare the EC correctly, and that it will automatically enter the data into the registry, but delete the name of the owner in the registry. The legal opinion concluded with the statement: "FEMA would not be well served by trying to hide the fact that elevation information required for insurance under the NFIP is in the public domain."

Strategy E — Leverage Alternative Data Sources

E.1 U.S. Census Bureau

For this study, Dewberry coordinated with the Census Bureau and orchestrated an April 2003 meeting between FEMA and the Census Bureau. The purpose of the meeting was to determine if there were ways for FEMA and Census to collaborate to solve common problems. FEMA specifically hoped to be able to collaborate on the Master Address File (MAF) and the MAF TIGER Accuracy Improvement Project (MTAIP) which Census is currently conducting with five goals as follows:

1. To achieve a 7.6-meter or better horizontal positioning accuracy for Census' TIGER road centerlines to a CE95 criterion (radial accuracy at the 95% confidence level, where 7.6 meters is the radius of a circle of uncertainty such that the true or theoretical location of points being measured fall within that circle 95% of the time.)
2. To add National Hydrography Dataset (NHD) data from USGS (specifically, reach codes) utilizing the NHD for alignment purposes when the NHD data exceeds the positional accuracy of available local GIS hydrography data.
3. To update and geocode addresses, initially using a GPS van with stereo cameras plus a laser range finder to obtain x/y coordinates of the front door of buildings if possible, and also to get street centerlines with an accuracy of ±3 meters. The pilot will focus on rural areas where they do not have normal street addresses.
4. To update the MAF.
5. To maintain the currency of TIGER data for growth areas between 2001 and 2010.

Census' use of a GPS van with stereo cameras (goal 3 above) is similar to the concept presented above for Sanborn's VISAT GPS van, but presumably with the stereo cameras pointed sideways. As of early 2004, Census had cancelled its GPS van initiative as being too expensive.

During the Census/FEMA meeting, there was complete agreement that the two agencies both needed to solve common problems and they wished to collaborate. Specifically, both agencies needed up-to-date geocoded addresses. However, the MAF is covered by Title 13 of the United States Code, and the Census Bureau cannot share the MAF with other government agencies. For example, the U.S. Postal Service, which also needs geocoded addresses, has been specifically excluded from receiving Census MAF data, but the USPS is required to give its data to Census. The same is true of FEMA. FEMA can give its data to Census to update the MAF, but Census cannot give its MAF data to FEMA or anyone else. This Title 13 restriction effectively thwarted FEMA's attempts to collaborate on the MTAIP.

E.2 U.S. Postal Service

Dewberry next coordinated with the U.S. Postal Service (USPS) Address Management Office which provided Dewberry with sample USPS files of zip+4 address ranges of Charlotte, NC. However, these files included geographic coordinates only for the start and end of mail routes, without geocoding any of the addresses along those routes. Dewberry concluded that such files would be of minimal benefit in establishing an elevation registry.

E.3 U.S. Army Corps of Engineers

As indicated above, the Philadelphia District has a sizeable structure database in its Susquehanna River Flood Warning and Response System (FWRS). For this study, Dewberry did not attempt to determine if other Engineer Districts have anything comparable that could be used to help populate an elevation registry. Should FEMA decide to establish a registry, the Corps' Director of Civil Works would be invaluable in official solicitation of cooperation and input from the Corps' various districts, divisions, and R&D laboratories that may have elevation data on structures surveyed in the past, or surveys planned in the future.

E.4 Community GIS Data

Many communities have GIS data that would be beneficial to FEMA in attempting to identify the most cost-effective way to generate thousands of elevation records for individual buildings, to include the following:

- Photogrammetric base maps and/or aerial triangulated aerial photography that could be used cost effectively to generate spot heights or LAG/HAG elevations.
- Digital orthophotos that could be used to overlay spot heights for surveyors to reference in measuring elevation offsets between spot heights and top of bottom floor elevations, elevation of lowest machinery, or elevation of lowest horizontal structural member.
- Georeferenced building footprint files that could be used to "cookie cut" LIDAR or IFSAR data to automatically compute LAG/HAG elevations.
- Georeferenced centroids for buildings or lots that could be used to geocode ECs that are currently not geocoded.
- Georeferenced parcel polygon files, as provided by Harris County, TX for this study, that could be used to geocode current ECs when those polygons are overlaid on top of digital orthophotos.
- Tax/appraisal records that indicate whether or not addressed structures have basements.

Each of these datasets has potential value to FEMA as will be subsequently apparent when performing the cost-effectiveness analyses in the Conclusion of Part I of this report.

E.5 National Parcelmap Data Portal (NPDP)

As explained at www.geodata.gov, the NPDP is a compilation of digital parcel maps of U.S. counties normalized by Boundary Solutions, Inc. at 1:12,000 scale (the same scale as digital orthophoto quarter quads) and available commercially as standardized ArcView shape files linked to street addresses, assessed values and other information. The NPDP consists of nearly 60 million parcels in approximately 200 major metropolitan areas nationwide, including over 400 jurisdictions. www.boundarysolutions.com/ORDER.html provides a list of these areas. Since Boundary Solutions purchases the data from the various jurisdictions for resale to users such as the insurance, hazard disclosure, infrastructure and real estate information industries, these communities are obviously among the thousands of communities nationwide believed to have digitized parcel maps. The significance for this study is that all Strategy B technologies (photogrammetry, Pictometry, LIDAR and IFSAR) will work in these jurisdictions by linking the dominant rooftop located within each parcel to its street address. (Note: rooftops are seen with photogrammetry, Pictometry, LIDAR, and IFSAR, as well as digital orthophotos now available nationwide.) Presumably, the jurisdictions listed would not need to purchase the data in the NPDP because these jurisdictions already have comparable or even newer data for their own use which they periodically update and sell to Boundary Solutions for normalization and resale to the public.

The NPDP may be of interest to FEMA for additional reasons beyond the elevation registry. In the event that a natural or manmade disaster strikes one of these metropolitan areas, the parcel polygons could be overlaid on top of current digital orthophotos or even high-resolution satellite imagery showing the damaged areas. With common ESRI GIS software, polygons defining the limits of areas totally destroyed, 75% destroyed, 50% destroyed, 25% destroyed, etc. could be quickly established. A spatial intersection of these polygons with the NPDP parcel polygon layer would return highly accurate listings of addresses, floor area, facility use, and assessed values of buildings on each parcel so FEMA could make timely and accurate damage assessments for the entire metropolitan area. Furthermore, since HAZUS is designed to work with parcel level data if it's available, the elevation registry with NPDP data would be valuable to HAZUS.

E.6 CitySets

With some similarities to the NPDP, CitySets is a detailed geographic dataset that focuses on downtown areas of major cities in the U.S. and includes digital orthophotography, three dimensional buildings (and not just building footprints), point address locations (including all addresses within large buildings), number of stories, construction materials and other attributes used by the insurance industry and those involved with risk management and disaster response. CitySets was developed by Sanborn Mapping for Risk Management Solutions (RMS), a software provider for the insurance industry. Whereas CitySets may be of marginal stand-alone value to the NFIP at this time, it could be used by the NFIP in the event that other FEMA programs choose to use CitySets in another FEMA database to support emergency response command centers, as currently used in Washington, D.C. and other major cities in the U.S. CitySets' major current value to the NFIP would be in providing a complete listing of addresses with geocoded building footprints for major cities.

E.7 Home Owner Support

Several of the technical alternatives, discussed below, would become more cost effective if costs could be avoided for paying surveyors to collect street addresses, count and measure the area of flood vents, and measure the vertical offset distances from the LAG to the top of bottom floor, garage floor, elevation of lowest machinery, and/or elevation of lowest horizontal structural member in V-zones.

For those communities that have accurate LAG elevations linked to street addresses, whether the LAGs came from LIDAR or photogrammetry, the insurance agents themselves could be allowed to enter selected data into the elevation registry, based on photographs, measurements and other information provided by home owners. Homeowner photographs could be provided showing all sides of the structure. The agent could identify the correct FEMA building diagram number and verify the number and size of flood vents —if a yardstick is photographed at close range next to the vents. If the location of the LAG point could be reasonably determined, then the homeowner could also provide a photograph showing a yardstick or tape measure being used to measure offset distances. The most common distances would be the offset distance from the LAG point to the top of foundation (from which 8 feet is subtracted to derive the elevation of the basement floor), to the bottom of a walk-out basement door, or to the bottom of the front door, for example. Surveyors themselves rarely survey inside of buildings. Instead, they normally compute the elevation of a basement floor as Top of Foundation minus 8 feet, or Bottom of Front Door minus 9 feet to allow one additional foot for floor joists and flooring materials.

Tape measures were used in 2000 for measurement of vertical offsets for the Susquehanna River Flood Warning and Response System that was tested to have vertical accuracy of 1.19 ft at the 95% confidence level. Dewberry believes that homeowners could make such vertical offset measurements and collect other necessary data, provided they had access to a web site or instruction pamphlet provided by the insurance agent that explained correct procedures to be used. They would also need some way to identify which spot heights or LAG points pertain to their home; this problem was explained previously with Figure 2. However, Dewberry does recognize that insurance agents may have practical reasons for resisting homeowner input in the rating process and may oppose the additional effort required.

E.8 Flood Zone Determination (FZD) Companies

The mandatory purchase requirements of the NFIP have created a requirement for all Federally-insured mortgage lenders to locate a subject property on a FIRM panel and make a determination as to whether flood insurance should be required as a condition for the issuing of a mortgage. Virtually all lending institutions have found it more effective to outsource for this service. This has given rise to the Flood Zone Determination (FZD) industry. FZD companies provide flood zone determination services to mortgage lending institutions, Write-Your-Own insurance companies and their agents, commercial insurers, real estate appraisers, and appraisal form providers. FZD services are typically provided through an electronic data interchange (EDI) with lenders. Through these interfaces mortgage lenders and other FZD clients provide real property information and in return receive completed FEMA Standard Determination Forms that include FIRM panel, zone and other data. In some instances, the FZD companies may also provide Census tract information to assist lenders in meeting other Federal regulations. While the majority of FZD services are provided in bulk to mortgage lenders, FZD companies do provide services to any client for single determinations. The application of internet-based technologies is becoming an increasingly important aspect of this business. The flood zone determinations are often but not always accompanied by a guarantee. Most FZD companies also offer a Life of Loan (LoL) service. Through the LoL service, these companies continuously track the flood zone status of properties and notify their customers whenever a change occurs.

Most large FZD companies maintain databases of information regarding property address, tax assessor parcel number, and flood zone. The content and comprehensiveness of these databases varies among companies.

First American and Transamerica

In 2003, First American Corporation announced its acquisition of Transamerica Finance Corporation’s Flood and Tax companies. First American Flood Data Services claims to be the largest flood zone determination provider in the country. They combine GIS technology, manual map reading, and a library of over 450,000 tax, plat, and flood maps to deliver their services.

Transamerica Flood Hazard Certification (TFHC), as part of its automated delivery system, has developed a database of 111,000,000 properties. The U.S. Census Bureau estimates that there are 118,000,000 structures in the U.S., so the TFHC database represents 94% of the structures in the U.S. The database includes property address results for all 50 States, Puerto Rico, the Virgin Islands, and other U.S. Territories. TFHC originally built its database by collecting comprehensive tabular data taken directly from the rolls of tax assessors and/or tax collectors. They combine this with spatial data using their own mapping library, digital flood maps, aerial photos, and GIS technology to determine the latitude/longitude of a property. TFHC passes records through its "triple-geocoder" to clean, standardize, and geocode addresses. Duplicate addresses are identified.

The TFHC database includes the following information that would be pertinent to the development of an elevation registry:

Latitude and longitude (mostly geocoded, not surveyed)
Address
Parcel number
Determination code
FIRM panel number
FIRM effective data
Community name
Flood zone

The TFHC database would not provide all of the needed components of the elevation registry but might provide an initial source of information to identify the "universe of floodprone structures" for which EC records should be sought.

DataQuick

DataQuick is a MacDonald Detweiler Company that claims to be the nation's leading provider of real property and land data. They maintain data on approximately 83 million properties in 880 jurisdictions in 36 states, primarily in the more populous areas of the country. The list at Table 14 summarizes the areas where DataQuick data are available.

Table 14 — DataQuick Data Availability

State	Available Data	State	Available Data
AL	3 counties	NV	34 counties and 1 city
AK	1 county	NJ	All 21 counties
AZ	15 counties	NM	2 counties
CA	58 counties	NY	16 counties
CO	14 counties	NC	15 counties
CT	169 communities	OH	23 counties
FL	59 counties	OK	3 counties
GA	10 counties	OR	11 counties
HI	4 counties	PA	14 counties
IL	19 counties	SC	13 counties
IA	1 county	TN	95 counties
MD	23 counties and 1 city	TX	13 counties
MA	351 communities	UT	4 counties
MI	5 counties	VT	2 communities
MN	2 counties	VA	15 counties and 3 cities
MO	4 counties and 1 city	WA	11 counties
MT	3 counties	WI	4 counties
NE	4 counties	WY	1 county

No data are available from DataQuick in the following states: Arkansas, Delaware, the District of Columbia, Idaho, Indiana, Kansas, Kentucky, Louisiana, Maine, Mississippi, New Hampshire, North Dakota, Puerto Rico, Rhode Island, South Dakota, Virgin Islands, and West Virginia. The total number of policies in force in these states as of September 2002 was 601,398 including over 367,000 policies in Louisiana. Texas is another state with a relatively high policy count (450,663) that may also be underserved by the DataQuick holdings. Only 13 counties are available, whereas 75 counties met the population and policies in force criteria for Q3 Flood Data production.

E. 9 Insurance Industry

Insurance companies also have collected large inventories of ECs. However, issues of obtaining and assembling data from disparate sources coupled with industry concerns over release of potentially business-sensitive data would make this a challenging source of EC data, especially since insurance companies may be reluctant to release information on their book of business.

E.10 NEMIS Database

In FY 1999, FEMA deployed the National Emergency Management Information System (NEMIS) which serves as the information technology standard for the agency's Presidential disaster operations. During the transition to NEMIS, the data in the Automated Disaster Assistance Management System (ADAMS), the predecessor system, was transferred to the newer system. NEMIS automates Federal disaster programs including incident activities, preliminary damage assessment, declaration processing, human services, infrastructure support, mitigation, and associated administrative and financial processing. During FY 2002, NEMIS supported more than 197 disasters, 42 of which were Presidential declarations.

Currently, NEMIS contains information on over 400,000 structures, including a structure’s address, type (basement, no basement), and UTM coordinates (latitude and longitude). Given the complexity of NEMIS, it would be more cost effective to restrict the elevation registry to only import NEMIS data and display it with other elevation registry data, and not export data to NEMIS nor require damage inspectors to enter data into the elevation registry directly.

Summary of Technology Capabilities

Table 15 summarizes the suitability of the various technologies evaluated for detecting/surveying information needed to populate an elevation registry. For airborne remote sensing (traditional photogrammetry, Pictometry, LIDAR or IFSAR), and even for the photogrammetric or LIDAR van, their inability to always see basement windows or walk-out basement doors (not visible from the street) can be offset by on-site measurements of vertical offsets, and simultaneously determine the street address, building diagram number, number and size of vents, etc. Such on-site measurements could be performed in minutes with a simple tape measure or steel tape, rather than requiring precise survey measurements.

Table 15 — Technology Suitability Matrix

Elevation Certificate items or elevation registry Items vs. ability to detect/survey by various methods	**Elevation Certificates**	**Aerial Photogrammetry**	**Pictometry**	**Airborne LIDAR**	**Airborne IFSAR**	**Photogrammetric Van**	**Home Owner**	**Drive-by Reconnaissance**	**On-site Measurements**	**Ancillary Community Data**
Street Address	**A**	**N**	**N**	**N**	**N**	**M**	**A**	**M**	**A**	**A**
City	A	A	A	A	A	A	A	A	A	A
State	A	A	A	A	A	A	A	A	A	A
Zip Code	A	S	S	S	S	M	A	M	A	A
Property Description	P	N	N	N	N	P	M	P	P	A
Building Use	A	S	M	N	N	A	A	A	A	A
Latitude/Longitude	**P**	**A**	**A**	**A**	**A**	**A**	**N**	**P**	**P**	**A**
Horizontal Datum	P	A	A	A	A	A	N	P	P	A
Source	P	A	A	A	A	A	N	P	P	A
B1. NFIP Community Name/Number	A	A	A	A	A	A	N	A	A	A
B2. County Name	A	A	A	A	A	A	A	A	A	A
B3. State	A	A	A	A	A	A	A	A	A	A
B4. Map and Panel Number	A	M	M	M	M	A	N	A	A	A
B5. Suffix	A	M	M	M	M	A	N	A	A	A
B6. FIRM Index Date	A	A	A	A	A	A	N	A	A	A
B7. FIRM Panel Date	A	M	M	M	M	A	N	A	A	A
B8. Flood Zone(s)	A	M	M	M	M	A	N	A	A	A
B9. BFE	A	M	M	M	M	A	N	A	A	A
B10. Source of BFE	A	A	A	A	A	A	N	A	A	A
B11. Elevation Datum	A	A	A	A	A	A	N	A	A	A
B12. CBRS	P	P	P	P	P	P	N	P	P	A
C1. Building elevations based on	A	A	A	A	A	A	A	N	N	A
Elev accuracy @ 95% confidence level	A	A	M	M	S	A	N	N	N	N

C2. Building Diagram Number	A	N	M	N	N	M	A	M	A	A
C3a. Elevation, top of bottom floor	**A**	**N**	**M**	**N**	**N**	**S**	**O**	**N**	**O**	**S**
C3b. Elevation, top of next higher floor	A	N	M	N	N	S	S	N	N	S
C3c. Bottom, lowest horiz structural member	**A**	**N**	**N**	**N**	**N**	**S**	**O**	**N**	**O**	**S**
C3d. Elevation, attached garage (top of slab)	A	M	M	S	S	M	O	N	O	S
C3e. Lowest elevation of machinery	**A**	**N**	**N**	**N**	**N**	**S**	**O**	**N**	**O**	**S**
C3f. Lowest adjacent grade (LAG)	**A**	**A**	**M**	**M**	**S**	**S**	**N**	**N**	**N**	**S**
C3g. Highest adjacent grade (HAG)	A	A	M	M	S	S	N	N	N	S
C3h. Number of flood vents <1' above grade	**A**	**N**	**N**	**N**	**N**	**M**	**M**	**M**	**A**	**N**
C3i. Area of flood vents	**A**	**N**	**S**	**N**	**N**	**S**	**A**	**S**	**A**	**N**
Certifier's Name	A	M	M	M	S	A	N	N	N	N
License Number	A	M	M	M	S	A	N	N	N	N
Ability to detect basements	**A**	**N**	**M**	**N**	**N**	**S**	**A**	**S**	**A**	**A**
Was structure previously flooded inside?	N	N	N	N	N	N	S	N	N	A
Depth of prior interior flooding	N	N	N	N	N	N	S	N	N	A

Street addresses are always mandatory.
Other bold items are most critical for an elevation registry

A = Can be determined - All of the time

M = Most of the time (>50%)

S = Some of the time (<50%)

N = None of the time, or almost never

O = Can measure vertical offsets

P = Possible if/when required

COST-EFFECTIVENESS (CE) ANALYSES

Methods for Populating an Elevation Registry

This section performs cost-effectiveness (CE) analyses of twenty (20) alternative methods for populating the elevation registry. These are 20 alternatives to the traditional survey method (Method 0) employed by those communities who hire surveyors to mass produce elevation surveys of all existing structures in or near floodplains community-wide.

Table 16 — Summary of Twenty Alternative Methods

The Base Method 0 assumes a community hires a survey firm to mass produce ECs digitally for batch entry into the registry (cost = $300 each). Methods 1 through 20 are lower cost alternatives. Existing ECs are digital for Method 1 but hardcopy for Methods 2 through 4. Future ECs (Methods 5 and 6) are digital and individually entered into the registry. Methods 7 through 20 all use remote sensing data, and all batch-entered into the registry, except for Methods 9, 16 and 18 where home owners enter records individually into the registry.	**Provided by Community or Surveyors**									**Home owner on-site measurements**	**Batch web entry into registry**	**Individual web entry into registry**
	ECs without Latitude/Longitude	**ECs with Latitude/Longitude**	**Photogrammetry for 2' contours**	**Photogrammetry for 5' contours**	**LIDAR DTMs equivalent to 2' contours**	**IFSAR DSMs equivalent to 10' contours**	**Pictometry**	**Building Footprints with Addresses**	**Community on-site measurements**			
0. Surveyed ECs accurate lat/long, batch entry		X									X	
1. Digital ECs, no/inacc. lat/long, batch entry	X										X	
2. Hardcopy ECs, no/inacc. lat/long, batch entry	X										X	
3. Hardcopy ECs, no/inacc. lat/long, 1 web entry	X											X
4. Hardcopy ECs accurate lat/long, 1 web entry		X										X
5. Future ECs, no/inacc. lat/long, 1 web entry	X											X
6. Future ECs, accurate lat/long, 1 web entry		X										X
7. Photogrammetry (2' CI), no offsets			X								X	
8. Photogrammetry (2' CI), surveyor offsets			X						X		X	
9. Photogr. (2' CI) with footprints, owner offsets			X							X		X
10 Photogrammetry (5' CI), no offsets				X							X	
11. Photogrammetry (5' CI), surveyor offsets				X					X		X	
12. Pictometry with LIDAR DTM					X		X				X	
13. LIDAR (2' CI), no footprints, no offsets					X						X	
14. LIDAR (2' CI) with footprints, no offsets					X			X			X	
15. LIDAR (2' CI), no footprints, surveyor offsets					X				X		X	
16. LIDAR (2' CI), no footprints, owner offsets					X					X		X
17. LIDAR (2' CI) with footprints, surveyor offsets					X			X	X		X	
18. LIDAR (2' CI) with footprints, owner offsets					X			X		X		X
19. IFSAR (10' CI) w/footprints, surveyor offsets						X		X	X		X	
20. Photogrammetric Van (VISAT)			X								X	

Color Legend for Table 16

Strategy A — Existing ECs methods are in blue
Strategy B — Airborne remote sensing methods are in green
Strategy C — Photogrammetric van method is in orange
Strategy D — Future EC methods are in yellow
Strategy E — Community-provided alternative data methods are in violet *
Strategy E — Home-owner provided alternative data methods are in pink *

* Alternative data (Strategy E) to augment airborne remote sensing data (Strategy B) is in one of two categories:

(1) "Reverse geocoding" whereby latitude and longitude of airborne data are linked to street addresses by use of addressed building footprints, centroids or parcel polygons

(2) On-site measurements from LAG to determine top of bottom floor, lowest horizontal structural member and other elevations and to count vents and take vent measurements

With Method 0, communities hire survey contractors: (1) to perform GPS elevation surveys of temporary bench marks (TBMs) consistent with NOS NGS-58 guidelines for GPS elevation surveys, or alternative GPS survey standard, (2) to extend conventional surveys from the TBMs to survey points on or adjacent to houses in order to determine elevations of the top of bottom floor in A-zones, bottom of lowest horizontal structural member (LHSM) in V-zones, lowest adjacent grade (LAG), highest adjacent grade (HAG), garage floor, and lowest machinery, (3) to provide accurate geographic coordinates and street addresses for each structure, (4) to determine the correct building diagram number, and (5) to determine the number, size and location of flood vents. Minor additional costs would be incurred to enter all appropriate data into the elevation registry, excluding the names of the home owners. As explained below with assumptions, Method 0 is assumed to cost $300 per structure on average; the other 20 lower cost methods are then compared with Method 0 for their cost effectiveness, with lower values given to methods that yield less-accurate or incomplete records.

The 20 alternative methods, summarized in Table 16 and further explained below, are not the only alternatives, but they do comprise major alternatives evaluated during this research project, avoiding dozens of additional combinations that depend upon whether or not a community has digital orthophotos, building footprints, centroids, and/or tax parcels, and whether or not the footprints, centroids, or parcels are linked to street addresses.

Each of these 20 methods has strengths and/or limitations in their ability to provide information required by the registry, evaluated in six categories: (1) ability to provide accurate geographic coordinates (latitude and longitude) and street addresses for individual records, (2) ability to provide information needed to identify the correct FEMA building diagram number, (3) ability to provide accurate top of bottom floor and LHSM elevations, (4) ability to provide accurate LAG and HAG elevations, (5) ability to provide accurate elevations of garage floor and lowest machinery, and (6) ability to identify and measure flood vents. Using traffic light symbology, when all six of these items can be provided with reasonable accuracy by the method being evaluated, the value to the registry will be color-coded green — of high value. When a key item such as top of bottom floor or LHSM elevation cannot be provided by the method being evaluated, the record value will be color-coded amber — of reduced value. When several key items, such as street address and top of bottom floor elevation cannot be provided by the method being evaluated, the record value will be color-coded red — of little or marginal value to the registry. A cost-effectiveness (CE) rating system is used, compared with 100% full value. Methods that are between 0% and 33.3% are color-coded red; methods that are between 33.3% and 66.7% are color-coded amber; and methods that are between 66.7% and 100% are color-coded green.

The following twenty (20) alternative methods were evaluated during this study. Methodology used to quantify the relative high-, mid-, and low-value of EC components is explained in the next section of this report.

1. Method 1 utilizes individual existing digital ECs or digital elevation records already available in databases, but which do not include accurate latitude/longitude information and therefore are not full value. These existing digital records would be quality controlled and reformatted for entry into the elevation registry. This method would include files from ISO, the LOMA 2000 database, the Policies in Force database (BureauNet), and potentially files from map determination companies or other sources. Because each of these files are in different formats, some computer programming may be required to reformat the records, and some addresses may need to be manually re-entered into the registry in the recommended format. However, Dewberry still estimates that such records can be reformatted for entry into the registry at a unit cost of $5 per structure. [Some of the existing digital ECs (Dewberry's and the U.S. Army Corps of Engineers') also include accurate latitude and longitude; they would therefore be full value and have even a higher EC ratio than those shown for Method 1 which assumes no latitude/longitude or inaccurate coordinates because of automated geocoding.] Method 1 is part of Strategy A to maximize the use of existing EC data.

2. Method 2 utilizes large batches of existing hardcopy ECs, normally maintained by communities. Because these commonly lack latitude and longitude, they are not full value. They would be batch digitized and batch processed into the registry. Method 2 is also part of Strategy A.

3. Method 3 utilizes individual existing hardcopy ECs or small quantities of ECs. Because these commonly lack latitude and longitude, they are not full value. These would be individually digitized and entered into the registry. Method 3 is also part of Strategy A.

4. Method 4 is the same as Method 3 except that these are individual or small quantities of ECs that are 100% of full value because they include accurate geographic coordinates (normally from GPS surveys). There are no known large quantities of such certificates beyond those already known to be in digital format. Method 4 is also part of Strategy A.

5. Method 5 utilizes individual future ECs that are not full value because they lack latitude/longitude values. With a web-based registry, it is intended for these ECs to be entered into the registry by the Land Surveyor or other professional licensed to perform such surveys, when validated by FEMA (as described later in this report). Method 5 is part of Strategy D to make the best use of future ECs produced by others, while minimizing costs to FEMA for surveying the new ECs.

6. Method 6 is the same as Method 5 except that these ECs are 100% of full value because they include accurate latitude/longitude values (normally from GPS surveys). Method 6 is also part of Strategy D. Methods 1 through 6 are color-coded green in all scenarios evaluated below as these six methods always yield high value records.

7. Method 7 utilizes stereo photogrammetric data already available in some communities for prior generation of 2' contours. This photogrammetric data would now be further used to stereo-compile photogrammetric spot heights and LAG/HAG elevations for large groups of structures batch processed into the registry. Without leveraging additional data sources, Method 7 alone would yield relatively low value records because: (1) the geographic coordinates are not linked to street addresses so the basic address would be missing from each record, (2) the building diagram numbers would be unknown, (3) there would be no vertical offset measurements up/down from the LAG to determine the elevation of the top of bottom floor, LHSM or other elevations, and (4) there would be no identification or measurement of flood vents. Method 7 is part of Strategy B to maximize the use of existing airborne remote sensing data, in this case, existing photogrammetric data previously determined to be suitable for prior generation of 2' contours.

8. Method 8 supplements Method 7 with vertical offset measurements and other data acquired on-site by a surveyor or other qualified person (e.g., a GIS technician) so as to complete high value records. This method assumes that the surveyor or GIS technician has a GPS receiver and/or GIS software necessary to link photogrammetric spot heights with street address and geographic coordinates of each structure surveyed, or can overlay the spot heights on top of digital orthophotos (as shown in Figure 2) so as to identify structures for address matching. Method 8 is a combination of Strategy B and Strategy E which leverages alternative data sources; in this case, the alternative data source would be community-

wide surveyor-measured offsets (or offsets measured by non-surveyors) and other data collected on-site at each structure, but without employing traditional surveying equipment to perform conventional or GPS surveys.

9. Method 9 is the same as Method 8, with two exceptions: (1) the homeowner himself or herself provides photographs and vertical measurements to the insurance agent who completes individual registry records rather than batch processed records as in Method 8; and (2) the community has street-addressed building footprints (see Figure 6) or alternative method for identifying the addresses that go with the photogrammetric spot heights. Without address matching, the homeowner will not know which spot heights pertain to his/her house and this method would be ineffective -- as with Method 16 described below. Method 8 is also a combination of Strategy B and Strategy E; but in this case, there are two alternative data sources, i.e., owner-provided data and measurements and the community-provided building footprints linked to street addresses.

10. Method 10 is the same as Method 7 except that the photogrammetric spot heights are equivalent to 5' contours instead of 2' contours. Because of the poorer accuracy, Method 10 yields lower value records than Method 7. Method 10 is part of Strategy B to maximize the use of existing airborne remote sensing data -- in this case, existing photogrammetric data suitable for generation of 5' contours.

11. Method 11 supplements Method 10 with vertical offset measurements and other data acquired on-site by a surveyor or other qualified person, as used in Method 8 above, so as to yield mid-value records. Method 11 is a combination of Strategy B and Strategy E which leverages alternative data sources; in this case, the alternative data source would be community-wide surveyor-measured offsets (or offsets measured by non-surveyors) and other data collected on-site at each structure, but without employing traditional surveying equipment to perform conventional or GPS surveys.

12. Method 12 utilizes oblique Pictometry imagery already available in a few communities, but now further used to identify building diagram numbers, identify full or walk-out basements, identify flood vents, and estimate vertical offset measurements relative to LIDAR digital terrain models (DTMs) equivalent to 2' contours. These records would be of mid value because the scale of the Pictometry imagery is such that basements may often be misidentified and because rigorous aerial triangulation is not performed for each image to enable direct measurements of points viewed in stereo. Method 11 is part of Strategy B to maximize the use of existing airborne remote sensing data, in this case, existing Pictometry imagery available in 100+ communities nationwide, but rapidly growing in popularity.

13. Method 13 utilizes high resolution raw LIDAR "point cloud" data, already available in some communities, typically used by communities to generate bare-earth DTMs equivalent to 2' contours. Without building footprints, a LIDAR specialty firm (such as Computation Consulting Services, CCS) would be needed to automatically extract building centroids and/or footprints and to compute LAG and HAG elevations using a "NoFP" method. Although LAG and HAG elevations can be derived with good accuracy, Method 13 would yield relatively low value records batch processed into the registry because: (1) the geographic coordinates of LIDAR points would not be linked to street addresses so the basic address would be missing from each record, (2) the building diagram numbers would be unknown, (3) the top of bottom floor and other elevations would be inaccurately estimated, (4) there would be no identification or measurement of flood vents, and (5) the automatic process for extracting buildings from raw LIDAR data would typically be less than 90% successful (depending largely on the point spacing of the raw LIDAR data). Method 13 is part of Strategy B to maximize the use of existing airborne remote sensing data, in this case, existing raw LIDAR "point cloud" data.

14. Method 14 utilizes the bare-earth DTM equivalent to 2' contours (as in Method 13), but provided in Triangulated Irregular Network (TIN) format and supplemented with addressed footprints provided by the community. LIDAR specialists at Dewberry or other LIDAR processing firm would use a "w/FP" method to "cookie cut" the LAG and HAG elevations from the TIN with street address also known for each LAG/HAG value. This method would yield mid-value records batch processed into the registry. Method 14 is a combination of Strategy B (existing LIDAR-derived bare-earth DTM data) and Strategy E (community-provided building footprints linked to street addresses).

15. Method 15 supplements Method 13 with vertical offset measurements and other data acquired on-site by a surveyor or other qualified person, yielding relatively high quality records batch processed into the registry. This method assumes that the surveyor or GIS technician would have a GPS receiver and/or GIS software necessary to link LIDAR data with street address and geographic coordinates of each structure surveyed, or could overlay LIDAR-derived building centroids on top of digital orthophotos (as shown in Figure 6) so as to perform address matching. Method 15 is a combination of Strategy B (existing raw LIDAR "point cloud" data) and Strategy E (community-wide surveyor measured offsets and other data collected on-site).

16. Method 16 (color-coded magenta) is the same as Method 15 except that the homeowner would provide vertical offset measurements and photos to

the insurance agent to complete a single record individually entered into the registry. However, a typical home owner does not have access to a GPS receiver or GIS software necessary to overlay LIDAR data on digital orthophotos or link LIDAR building centroid data with street addresses and geographic coordinates. Therefore, this method would be ineffective (color-coded magenta) unless the homeowner, insurance agent or community has GIS software to overlay LIDAR building centroid points or parcel polygons on top of digital orthophotos so that the someone can identify which LIDAR centroid and LAG/HAG elevation data pertain to his or her street address. Only with such added support would this method provide a high value record. Method 16 is a combination of Strategy B (existing raw LIDAR "point cloud" data) and Strategy E (homeowner measured offsets and other data collected on-site — plus community-provided support necessary to link LIDAR-derived building centroids or footprints and LAG/HAG elevations to street addresses).

17. Method 17 supplements Method 14 with vertical offset measurements and other data acquired on-site by a surveyor or other qualified person, yielding high quality records batch processed into the registry. Because addressed footprint files would be provided, this method does not assume that the surveyor or GIS technician has a GPS receiver and/or GIS software needed for address matching. Because addressed footprints are provided by this method, each street address would already be linked to the geographic coordinates of the LIDAR-derived LAG/HAG elevations. Method 17 is a combination of Strategy B (bare-earth LIDAR TIN) and Strategy E (community-provided building footprints linked to street addresses, and community-wide surveyor measured offsets and other data collected on-site).

18. Method 18 is the same as Method 17 except that the homeowner would provide vertical offset measurements and photos to the insurance agent to complete a single record individually entered into the registry. Because addressed footprints would be provided by this method, each street address would already be linked to the geographic coordinates of the LIDAR-derived LAG/HAG elevations. Method 18 is also a combination of Strategy B (bare-earth LIDAR TIN) and Strategy E (owner-provided data and measurements and community-provided building footprints linked to street addresses).

19. Method 19 utilizes IFSAR data, already available in some regions, and typically used by states/counties to generate broad area coverage of digital surface models (DSMs) of top surfaces, as opposed to DTMs of bare-earth surfaces -- combined with addressed building footprints as well as vertical offset measurements and other data acquired on-site by a surveyor or other qualified person. Because addressed footprint files would be provided, this method does not assume that the surveyor or GIS

technician has a GPS receiver and/or GIS software needed for address matching. Because addressed footprints would be provided by this method, each street address is already linked to the geographic coordinates of the IFSAR-derived LAG/HAG elevations. Method 19 is a combination of Strategy B (IFSAR DSM) and Strategy E (surveyor-provided data and measurements and community-provided building footprints linked to street addresses). These records are of low value primarily because of the inherent accuracy of the IFSAR data, typically equivalent to 10' contours. The CE ratio can be improved by using the home owner, instead of a surveyor, to measure the vertical offsets and collect other data, but the value of the records are still low.

20. Method 20 utilizes photogrammetric van technology, such as Sanborn's VISAT, to acquire stereo images of structures as the van drives streets at normal traffic speed, recording the six required positioning and orientation parameters required for each image necessary to make accurate 3-D measurements of ground features measured in stereo. This technology is comparable to aerial photogrammetry except that the cameras are on the ground, pointing sideways instead of downward. Method 20 is part of Strategy C to evaluate the use of mobile photogrammetric vans. This method also yields low value records.

In summary, the following methods pertain only to individual structures or perhaps to small batches of structures processed individually into the registry: 3, 4, 5, 6, 9, 16 and 18. More importantly, the following methods pertain to community-wide initiatives that could be batch processed into the registry: 1, 2, 7, 8, 10, 11, 12, 13, 14, 15, 17, 19 and 20.

Base Scenario

In order to perform cost-effectiveness assessments of the 20 different methods for populating the registry, it is desirable to assess both the total value of each accurate and complete EC entered into an elevation registry, as well as the relative value of the most important elevation registry items highlighted (bold) in Table 15, considering that some EC items may be less accurate or less complete and therefore have lesser value to the registry.

Dewberry's best estimate of the correct value of each variable is reflected in the Base Spreadsheet at Table 17 where EC elevation values become worthless when elevation errors are 4 feet or worse at the 95% confidence level, based on input from FEMA.

To estimate the total value of surveyed ECs in the registry (Method 0), Dewberry considered its own costs for performing such surveys as well as cost proposals and input received from many other sources, including cost quotes from survey firms nationwide. The unit costs varied from a low of $150 to a high of $2300 per structure.

There are many variables that cause large variations in the unit cost of EC surveys. Costs are lowest under the following conditions: (a) thousands of structures to be surveyed in the project area, (b) all structures are relatively close together in high density housing areas, (c) all structures are near to accurate, stable and GPS-able survey monuments that can easily be located by surveyors (d) survey monuments do not need to be validated prior to use, (e) structures are relatively simple (few split foyers and split levels), (f) few basements or crawl spaces, (g) communities notify owners of authorized survey activity on/near their property, (h) no strict deadline to be met, (i) surveys are performed on all structures within broad areas (e.g., entire SFHA for a community), (j) surveys are performed by local survey firms that do not incur travel/lodging/per diem expenses, and (k) survey specifications are relatively lax, allowing the surveyor to use the least expensive means to accomplish a survey that satisfies the scope of work.

Costs are higher under the following conditions: (a) dozens or hundreds of structures are surveyed, rather than thousands of structures, (b) structures are dispersed and/or isolated, (c) the most desirable survey monuments are far from the survey project area, (d) surveyors need to first identify and recover suitable survey monuments and then validate their accuracy relative to other survey monuments in the community, (e) structures are complex with many levels, or difficult to classify building diagrams, e.g., split foyers, (f) complex basements or crawl spaces, or basements that do not have standard 8' foundation walls, (g) surveyors have to notify home owners and/or seek prior permission to survey, (h) tight schedules and strict deadlines that require accelerated planning and diversion of resources from other projects, (i) surveys are based on assigned address lists that require individual location, (j) surveys are performed by out-of-state specialists who incur travel, lodging and per diem expenses, and (k) strict conformance with NOAA Technical Manual NOS NGS-58 is mandated by the scope of work, whereby all GPS surveys must be performed twice, on two different days with distinctly different satellite geometry.

The lowest cost estimate ($150 per structure) came from Charlotte-Mecklenburg Storm Water Services for whom Dewberry had surveyed over 2,000 ECs in 1996. Costs are lower there in 2004 because significant additional costs were incurred in 1996 when two weeks were spent in finding six survey control monuments throughout the county that, when surveyed relative to each other, all agreed within 1 inch. Two weeks of survey team expenses were incurred before surveys were ever started on the first EC in 1996. Because of significant discrepancies found between the county's survey monuments in 1996, many thousands of dollars were spent in identifying FA0318, FA0357, FA2462, FA2594, FA4563, and FA1406 as six monuments that could be used throughout the county, so that EC surveys from any of these monuments would yield similar results within 1 inch, regardless of which monument was used. If Dewberry had not gone through this additional expense in 1996, surveys from other monuments might yield structure elevations that differed by 6 inches or more because they would be surveyed relative to monuments that were inaccurate or inconsistent with other local monuments. Now, in 2004, surveyors do not need to repeat this initial validation process, so new ECs are less expensive than when starting afresh with new surveys that conform to NOS NGS-58.

Dewberry's best judgment is that the value of each EC accurately surveyed should be $300 nationwide when local surveyors are used on large projects. When Dewberry's surveyors perform single surveys locally, the cost is approximately $600 when only one house is surveyed. When they are surveyed locally for batch processing, the cost is about $300 when the control points first need to be validated prior to use, as is necessary for the majority of elevation surveys. When Dewberry hires local surveyors to survey up to a hundred certificates in their own community, the unit cost is approximately $300. For this reason, the base scenario assumes traditional ECs may be mass produced community-wide for $300 each, as indicated at Table 17.

Communities will find that their actual costs may be higher or lower than $300, and for this reason sensitivity analyses are performed for unit costs that vary between $100 and $600 (see Table 18).

Table 17 — Cost-Effectiveness Model Base Spreadsheet

A	B	C	D	E	F	G	H	I	J
Cost-Effectiveness (CE) Ratio and Relative Value of Different Methods for Generating Data for the Elevation Registry **Assumes Value of Elevations Degrade to Zero as Elevation Errors become 4' or larger at the 95% confidence level**	Address Geocoding to get Latitude/Longitude and BFE	FEMA Building Diagram No.	Top of Bottom Floor (TBF) in A-zone, Lowest Horiz Str Member in V-zone	LAG and HAG Elevations	Other Elevations (Garage and Lowest Machinery)	Number and Area of Flood Vents	Total Percent Value of EC	Using available data, additional cost per structure added to registry	CE Ratio compared with $300 value of ECs surveyed and entered in registry when mass-produced community-wide
Maximum Possible Percentage Points	5	5	55	25	5	5	100	N/A	N/A
0. Surveyed ECs accurate lat/long, batch entry	5.0	5.0	55.0	25.0	5.0	5.0	100	$300	1.00
1. Digital ECs, no/inacc. lat/long, batch entry	0.0	5.0	55.0	25.0	5.0	5.0	95.0	$2.50	114.0
2. Hardcopy ECs, no/inacc. lat/long, batch entry	0.0	5.0	55.0	25.0	5.0	5.0	95.0	$7.50	38,00
3. Hardcopy ECs, no/inacc. lat/long, 1 web entry	0.0	5.0	55.0	25.0	5.0	5.0	95.0	$15.00	19.00
4. Hardcopy ECs accurate lat/long, 1 web entry	5.0	5.0	55.0	25.0	5.0	5.0	100	$15.00	20.00
5. Future ECs, no/inacc. lat/long, 1 web entry	0.0	5.0	55.0	25.0	5.0	5.0	95.0	$10.00	28.50
6. Future ECs, accurate lat/long, 1 web entry	5.0	5.0	55.0	25.0	5.0	5.0	100	$10.00	30.00
7. Photogrammetry (2' CI), no offsets	0.0	0.0	9.5	17.2	0.9	0.0	27.5	$12.50	6.60
8. Photogrammetry (2' CI), surveyor offsets	5.0	5.0	47.3	21.5	4.3	5.0	88.1	$62.50	4.23
9. Photogr.(2' CI) with footprints, owner offsets	5.0	5.0	47.3	21.5	4.3	5.0	88.1	$20.00	13.22
10 Photogrammetry (5' CI), no offsets	0.0	0.0	3.9	7.0	0.4	0.0	11.2	$12.50	2.69
11. Photogrammetry (5' CI), surveyor offsets	5.0	5.0	19.3	8.8	1.8	5.0	44.8	$62.50	2.15
12. Pictometry with LIDAR DTM (2' CI)	0.0	4.0	18.9	17.2	1.7	0.0	41.8	$52.50	2.39
13. LIDAR (2' CI), no footprints, no offsets	0.0	0.0	8.0	14.6	0.7	0.0	23.4	$12.50	5.61
14. LIDAR (2' CI) with footprints, no offsets	5.0	0.0	11.8	21.5	1.1	0.0	39.4	$7.50	15.76
15. LIDAR (2' CI), no footprints, surveyor offsets	5.0	5.0	40.2	18.3	3.7	5.0	77.1	$62.50	3.70
16. LIDAR (2' CI), no footprints, owner offsets	0.0	5.0	40.2	18.3	3.7	5.0	72.1	$20.00	10.82
17. LIDAR (2' CI) with footprints, surveyor offsets	5.0	5.0	47.3	21.5	4.3	5.0	88.1	$57.50	4.60
18. LIDAR (2' CI) with footprints, owner offsets	5.0	5.0	47.3	21.5	4.3	5.0	88.1	$15.00	17.62
19. IFSAR (10' CI) w/footprints, surveyor offsets	5.0	5.0	0.0	0.0	0.0	5.0	15.0	$57.50	0.78
20. Photogrammetric Van (VISAT)	5.0	4.0	8.8	4.0	0.8	1.0	23.6	$37.50	1.89

*Note: no "owner" method works without footprints, centroids, or parcels linked to street addresses

Elevation Accuracy Multipliers that degrade maximum value when less than best accuracy		
If 95% of elevations accurate within 6"	1.00	Assumed accuracy of conventional/GPS ECs
If 95% of elevations accurate within 1'	0.90	
If 95% of elevations accurate within 1.2' (2' CI)	0.86	Accuracy of 2' CI photogrammetry & LIDAR
If 95% of elevations accurate within 1.5'	0.80	Accuracy of VISAT photogrammetric van
If 95% of elevations accurate within 2'	0.70	
If 95% of elevations accurate within 3' (5' CI)	0.35	Accuracy of 5' CI photogrammetry
If 95% of elevations accurate within 4'	0.00	
If worse than 4' at 95% confidence level	0.00	Accuracy of 10' CI IFSAR

Column A of Table 17 lists Method 0 and the 20 different technology combinations considered as alternatives. They will be further explained below in conjunction with various parameters that define the mathematical cost-effectiveness model. Webster's dictionary defines "parameter" as follows: "In mathematics, a quantity or constant whose value varies with the circumstances of its application; any constant, with variable values, used as a reference for determining other variables."

The eight bottom rows of Table 17 show the elevation accuracy parameters (multipliers) that degrade the maximum value of all elevation entries when less than the best (6") accuracy. These accuracy multipliers were provided by FEMA. This assumes the maximum multiplier of 1.0 for traditional ground-surveyed ECs assumed to have a vertical accuracy of 6" or better at the 95% confidence level. This also assumes the worthless multiplier of 0.0 when elevations are accurate to 4 ft at the 95% confidence level; this equates to approximate 6.7' contours.

Column B lists the value, for each technology, of being able to provide accurate geocoding (latitude and longitude) of street addresses, as opposed to map coordinates or automated geocoding which has been demonstrated to have errors of hundreds of feet, implying that the coordinates could be incorrectly attributed to a neighboring house or another house across the street. Inaccurate coordinates will provide incorrect information when estimating BFEs or updating flood risk with new flood information or when identifying addresses to receive flood warnings. A base value of 5% was assigned to this parameter.

In the Base Scenario spreadsheet shown in color at APPENDIX Q, column B entries in pink are those with no building footprints, i.e., there would be difficulty linking the remote sensing data to the correct street addresses if the data could not be overlaid on top of digital orthophotos or base maps; and those entries in yellow would have difficulty doing so if the building footprints are not linked to street addresses.

Column C lists the value, for each technology, of being able to determine the correct FEMA building diagram number. This is needed for rating flood insurance policies. A base value of 5% was assigned to this parameter.

Column D lists the value, for each technology, of being able to accurately determine the top of bottom floor in A-zones as well the elevation of the lowest horizontal structural member (LHSM) in V-zones. A base value of 55% was assigned to the top of bottom floor/LHSM parameter as FEMA officials considered these elevations to provide more than half the total value of an EC record for insurance rating purposes.

Column E lists the value, for each technology, of being able to accurately determine the LAG and HAG, recognizing that the LAG is clearly more important than the HAG. A base value of 25% was assigned to the LAG/HAG parameter because the LAG is vital for mandatory purchase requirements.

Column F lists the value, for each technology, of being able to accurately determine the elevation of the garage and lowest machinery. A base value of 5% was assigned to this parameter.

Column G lists the value, for each technology, of being able to determine the number and area of flood vents within 1 foot of grade. A base value of 5% was assigned to this parameter.

Column H lists the total percentage point value of an EC produced by each of the 20 technology combinations, as a percentage of the maximum value ($300) for an accurate and complete EC. Using "traffic light" color coding scheme, Column H entries in green represent "go" or high-value records from that technique (values between 66.7% and 100%); entries in amber represent "caution" or mid-value records from that technique (values between 33.3% and 66.7%); and entries in red represent "stop" or low-value records from that technique (values between 0% and 33.3%). Method 16 is color-coded magenta because, without addressed footprints, no homeowner option will work unless there is another alternative for linking remote sensing data to street addresses, such as addressed centroids or footprints. With none of these, the homeowner cannot determine which LAG/HAG elevations pertain to his/her address.

Column I uses various cost models to compute the additional costs necessary to produce the EC record entered into the elevation registry, assuming that the remote sensing data (aero-triangulated aerial photography, Pictometry images, raw "point cloud" and/or bare-earth LIDAR data, IFSAR data, or VISAT data) has already been acquired and paid for by the county/community. Also, when building footprints, centroids or tax parcels are available from community GISs, it is assumed that these costs have already been paid for.

Column J computes the Cost-Effectiveness (CE) ratio of the $300 value divided by the additional costs in column I, beyond costs already borne by the community to acquire remote sensing data and addressed footprints when available. All CE ratios larger than 1.00 indicate a good CE ratio, i.e., better than 1:1 (more than $1 in value for each dollar spent), and all ratios smaller than 1.00 indicate a poor CE ratio, i.e., poorer than 1:1 (less than $1 value for each dollar spent).

The following are the remaining CE parameters in the full spreadsheet at APPENDIX Q that will be varied, below, in sensitivity analyses over their most probable range of uncertainty:

- Spreadsheet parameter K3 (the value in cell K3 of the spreadsheet) is the reduced accuracy and value of top of bottom floor and LHSM (column D) and other elevations (column F) by not knowing the vertical offset between these elevations and the LAG or HAG (column E). Base value = 0.25.

- Spreadsheet parameter K5 is the reduced accuracy of determining the LAG elevations automatically for LIDAR and IFSAR by not having a file of building footprints. Base value = 0.85.
- Spreadsheet parameter K7 is the uncertainty in being able to link LAG values with the correct street address, as well as uncertainty in a technology's ability to see all sides of a building to determine the correct building diagram number. Base value = 0.80 for Pictometry and VISAT.
- Spreadsheet parameter K9 is the reduced confidence in Pictometry's ability to see and accurately measure elevation offsets relative to surrounding DTMs. Base value = 0.50.
- Spreadsheet parameter K11 is the uncertainty in VISAT being able to see past shrubbery to measure vertical offsets, e.g., top of bottom floor and other elevations, relative to the LAG. Base value = 0.20 based on Pinellas County data.
- Spreadsheet parameter K13 is the unit cost for image identification and measurement of VISAT images to determine addresses and other items required for ECs. Base cost = $35.00, based on Sanborn cost quote.
- Spreadsheet parameter K15 is the unit cost to digitize existing ECs for database entry (bulk processing) into the registry. Base cost = $5.00, based on cost quote from a Dewberry subcontractor for double entry of most entries (with automatic comparison of two files to identify and correct errors), plus a scanned image of the original EC.
- Spreadsheet parameter K17 is the unit cost for batch entries of EC data by all methods other than individual web-based entries of new ECs into the registry. Base cost = $2.50. This value was computed based on $1.5 million estimated cost for developing a web-based registry for batch entry of ECs, plus an estimated $1 each for costs incurred in obtaining an estimated one million ECs from CRS communities that currently hold them. This $1 unit cost for acquisition of ECs is in addition to the estimated cost of $5 for digitizing each hardcopy EC.
- Spreadsheet parameter K18 is the unit cost for individual web-based entry of a single EC into the registry. Base cost = $10.00. This value was computed based on $2.5 million estimated cost for developing a web-based registry for entry of individual ECs, amortized over 5 years assuming 50,000 web-based entries per year.
- Spreadsheet parameter K19 is the unit cost for generation of two or three photogrammetric spot heights per building, assuming that the aero-triangulated digital imagery is already available within a community. Normally, two or three ground elevations at corners of a building are visible in stereo whereas the building itself normally blocks the stereo view of at least one corner spot height per building. Base cost = $10.00, based on cost estimates from BAE/ADR which provided this service for the Susquehanna River Flood Warning and Response System for the Philadelphia District, U.S. Army Corps of Engineers (USACE).
- Spreadsheet parameter K21 is the unit cost for a survey firm to measure all the vertical offsets, relative to LAG elevations or spot heights, count

and measure the area of flood vents, take a digital photo of the building, determine its building diagram number, and verify its address. Base cost = $50 based on Dewberry assumption that 2004 costs would be higher than the USACE's actual unit costs ($85) in 2000, when utilizing an out-of-state surveyor, further increased by appreciated costs between 2000 and 2004, but reduced significantly with the use of a local surveyor, GIS technician, or even a GIS-enabled summer intern hired for this project.

- Spreadsheet parameter K23 is the assumed $300 value of each accurate and complete EC entered into the registry.
- Spreadsheet parameter K25 is the unit cost for Pictometry to load and review 4-view images, to identify EC items to be measured, and to determine elevations relative to the best available DTM. Base cost = $50.00, based on cost quote from Pictometry.
- Spreadsheet parameter K27 is the countywide cost for CCS to use "NoFP" methods to process LIDAR last-return "point cloud" data to automatically extract buildings, determine LAGs and HAGs, and estimate top of bottom floor elevations. Base cost = $10,000 per countywide LIDAR dataset with average area of 500 square miles. There is little difference in cost for small areas or large areas since the process is automated.
- Spreadsheet parameter K29 is the countywide cost for Dewberry to use "w/FP" methods to process LIDAR bare-earth Triangulated Irregular Network (TIN) data to determine LAG elevations when building footprint data is made available to Dewberry in addition to the LIDAR bare earth TIN data. Base cost = $5,000 per countywide LIDAR bare-earth TIN dataset with average area of 500 square miles.
- Spreadsheet parameter K31, the average number of buildings to be measured from a countywide LIDAR or IFSAR dataset. Base value = 1,000.

CE Model Sensitivity to EC Total Value

Table 18 varies the value of ECs in the elevation registry between $100 and $600 each.

Table 18 — CE Model Sensitivity to EC Total Value

Cost-Effectiveness Ratios, Varying the Value of EC Records in Registry	$100	$200	$300 Base	$400	$500	$600
1. Digital ECs, no/inacc. lat/long, batch entry	38.00	76.00	114.0	152.0	190.0	228.0
2. Hardcopy ECs, no/inacc. lat/long, batch entry	12.67	25.33	38.00	50.67	63.33	76.00
3. Hardcopy ECs, no/inacc. lat/long, 1 web entry	6.33	12.67	19.00	25.33	31.67	38.00
4. Hardcopy ECs accurate lat/long, 1 web entry	6.67	13.33	20.00	26.67	33.33	40.00
5. Future ECs, no/inacc. lat/long, 1 web entry	9.50	19.00	28.50	38.00	47.50	57.00
6. Future ECs, accurate lat/long, 1 web entry	10.00	20.00	30.00	40.00	50.00	60.00
7. Photogrammetry (2' CI), no offsets	2.20	4.40	6.60	8.81	11.01	13.21
8. Photogrammetry (2' CI), surveyor offsets	1.41	2.82	4.23	5.64	7.05	8.46
9. Photogr.(2' CI) with footprints, owner offsets	4.41	8.81	13.22	17.62	22.03	26.43
10 Photogrammetry (5' CI), no offsets	0.90	1.79	2.69	3.58	4.48	5.38
11. Photogrammetry (5' CI), surveyor offsets	0.72	1.43	2.15	2.86	3.58	4.30
12. Pictometry with LIDAR DTM	0.80	1.59	2.39	3.19	3.98	4.78
13. LIDAR (2' CI), no footprints, no offsets	1.87	3.74	5.61	7.49	9.36	11.23
14. LIDAR (2' CI) with footprints, no offsets	5.25	10.51	15.76	21.01	26.27	31.52
15. LIDAR (2' CI), no footprints, surveyor offsets	1.23	2.47	3.70	4.94	6.17	7.40
16. LIDAR (2' CI), no footprints, owner offsets *	3.61	7.21	10.82	14.43	18.03	21.64
17. LIDAR (2' CI) with footprints, surveyor offsets	1.53	3.06	4.60	6.13	7.66	9.19
18. LIDAR (2' CI) with footprints, owner offsets	5.87	11.75	17.62	23.49	29.37	35.24
19. IFSAR (10' CI) w/footprints, surveyor offsets	0.26	0.52	0.78	1.04	1.30	1.57
20. Photogrammetric Van (VISAT)	0.63	1.26	1.89	2.52	3.15	3.78

Conclusions from Table 18.

There is a direct linear relationship between the estimated value of an EC in the registry and the variations in CE ratios. The higher the value placed on an EC, the higher the CE ratio for alternative methods for producing elevation data for the registry. This is logical and intuitive. However, because of this linear relationship, Table 18 will not be used below for comparison of best case and worst case scenarios for the various technologies because the $100 value per EC record would artificially force the worst CE ratio and/or the $600 value per EC record would artificially force the best CE ratio for all 20 methods evaluated.

CE Model Sensitivity to Elevation Registry Cost Parameters

Table 19 varies the assumed cost for individual and batch entry of data into the elevation registry over the maximum range of uncertainty.

Table 19 — CE Model Sensitivity to Elevation Registry Cost Parameters

Cost-Effectiveness Ratios, Varying the Unit Costs for Entry of Individual and/or Large Batches of Elevation Records into an Elevation Registry	**Unit cost of individual web entry into elevation registry**					**Unit cost of large batch entry into elevation registry**				
	$5	**$7.50**	**$10 base value**	**$15**	**$20**	**$1**	**$1.75**	**$2.50 Base Value**	**$3.75**	**$5**
1. Digital ECs, no/inacc. lat/long, batch entry						285	163	**114**	76	57
2. Hardcopy ECs, no/inacc. lat/long, batch entry						47	42	**38**	33	29
3. Hardcopy ECs, no/inacc. lat/long, 1 web entry	29	23	**19**	14	11					
4. Hardcopy ECs accurate lat/long, 1 web entry	30	24	**20**	15	12					
5. Future ECs, no/inacc. lat/long, 1 web entry	57	38	**28**	19	14					
6. Future ECs, accurate lat/long, 1 web entry	60	40	**30**	20	15					
7. Photogrammetry (2' CI), no offsets						7.5	7.0	**6.6**	6.0	5.5
8. Photogrammetry (2' CI), surveyor offsets						4.3	4.3	**4.2**	4.2	4.1
9. Photogr. (2' CI) with footprints, owner offsets	18	15	**13**	11	8.8					
10 Photogrammetry (5' CI), no offsets						3.1	2.9	**2.7**	2.4	2.2
11. Photogrammetry (5' CI), surveyor offsets						2.2	2.2	**2.2**	2.1	2.1
12. Pictometry with LIDAR DTM (2' CI)						2.5	2.4	**2.4**	2.3	2.3
13. LIDAR (2' CI), no footprints, no offsets						6.4	6.0	**5.6**	5.1	4.7
14. LIDAR (2' CI) with footprints, no offsets						20	18	**16**	14	12
15. LIDAR (2' CI), no footprints, surveyor offsets						3.8	3.8	**3.7**	3.6	3.6
16. LIDAR (2' CI), no footprints, owner offsets *	14	12	**11**	8.7	7.2					
17. LIDAR (2' CI) with footprints, surveyor offsets						4.7	4.7	**4.6**	4.5	4.4
18. LIDAR (2' CI) with footprints, owner offsets	26	21	**18**	13	11					
19. IFSAR (10' CI) w/footprints, surveyor offsets						0.8	0.8	**0.8**	0.8	0.8
20. Photogrammetric Van (VISAT)						2.0	1.9	**1.9**	1.8	1.8

Conclusions from Table 19

The CE ratios have large variations for those methods where the cost of registry entry is the only cost for the method (as with Methods 1, 5 and 6). The CE ratios have small variations for those methods where the cost of registry entry is a small percentage of the total cost for the method (as with Methods 8, 11, 12, 15, 17, 19 and 20 where the cost of surveyor offsets, Pictometry or VISAT measurements comprise the major cost). All variations are logical and intuitive.

CE Model Sensitivity to Accuracy/Digitization Cost of Existing ECs

Strategy A pertains to Methods 1, 2, 3 and 4. Table 20 shows the sensitivity of the CE model to variations in the accuracy and digitization cost of existing ECs as accuracy and digitization cost parameters are varied by ±50%.

Table 20 — CE Model Sensitivity to Accuracy/Digitization Cost of Existing ECs

A	B	C	D	E	F
Cost-Effectiveness Ratios for Existing (old) Elevation Certificates, entered in an elevation registry, Varying Accuracy and Cost Parameters by ± 50%	**Base Scenario**	**If 50% poorer vertical accuracy than in base scenario**	**If 50% better vertical accuracy than in base scenario**	**If unit costs for digitization of old ECs are 50% less than in base scenario**	**If unit costs for digitization of old ECs are 50% more than in base scenario**
1. Digital ECs, no/inacc. lat/long, batch entry	**114**	109	119	114	114
2. Hardcopy ECs, no/inacc. lat/long, batch entry	**38.0**	36.3	39.7	57.0	28.5
3. Hardcopy ECs, no/inacc. lat/long, 1 web entry	**19.0**	18.2	19.9	22.8	16.3
4. Hardcopy ECs accurate lat/long, 1 web entry	**20.0**	19.2	20.9	24.0	17.1

Conclusions from Table 17, Table 19 and Table 20

A variation of ±50% in the assumed vertical accuracy of existing ECs has minimal effect (<5%) on their CE ratios (see Table 20, columns C and D).

A variation of ±50% in the assumed cost of digitizing old ECs has a moderate effect (up to 20%) on CE ratios for single web entries (Methods 3 and 4) and larger effect (up to 50%) on CE ratios for batch entries (see Table 20, columns E and F) for Method 2. There is no effect on Method 1 where records are already digitized.

Method 1 for existing digital EC records with no latitude/longitude or automated geocoding, using batch entry procedures:

- These ECs have a high value of 95%, but deducted 5% in value because they do not include accurate latitude and longitude needed for update of the registry as BFEs change, etc.

- Best Case Scenario: CE ratio = 285 when the unit cost of large batch entry into the elevation registry is $1 instead of $2.50 (see Table 19, line 1, $1 column).
- Worst Case Scenario: CE ratio = 57 when the unit cost of large batch entry into the elevation registry is $5 instead of $2.50 (see Table 19, line 1, $5 column).

Method 2: For existing hardcopy ECs with no latitude/longitude or automated geocoding, using batch entry procedures:

- These ECs have a high value of 95%, but deducted 5% in value because they do not include accurate latitude and longitude needed for update of the registry as BFEs change, etc.
- Best Case Scenario: CE ratio = 57 when the unit cost for digitizing hardcopy ECs is assumed to be $2.50 instead of $5.00 (see Table 20, line 2, column E).
- Worst Case Scenario: CE ratio = 28.5 when the unit cost for digitizing hardcopy ECs is assumed to cost $7.50 instead of $5.00 (see Table 20, line 2, column F).

Method 3: For existing hardcopy ECs with no latitude/longitude or automated geocoding, using single web entry procedures:

- These ECs have a high value of 95%, but deducted 5% in value because they do not include accurate latitude and longitude needed for update of the registry.
- Best Case Scenario: CE ratio = 29 when the unit cost of individual web entry into the elevation registry is $5 instead of $10 (see Table 19, line 3, $5 column).
- Worst Case Scenario: CE ratio = 11 when the unit cost of individual web entry into the elevation registry is $20 instead of $10 (see Table 19, line 3, $20 column).

Method 4: For existing hardcopy ECs with accurate latitude/longitude, using single web entry procedures:

- These ECs have the maximum value of 100% because they include accurate latitude/longitude needed for update of the registry records.
- Best Case Scenario: CE ratio = 30 when the unit cost of individual web entry into the elevation registry is $5 instead of $10 (see Table 19, line 4, $5 column).
- Worst Case Scenario: CE ratio = 12 when the unit cost of individual web entry into the elevation registry is $20 instead of $10 (see Table 19, line 4, $20 column).

For existing ECs, the CE computer model is most sensitive to the unit cost of entering records into the elevation registry; it is least sensitive to variations in the assumed vertical accuracy of existing ECs.

CE Model Sensitivity to Accuracy of Future Ground-Surveyed ECs

Strategy D pertains to Methods 5 and 6. Table 21 shows the sensitivity of the CE model to variations in the accuracy of future ground-surveyed ECs as accuracy parameters are varied by ±50%.

Table 21 — CE Model Sensitivity to Accuracy of Future Ground-Surveyed ECs

A	B	C	D
Cost-Effectiveness Ratios for Future (new) Elevation Certificates, entered in an elevation registry, Varying Accuracy Parameters by ± 50%	**Base Scenario**	**If 50% poorer vertical accuracy than in base scenario**	**If 50% better vertical accuracy than in base scenario**
5. Future ECs, no/inacc. lat/long, 1 web entry	**28.5**	27.2	29.8
6. Future ECs, accurate lat/long, 1 web entry	**30.0**	28.7	31.3

<u>Conclusions from Table 17, Table 19 and Table 21</u>

Variations of ±50% in the assumed vertical accuracy of future new ECs has minimal effect (<5%) on their CE ratios (see Table 21, columns C and D).

Method 5: Future ECs, no latitude/longitude or georeferenced only, single web entry:

- These ECs have a high value of 95%, but deducted 5% in value because they do not include accurate latitude and longitude needed for update of the registry.
- Best Case Scenario: CE ratio = 57 when the unit cost of individual web entry into the elevation registry is assumed to be $5 instead of $10 assumed in the base scenario (see Table 19, line 5, $5 column).
- Worst Case Scenario: CE ratio = 14 when the unit cost of individual web entry into the elevation registry is assumed to be $20 instead of $10 assumed in the base scenario (see Table 19, line 5, $20 column).

Method 6: Future ECs, accurate latitude/longitude, single web entry:

- These ECs have the maximum value of 100% because they include accurate latitude/longitude needed for update of the registry records.

- Best Case Scenario: CE ratio = 60 when the unit cost of individual web entry into the elevation registry is assumed to be $5 instead of $10 assumed in the base scenario (see Table 19, line 6, $5 column).
- Worst Case Scenario: CE ratio = 15 when the unit cost of individual web entry into the elevation registry is assumed to be $20 instead of $10 assumed in the base scenario (see Table 19, line 6, $20 column).

CE Model Sensitivity to Accuracy/Cost of Photogrammetry ECs

Table 22 shows the sensitivity of the CE model to variations in the accuracy and cost of photogrammetric ECs as accuracy and cost parameters are varied by ±50%.

Table 22 — CE Model Sensitivity to Accuracy/Cost of Photogrammetry ECs

A	B	C	D	E	F	G	H
Cost-Effectiveness Ratios for Photogrammetric Elevation Records, entered in an Elevation Registry, Varying Accuracy and Cost Parameters by ± 50%	**Base Scenario**	**If photogrammetric spot heights 50% poorer vertical accuracy than in base scenario**	**If photogrammetric spot heights 50% better vertical accuracy than in base scenario**	**If photogrammetric spot heights cost 50% less than in base scenario**	**If photogrammetric spot heights cost 50% more than in base scenario**	**If surveyor measured offsets cost 50% less than in base scenario**	**If surveyor measured offsets cost 50% more than in base scenario**
7. Photogrammetry (2' CI), no offsets	**6.6**	7.5	5.7	11.0	4.7	6.6	6.6
8. Photogrammetry (2' CI), surveyor offsets	**4.2**	4.7	3.7	4.6	3.9	7.1	3.0
9. Photogr.(2' CI) with footprints, owner offsets	**13.2**	14.8	11.7	17.6	10.6	13.2	13.2
10 Photogrammetry (5' CI), no offsets	**2.7**	6.1	0.0	4.5	1.9	2.7	2.7
11. Photogrammetry (5' CI), surveyor offsets	**2.2**	4.0	0.7	2.3	2.0	3.6	1.5

Conclusions from Table 17, Table 19 and Table 22

Variations of ±50% in the assumed vertical accuracy of photogrammetric spot heights has a relatively small effect (between 11% and 16%) on the CE ratios of the three 2' CI photogrammetric methods but a major effect (several hundred percent) on the CE ratios of the two 5' CI photogrammetric methods (see Table 22, columns C and D).

Variations of ±50% in the assumed cost of photogrammetric spot heights has a major effect (up to 67%) on the CE ratios of Methods 7 and 10 where photogrammetric spot heights are the major cost, but a small effect (7% to 10%) on the CE ratios of Methods 8 and 11 where surveyor offsets comprise the major cost (see Table 22, columns E and F).

Variations of ±50% in the assumed cost of surveyor offset measurements has no effect on Methods 7, 9 and 10 that don't use surveyor offsets, but a major effect (up to 69%) on the CE ratios of options 8 and 11 because the cost of offset measurements is the major cost driver for these methods (see Table 22, columns G and H).

Method 7: For photogrammetry (2' contours) with no surveyor offsets or data:

- These ECs have a poor value of 27.5% because there is no presumed way to link photogrammetric spot heights with street addresses, and there is no way to determine the correct building diagram number, measure accurate vertical offsets to determine top of bottom floor or LHSM elevations, or measure vents.
- Best Case Scenario: CE ratio = 11 when cost of photogrammetric spot heights are 50% less than in base scenario (see Table 22, line 7, column E).
- Worst Case Scenario: CE ratio = 4.7 when cost of photogrammetric spot heights are 50% more than in base scenario (see Table 22, line 7, column F).

Method 8: For photogrammetry (2' contours) with surveyor offsets and data:

- These ECs have a high value of 88.1% because of the high accuracy spot heights and because the surveyor can perform accurate geocoding, determine the correct building diagram number, measure accurate vertical offsets to determine top of bottom floor and LHSM elevations, and measure vents.
- Best Case Scenario: CE ratio = 7.1 when costs of surveyor measured offsets are 50% less than in base scenario (see Table 22, line 8, column G).
- Worst Case Scenario: CE ratio = 3.0 when costs of surveyor measured offsets are 50% more than in base scenario (see Table 22, line 8, column H).

Method 9: For photogrammetry (2' contours) with owner-provided offsets and data:

- These ECs have a high value of 88.1% because of the high accuracy spot heights and because the home owner can help to identify his/her home on

an orthophoto for accurate geocoding, can provide photos to help the insurance agent determine the correct building diagram number, and can measure vents and vertical offsets needed to determine top of bottom floor and LHSM elevations.
- Best Case Scenario: CE ratio = 18 when the unit cost of individual web entry into the elevation registry is $5 instead of $10 (see Table 19, line 9, $5 column).
- Worst Case Scenario: CE ratio = 8.8 when the unit cost of individual web entry into the elevation registry is $20 instead of $10 (see Table 19, line 9, $20 column).

Method 10: For photogrammetry (5' contours) with no surveyor offsets or data:
- These ECs have a poor value of 11.2% because the spot heights have considerably poorer accuracy than those from 2' contours, because there is no presumed way to link photogrammetric spot heights with street addresses, and because there is no way to determine the correct building diagram number, measure accurate vertical offsets to determine top of bottom floor or LHSM elevations, or measure vents.
- Best Case Scenario: CE ratio = 6.1 when the photogrammetric spot height accuracies are 50% better than in the base scenario (see Table 22, line 10, column C).
- Worst Case Scenario: CE ratio = 0.0 when the photogrammetric spot height accuracies are 50% poorer than in the base scenario (see Table 22, line 10, column D).

Method 11: For photogrammetry (5' contours) with surveyor offsets and data:
- These ECs have a mid value of 44.8% because the spot heights have considerably poorer accuracy than those from 2' contours, providing poor elevation accuracy for LAG, HAG, top of bottom floor, LHSM, etc.
- Best Case Scenario: CE ratio = 4.0 when photogrammetric spot height accuracies are 50% better than in the base scenario (see Table 22, line 11, column C).
- Worst Case Scenario: CE ratio = 0.7 when the photogrammetric spot height accuracies are 50% poorer than in the base scenario (see Table 22, line 11, column D).

CE Model Sensitivity to Accuracy/Cost of Pictometry ECs

Table 23 shows the sensitivity of the CE model to variations in the accuracy and cost of Pictometry ECs as accuracy and cost parameters are varied by ±50%.

Table 23 — CE Model Sensitivity to Accuracy/Cost of Pictometry ECs

A	B	C	D	E	F
Cost-Effectiveness Ratios for Pictometry Elevation Records, entered in an Elevation Registry, Varying Accuracy and Cost Parameters by ± 50%	**Base Scenario**	**If Pictometry relative elevation accuracy is 50% poorer than in base scenario**	**If Pictometry relative elevation accuracy is 50% better than in base scenario**	**If Pictometry unit measurement costs are 50% less than in base scenario**	**If Pictometry unit measurement costs are 50% higher than in base scenario**
12. Pictometry with LIDAR DTM (2' CI)	**2.4**	1.8	3.0	4.6	1.6

<u>Conclusions from Table 17, Table 19 and Table 23</u>

A variation of ±50% in the assumed vertical accuracy of Pictometry's relative elevations has a moderate effect (up to 33%) on the CE ratio of the Pictometry method (see Table 23, columns C and D).

A variation of ±50% in the assumed unit costs for Pictometry measurements has a major effect (up to 92%) on the CE ratio of the Pictometry option (see Table 23, columns E).

Method 12: For Pictometry with LIDAR DTM, 2' CI:

- These ECs have a mid value of 41.8% because Pictometry's relative elevations sometimes misidentify basements, because without a separate georeferenced address file there is no presumed way to link Pictometry images of houses with their street addresses for geocoding, and because there is no way to measure vents. However, Pictometry's greatest value is in "seeing" each house in perspective and identification of illegal construction — factors not considered in assessing the value of ECs.
- Best Case Scenario: CE ratio = 4.6 when the unit cost of Pictometry measurements are 50% less than in base scenario (see Table 23, line 12, column E).

- Worst Case Scenario: CE ratio = 1.6 when the unit cost of Pictometry measurements are 50% more than in base scenario (see Table 23, line 12, column F).

CE Model Sensitivity to Accuracy/Cost of LIDAR ECs

Table 24 shows the sensitivity of the CE model to variations in the accuracy and cost of LIDAR ECs as accuracy and cost parameters are varied by ±50%.

Table 24 — CE Model Sensitivity Accuracy/Cost of LIDAR ECs

A	B	C	D	E	F	G	H
Cost-Effectiveness Ratios for LIDAR Elevation Records, entered in an Elevation Registry, Varying Accuracy and Cost Parameters by ± 50%	**Base Scenario**	**If LIDAR elevations have 50% poorer vertical accuracy than in base scenario**	**If LIDAR elevations have 50% better vertical accuracy than in base scenario**	**If LIDAR processing unit costs are 50% less than in base scenario**	**If LIDAR processing unit costs are 50% more than in base scenario**	**If 1,500 homes are automatically processed instead of the 1,000 in base scenario**	**If 500 homes are automatically processed instead of the 1,000 in base scenario**
13. LIDAR (2' CI), no footprints, no offsets	**5.6**	4.8	6.4	9.4	4.0	7.7	3.1
14. LIDAR (2' CI) with footprints, no offsets	**15.8**	13.8	17.7	23.6	11.8	20.3	9.5
15. LIDAR (2' CI), no footprints, surveyor offsets	**3.7**	3.3	4.1	4.0	3.4	3.9	3.2
16. LIDAR (2' CI), no footprints, owner offsets *	**10.8**	9.5	12.1	14.4	8.7	13.0	7.2
17. LIDAR (2' CI) with footprints, surveyor offsets	**4.6**	4.1	5.1	4.8	4.4	4.7	4.2
18. LIDAR (2' CI) with footprints, owner offsets	**17.6**	15.6	19.7	21.1	15.1	19.8	13.2

<u>Conclusions from Table 17, Table 19 and Table 24</u>

Variations of ±50% in the assumed vertical accuracy of LIDAR elevations has a relatively minor effect (up to 16%) on the CE ratios of the six LIDAR options (see Table 24, columns C and D). Column D represents accuracy actually tested in Beaufort County, SC.

Variations of ±50% in the assumed cost of LIDAR processing has a major effect (33% to 679%) on the CE ratios of the two LIDAR options (Methods 13, 14) with no offsets, but lesser effects (4% to 33%) on the four LIDAR options with offsets (see Table 24, columns E and F).

Variations of ±50% in the number of homes with LIDAR automatically processed per community has a small effect (5% to 15%) on the CE ratios of the two LIDAR methods (15 and 17) with surveyor offsets; a large effect (37% to 80%) on the CE ratios of the two LIDAR methods (13 and 14) with no offsets; and a small to moderate effect (12% to 50%) on the CE ratios of the two LIDAR methods (16 and 18) with owner-provided offsets (see Table 24, columns G and H).

Method 13: For LIDAR, no footprints, no surveyed offsets:

- These ECs have a low value of 23.4% because there is no presumed way to link LIDAR mass points with street addresses for geocoding, and there is no way to determine the correct building diagram number, measure accurate vertical offsets for determination of top of bottom floor or LHSM elevations, or measure flood vents.
- Best Case Scenario: CE ratio = 9.4 when LIDAR processing unit costs are 50% less than assumed in the base scenario (see Table 24, line 13, column E).
- Worst Case Scenario: CE ratio = 3.1 when only 500 homes are automatically processed per county instead of 1,000 assumed in the base scenario (see Table 24, line 13, column H). .

Method 14: For LIDAR with footprints, no surveyed offsets:

- These ECs have a mid value of 39.4% because there is no way to determine the correct building diagram number, measure accurate vertical offsets needed for top of bottom floor and LHSM elevations, and measure flood vents.
- Best Case Scenario: CE ratio = 23.6 when LIDAR processing unit costs are 50% less than assumed in the base scenario (see Table 24, line 14, column E).
- Worst Case Scenario: CE ratio = 9.5 when only 500 homes are automatically processed per county instead of 1,000 assumed in the base scenario (see Table 24, line 14, column H).

Method 15: For LIDAR, no footprints, surveyor offsets:

- These ECs have a relatively high value of 77.1% because of the relatively high accuracy LIDAR mass points with buildings automatically extracted, and because the surveyor can perform accurate geocoding, determine the correct building diagram number, measure accurate vertical offsets, and measure flood vents.
- Best Case Scenario: CE ratio = 4.1 when LIDAR vertical accuracy is 50% better than assumed in the base scenario (see Table 24, line 15, column D).
- Worst Case Scenario: CE ratio = 3.2 when only 500 homes are automatically processed per county instead of 1,000 assumed in the base scenario (see Table 24, line 15, column H).

- This CE cost model is remarkably stable, with maximum and minimum values fluctuating only between 3.2 and 4.1 for all variables.

Method 16: For LIDAR, no footprints, owner-provided offsets:

- These ECs are color-coded magenta (not do-able) because the homeowner has no good way to link the street address with the LIDAR data for geocoding and determination of BFE. The various surveyor methods (e.g., Method 15) are presumed to have GIS tools to overlay LIDAR points on digital orthophotos to assist in identification of houses, but a homeowner or Insurance Agent (e.g., Method 16) is not presumed to have this capability. This method can only be considered if there is some alternative means for the home owner to know which LIDAR LAG/HAG elevations pertain to his/her house; only then can best and worst case scenarios be considered:
- Best Case Scenario: CE ratio = 14.4 when the LIDAR processing unit costs are 50% less than assumed in the base scenario (see Table 24, line 16, column E).
- Worst Case Scenario: CE ratio = 7.2 when the unit cost of individual web entry into the elevation registry is $20 instead of $10 assumed in the base scenario (see Table 19, line 16, $20 column) and when only 500 homes are automatically processed per county instead of 1,000 assumed in the base scenario (see Table 24, line 16, column H).

Method 17: For LIDAR with footprints, surveyor offsets:

- These ECs have a high value of 88.1% because of the high accuracy LIDAR mass points and because the surveyor can perform accurate geocoding, determine the correct building diagram number, measure accurate vertical offsets for accurate determination of top of bottom floor and LHSM elevations, and measure flood vents.
- Best Case Scenario: CE ratio = 5.1 when LIDAR elevations have 50% better vertical accuracy than in base scenario (see Table 24, line 17, column D). The best case scenario is a real possibility since LIDAR datasets sometimes are tested at accuracies equivalent to 1' contours rather than the normal 2' contours.
- Worst Case Scenario: CE ratio = 4.1 when LIDAR elevations have 50% poorer vertical accuracy than in base scenario (see Table 24, line 17, column C).
- This CE cost model is remarkably stable, with maximum and minimum values fluctuating only between 4.1 and 5.1 for all variables. Technical methods are stable as parameters are varied when the methods yield geocoded positions as well as accurate top of bottom floor, LHSM and LAG elevations. Methods are less stable when they do some tasks well and other tasks poorly.

Method 18: For LIDAR with footprints, owner-provided offsets:

- These ECs have a high value of 88.1% because of the high accuracy LIDAR mass points which are addressed because of the footprints, and because the home owner can provide photos to help the insurance agent determine the correct building diagram number, and can measure flood vents and vertical offsets needed to determine top of bottom floor or LHSM elevation.
- Best Case Scenario: CE ratio = 26 when unit cost of individual web entry into the elevation registry is $5 instead of $10 assumed in the base scenario (see Table 19, line 18, $5 column).
- Worst Case Scenario: CE ratio = 11 when unit cost of individual web entry into the elevation registry is $20 instead of the assumed $10 (see Table 19, line 18, $20 column).

CE Model Sensitivity to Accuracy/Cost of IFSAR ECs

Table 25 shows the sensitivity of the CE model to variations in the accuracy and cost of IFSAR ECs as accuracy and cost parameters are varied by ±50%.

Table 25 — CE Model Sensitivity to Accuracy/Cost of IFSAR ECs

A	B	C	D	E	F	G	H
Cost-Effectiveness Ratios for IFSAR Elevation Records, entered in an Elevation Registry, Varying Accuracy and Cost Parameters by ± 50%	**Base Scenario**	**If IFSAR elevations have 50% poorer vertical accuracy than in base scenario**	**If IFSAR elevations have 50% better vertical accuracy than in base scenario**	**If IFSAR processing unit costs are 50% less than in base scenario**	**If IFSAR processing unit costs are 50% more than in base scenario**	**If 1,500 homes are automatically processed instead of the 1,000 in base scenario**	**If 500 homes are automatically processed instead of the 1,000 in base scenario**
19. IFSAR (10' CI) w/footprints, surveyor offsets	**0.78**	0.78	2.33	0.82	0.75	0.81	0.72

Conclusions from Table 17, Table 19 and Table 25

A variation of ±50% in the assumed vertical accuracy of IFSAR elevations has a huge effect (up to 300%) on the CE ratios of the IFSAR option (see Table 25, line 19, column D) because improving the vertical accuracy from the equivalent of 10' contours to the equivalent of 5' contours drastically changes the value of the EC elevation data (LAG/HAG and derived top of bottom floor or LHSM elevations).

A variation of ±50% in the assumed costs of IFSAR processing has an insignificant effect on the CE ratio of the IFSAR method (see Table 25, line 19, columns E and F). A variation of ±50% in the number of homes with IFSAR automatically processed per community has a minor effect on the CE ratios of the IFSAR method (see Table 25, line 19, columns G and H).

Method 19: IFSAR with footprints, surveyor offsets:

- These ECs have a low value of 15.0% because of poor accuracy of the IFSAR data which is assumed to be equivalent to 10' contours in the base scenario, having no value to the elevations of LAG, HAG, top of bottom floor, LHSM, or other elevations for purposes of *eRating*.
- Best Case Scenario: CE ratio = 2.33 when the vertical accuracy of the IFSAR data is 50% better than assumed in the base scenario, i.e., equivalent to 5' contours instead of 10' contours (see Table 25, line 19, column D).
- Worst Case Scenario: CE ratio = 0.72 when only 500 houses are automatically processed per county rather than 1,000 houses assumed in the base scenario (see Table 25, line 19, column H).

CE Model Sensitivity to Accuracy/Cost of Photogrammetric Van ECs

Strategy C pertains to Method 20 only. Table 26 shows the sensitivity of the CE model to variations in the accuracy and cost of photogrammetric van ECs as accuracy and cost parameters are varied by ±50%.

Table 26 — CE Model Sensitivity to Accuracy/Cost of Photogrammetric Van ECs

A	B	C	D	E	F
Cost-Effectiveness Ratios for Photogrammetric Van Elevation Records, entered in an Elevation Registry, Varying Accuracy and Cost Parameters by ± 50%	**Base Scenario**	**If photogrammetric van elevations are 50% poorer than in base scenario**	**If photogrammetric van elevations are 50% better than in base scenario**	**If VISAT's unit measurement costs are 50% less than in base scenario**	**If VISAT's unit measurement costs are 50% higher than in base scenario**
20. Photogrammetric Van (VISAT)	**1.89**	1.63	2.09	3.54	1.29

Conclusions from Table 17, Table 19 and Table 26.

A variation of ±50% in the assumed vertical accuracy of VISAT elevations has an small effect (10% to 16%) on the CE ratio of the VISAT option (see Table 26, line 20, columns C and D).

A variation of ±50% in the assumed costs of VISAT processing has a major effect (46% to 87%) on the CE ratio of the VISAT option (see Table 26, line 20, columns E and F).

Line 20: VISAT Photogrammetric Van:

- These ECs have a low value of 23.6% because of the VISAT's inability (demonstrated in Pinellas County, FL) to see (in stereo) the majority of the target points to be surveyed. It is possible that improved camera configuration could solve a major part of this problem, or that other geographic areas may have considerably less vegetation that blocks the view of features to be surveyed. When target points were visible in stereo, they were surveyed with vertical accuracy of 1.5' at the 95% confidence level, which is good.
- Best Case Scenario: CE ratio = 3.54 when the VISAT unit measurement costs are 50% less than assumed in the base scenario (see Table 26, line 20, column E).
- Worst Case Scenario: CE ratio = 1.29 when the VISAT unit measurement costs are 50% more than assumed in the base scenario (see Table 26, line 20, column F).

STRATEGY SUMMARIES

This section explains all strategies and methods summarized in Table 27 and synopsizes the advantages, disadvantages, costs and conclusions for each. Using "stop light" analogy, green represents high value data, amber represents mid value data, and red represents relatively low value data. However, lower value methods with high CE ratios provide better return for each dollar invested, even though they don't necessarily produce EC records of the highest quality.

Table 27 — Summary of Elevation Alternatives

Strategy	Method	Major Limitations	% Value	Unit Cost	CE Ratio
A	1. Digital ECs, no/inacc. lat/long, batch entry	No latitude & longitude	**95.0**	$2.50	114.0
A	2. Hardcopy ECs, no/inacc. lat/long, batch entry	No latitude & longitude	**95.0**	$7.50	38.00
A	3. Hardcopy ECs, no/inacc. lat/long, 1 web entry	No latitude & longitude	**95.0**	$15.00	19.00
A	4. Hardcopy ECs accurate lat/long, 1 web entry	None	**100**	$15.00	20.00
D	5. Future ECs, no/inacc. lat/long, 1 web entry	No latitude & longitude	**95.0**	$10.00	28.50
D	6. Future ECs, accurate lat/long, 1 web entry	None	**100**	$10.00	30.00
B	7. Photogrammetry (2' CI), no offsets	Slightly less accurate + no TBF elev, address, bldg diag, vents	**27.5**	$12.50	6.60
B & E	8. Photogrammetry (2' CI), surveyor offsets	Slightly less accurate than ground surveys	**88.1**	$62.50	4.23
B & E	9. Photogr.(2' CI) with footprints, owner offsets	Slightly less accurate than ground surveys	**88.1**	$20.00	13.22
B	10 Photogrammetry (5' CI), no offsets	Considerably less accurate + no TBF elev, address, bldg diag, vents	**11.2**	$12.50	2.69
B & E	11. Photogrammetry (5' CI), surveyor offsets	Considerably less accurate than ground surveys	**44.8**	$62.50	2.15
B	12. Pictometry with LIDAR DTM	No address, some misidentified basements	**41.8**	$52.50	2.39
B	13. LIDAR (2' CI), no footprints, no offsets	Somewhat less accurate + no TBF elev, address, bldg diag, vents	**23.4**	$12.50	5.61
B & E	14. LIDAR (2' CI) with footprints, no offsets	Slightly less accurate than ground svy + no TBF elev, bldg diag, vents	**39.4**	$7.50	15.76
B & E	15. LIDAR (2' CI), no footprints, surveyor offsets	Somewhat less accurate than ground surveys	**77.1**	$62.50	3.70
B & E	16. LIDAR (2' CI), no footprints, owner offsets/data *	Somewhat less accurate plus errors or difficulty in owner georeferencing	**72.1**	$20.00	10.82
B & E	17. LIDAR (2' CI) with footprints, surveyor offsets	Slightly less accurate than ground surveys	**88.1**	$57.50	4.60
B & E	18. LIDAR (2' CI) with footprints, owner offsets/data	Slightly less accurate than ground surveys	**88.1**	$15.00	17.62
B & E	19. IFSAR (10' CI) with footprints, surveyor offsets	Accuracy has zero value to registry	**15.0**	$57.50	0.78
C	20. Photogrammetric Van (VISAT)	Can't measure many points because foliage blocks stereo view	**23.6**	$37.50	1.89

Table 28 summarizes the 20 methods ranked by their total value and by their range of possible CE ratios. Some of the lower-ranked methods (amber and red) have better CE ratios because they cost relatively little to produce elevation data of some usable but lesser value, e.g., method 14 which costs only $7.50 per house can generate records with 39.4% of the value of a $300 EC while providing data potentially usable for LOMA determinations, and a framework for future addition of on-site measurements to complete high value records.

Table 28 — Methods Ranked by Overall Value of EC Records

Method	Major Limitations	% Value	Best CE Ratio	Worst CE Ratio
6. Future ECs, accurate lat/long, 1 web entry	None	**100**	60	15
4. Hardcopy ECs accurate lat/long, 1 web entry	None	**100**	30	12
1. Digital ECs, no/inacc. lat/long, batch entry	No latitude & longitude	**95.0**	285	57
2. Hardcopy ECs, no/inacc. lat/long, batch entry	No latitude & longitude	**95.0**	57	28.5
5. Future ECs, no/inacc. lat/long, 1 web entry	No latitude & longitude	**95.0**	57	14
3. Hardcopy ECs, no/inacc. lat/long, 1 web entry	No latitude & longitude	**95.0**	29	11
18. LIDAR (2' CI) with footprints, owner offsets/data	Slightly less accurate than ground surveys	**88.1**	26	11
9. Photogr.(2' CI) with footprints, owner offsets	Slightly less accurate than ground surveys	**88.1**	18	8.8
8. Photogrammetry (2' CI), surveyor offsets	Slightly less accurate than ground surveys	**88.1**	7.1	3.0
17. LIDAR (2' CI) with footprints, surveyor offsets	Slightly less accurate than ground surveys	**88.1**	5.1	4.1
15. LIDAR (2' CI), no footprints, surveyor offsets	Somewhat less accurate than ground surveys	**77.1**	4.1	3.2
16. LIDAR (2' CI), no footprints, owner offsets/data *	Somewhat less accurate plus errors or difficulty in owner georeferencing	**72.1**	**14.4**	**7.2**
11. Photogrammetry (5' CI), surveyor offsets	Considerably less accurate than ground surveys	**44.8**	4.0	0.7
12. Pictometry with LIDAR DTM	No address, some misidentified basements	**41.8**	4.6	1.6
14. LIDAR (2' CI) with footprints, no offsets	Slightly less accurate than ground svy + no TBF elev, bldg diag, vents	**39.4**	23.6	9.5
7. Photogrammetry (2' CI), no offsets	Slightly less accurate + no TBF elev, address, bldg diag, vents	**27.5**	11.0	4.7
20. Photogrammetric Van (VISAT)	Can't measure many points because foliage blocks stereo view	**23.6**	3.5	1.3
13. LIDAR (2' CI), no footprints, no offsets	Somewhat less accurate + no TBF elev, address, bldg diag, vents	**23.4**	9.4	3.1
19. IFSAR (10' CI) with footprints, surveyor offsets	Accuracy has zero value to registry	**15.0**	2.3	0.7
10 Photogrammetry (5' CI), no offsets	Considerably less accurate + no TBF elev, address, bldg diag, vents	**11.2**	6.1	0.0

Table 29 summarizes the various methods ranked by their total cost. Method 1 refers to existing digital elevation records, assumed to be of high value (green), that can be incorporated into the registry most cost effectively ($2.50), either with or without accurate latitude/longitude. Method 2 is the next low-cost option that yields high value records. Method 14, which costs only $7.50 per house, provides geocoded addresses and accurate LAG elevations, but not top of bottom floor elevations. Low value records (red) plus Method 12 (amber) do not provide street addresses but latitude/longitude coordinates only — making these methods generally unusable in a GIS until the community can provide reverse-geocoding. All of the higher cost methods involve surveyor-provided offset measurements and supporting data batch processed community-wide.

Table 29 — Methods Ranked by Overall Cost of EC Records

Method	% Value	Web Entry Costs	R.S. Data Process Costs	Offset Measure -ment Costs	Digiti-zation Costs	Total Unit Costs
1. Digital ECs, no/inacc. lat/long, batch entry	**95.0**	$2.50				$2.50
2. Hardcopy ECs, no/inacc. lat/long, batch entry	**95.0**	$2.50			$5	$7.50
14. LIDAR (2' CI) with footprints, no offsets	**39.4**	$2.50	$5			$7.50
6. Future ECs, accurate lat/long, 1 web entry	**100**	$10				$10
5. Future ECs, no/inacc. lat/long, 1 web entry	**95.0**	$10				$10
7. Photogrammetry (2' CI), no offsets	**27.5**	$2.50	$10			$12.50
13. LIDAR (2' CI), no footprints, no offsets	**23.4**	$2.50	$10			$12.50
10 Photogrammetry (5' CI), no offsets	**11.2**	$2.50	$10			$12.50
4. Hardcopy ECs accurate lat/long, 1 web entry	**100**	$10			$5	$15
3. Hardcopy ECs, no/inacc. lat/long, 1 web entry	**95.0**	$10			$5	$15
18. LIDAR (2' CI) with footprints, owner offsets/data	**88.1**	$10	$5			$15
9. Photogr. (2' CI) with footprints, owner offsets	**88.1**	$10	$10			$20
16. LIDAR (2' CI), no footprints, owner offsets/data *	**72.1**	**$10**	**$10**			**$20**
20. Photogrammetric Van (VISAT)	**23.6**	$2.50	$35			$37.50
12. Pictometry with LIDAR DTM	**41.8**	$2.50	$50			$52.50
17. LIDAR (2' CI) with footprints, surveyor offsets	**88.1**	$2.50	$5	$50		$57.50
19. IFSAR (10' CI) with footprints, surveyor offsets	**15.0**	$2.50	$5	$50		$57.50
8. Photogrammetry (2' CI), surveyor offsets	**88.1**	$2.50	$10	$50		$62.50
15. LIDAR (2' CI), no footprints, surveyor offsets	**77.1**	$2.50	$10	$50		$62.50
11. Photogrammetry (5' CI), surveyor offsets	**44.8**	$2.50	$10	$50		$62.50

Strategy A — Existing Elevation Certificates

Strategy A pertains to all existing ECs, including those already in digital format plus hardcopy ECs that require digitization, quality control and entry into the registry (methods 1, 2, 3 and 4). Existing ECs are high value records, between 95% and 100% of maximum value, depending on the accuracy of latitude and longitude coordinates. They are assumed to have the highest elevation accuracy of ±0.5 ft at the 95% confidence level.

Advantages: Ground-surveyed ECs provide the maximum benefits in all Table 17 categories with high total values and CE ratios. GPS ECs are better than conventional ECs because GPS provides accurate latitude and longitude of the surveyed buildings needed for a GIS-based registry and for revisions to BFEs and other updates. Ground surveys, combining GPS and conventional survey procedures, provide the most accurate and complete way to generate EC data.

Disadvantage: Some existing ECs have missing data and questionable accuracy, and they generally lack latitude and longitude. As shown in Table 8, geocoding services often have positioning errors of several hundred feet. Still, these issues are less significant that any of the other airborne remote sensing methods and alternative datasets evaluated herein.

Costs: Compared with the assumed $300 value of each EC when surveyed community-wide, the costs for entering existing ECs into the registry are minimal and include: (a) $5 each for digitization of ECs when mass produced, (b) $2.50 each for batch entry into the registry, and (c) $10 each for entry of individual ECs into the registry. When community ECs are mass processed (Method 2), hardcopy ECs can be digitized for as little as $5 each on average with an additional $2.50 each for quality control and processing into the registry. Digitization, quality control and entry of individual ECs into the registry (Methods 3 and 4) cost $15 per record when assuming $10 each for development of the web-based registry.

Conclusion: Land survey methods used for existing ECs can achieve elevation accuracy of ± 0.5 ft at the 95% confidence level for the lowest floor, LAG and HAG. Existing EC data already in digital format (Method 1) can most efficiently be converted into the elevation registry data format for an estimated average cost of $2.50 per record. Existing hardcopy ECs held by communities, ISO and others (Method 2) could also be digitized, quality controlled and entered into the registry for an estimated average cost of $7.50 per record. When alternative elevation records are already in digital format (e.g., Policies in Force, LOMA 2000, Corps of Engineers), they can be quality controlled and reformatted for the registry for an estimated $2.50 each, but such alternative records typically have issues pertaining to accuracy and completeness. Methods 1 and 2 are the most obvious for initial implementation of the registry.

Strategy B — Airborne Remote Sensing — Photogrammetry

Photogrammetry methods 7, 8, 9, 10 and 11 assume that a community has aerial photography and aerial triangulation (AT) data suitable for generating digital elevation data equivalent to either 2' or 5' contours, two of the most common contour intervals, which can be provided for additional photogrammetric mapping of footprints and spot heights used for LAG and HAG elevations.

Advantages: This research project has demonstrated that photogrammetric spot heights can be generated with predictable accuracy (related to the supported contour interval) at adjacent grades next to the corners of houses, while also providing latitude/longitude. Spot heights can be used to mass produce accurate LAG/HAG elevations, but not top of bottom floor elevations needed for ECs.

Disadvantages: From photogrammetry alone, street addresses are unknown and require on-site address determinations. Similarly, top of bottom floor and lowest horizontal structural member (LHSM) elevations cannot be measured or accurately estimated because the map compiler cannot see inside buildings to map unseen features. Supplementary measurements and data needed to complete ECs must be provided by contracted surveyors or others (e.g., summer GIS interns) for batch entry into the registry, or individually provided by homeowners who measure vertical offsets and provide other required information to their insurance agent for completing individual records in the registry.

Costs: When mass produced, it costs an estimated $10 per house for building footprints and spot heights, plus an additional $50 per house for a surveyor to visit each house to link the street address to the latitude/longitude, to make vertical offset measurements for top of bottom floor/LHSM elevations, etc., to determine the building diagram number, and to record vent data. It costs an additional $2.50 per house for batch entry of the data into the registry, for a total cost of $62.50 per house for Method 8 which yields high quality data (green) and Method 11 which yields mid quality data (amber) . For methods 7 and 10, the on-site data is not acquired and the unit costs are only $12.50 per house, but the quality is poor (red in Table 29) as top of bottom floor/LHSM elevations, latitude and longitude, building diagram numbers and vent information are missing. Method 9 uses the homeowner, working in cooperation with the insurance agent, to substitute for the surveyor, and then the ECs are processed individually into the registry at an estimated total cost of $20 per house for high quality records.

Conclusion: When a community already has 2' photogrammetric contours, photogrammetric spot heights combined with on-site offset measurements can achieve elevation accuracy of ±1.2 ft at the 95% confidence level for the lowest floor, LAG and HAG. Of the photogrammetric methods 7 through 11 considered for this study, Method 8 stands out as the most practical, costing an estimated average of $62.50 per record, $50 of which is the estimated unit cost for on-site offset measurements.

Strategy B — Airborne Remote Sensing — Pictometry

Pictometry Method 12 assumes that a community already has Pictometry imagery that can be further utilized to support elevation registry requirements.

Advantages. This research project has demonstrated that Pictometry oblique images are the only airborne remote sensing tools that can: (1) determine the existence or absence of basement windows and vents much of the time, (2) see and measure the vertical offsets between LAG and top of bottom floor elevations, and (3) determine the building diagram numbers. These oblique images are also useful in identification of unauthorized construction.

Disadvantages. As with other airborne remote sensing technologies, street addresses cannot be determined from Pictometry images. However, the major disadvantage is that Pictometry elevations are not *absolute*, but *relative* to LAG/HAG elevations extracted from the best available digital terrain models (DTMs). This research project demonstrated that elevations may be accurate or inaccurate, depending on the DTMs used and the presence or absence of trees and shrubbery that obscure views of basement windows, vents, etc. If accurate DTMs are not available, Pictometry defaults to the use of USGS DEMs which normally lack accuracy needed for registry entries. Also, Pictometry images cannot see beneath buildings to measure offsets to LHSM elevations in V-zones.

Costs. When Pictometry imagery is already available, analyses and measurements of the imagery cost approximately $50 per house, but volume discounts would apply. Batch entry of EC data into the registry costs an additional $2.50 for a total cost of $52.50 per house by this method.

Conclusions. We conclude that this method is unreliable for its intended *e*Rating purpose. Pictometry datasets evaluated in Prince George's County, MD, and Arlington County, VA had mixed results that were not particularly impressive because of the relatively high percentage of structures for which the presence or absence of basements was misinterpreted, causing large errors in top of bottom floor elevations. Since the LAG/HAG elevations already came from LIDAR or other sources, the Pictometry imagery provided marginal additional benefits for generating data needed for ECs. Therefore, even though Pictometry is the only airborne remote sensing method that can detect basement windows and vents, and the only airborne remote sensing method that can see and measure vertical offsets between LAG and top of bottom floor elevations, Dewberry concludes that the major advantage of this technology is to provide the insurance agent or others with a "birds eye" view of the structure from all sides to help in "seeing" the building being insured, and also to help in identification of unauthorized construction. The error rate is simply too high to accept Pictometry interpretations as authoritative regarding the presence or absence of basements.

Strategy B — Airborne Remote Sensing — LIDAR

LIDAR methods 13, 14, 15, 16, 17 and 18 assume that a community already has LIDAR data suitable for generating digital elevation data equivalent to 2' contours or better and this data can be processed by LIDAR specialists to determine LAG and HAG elevations when LAG/HAG points are visible from the air.

Advantages. This project has demonstrated that LIDAR data can be used to generate LAG and HAG elevations with ≈ 1' vertical accuracy that improves with the availability of building footprints, narrower post spacing and other variables. Although LAG and HAG elevations may be accurate enough to be used for LOMA's, estimated top of bottom floor elevations are unreliable.

Disadvantages. From LIDAR alone, street addresses are unknown and require on-site address determinations. Similarly, top of bottom floor/LHSM elevations cannot be measured directly because the LIDAR cannot map inside buildings; top of bottom floor elevations can be estimated, but with a high error rate that Dewberry considers to be unacceptable. Utilizing Strategy E, supplementary measurements and data needed to complete ECs must be provided by contracted surveyors or others (e.g., summer GIS interns) for batch entry into the registry, or individually provided by homeowners who measure vertical offsets and provide street addresses, photos, vent and other required information to their insurance agents for completing individual records in the registry.

Costs. When counties already have LIDAR raw "point cloud" data and bare-earth DTM datasets in TIN format, entire small- to mid-sized counties can be post-processed to determine accurate LAG and HAG elevations of all buildings for a total cost of approximately $5,000 per county if building footprint files are available and linked to street addresses, or $10,000 per county if there are no footprints — regardless of the number of buildings to be processed in the county. Because these processes are automated, costs do not increase appreciably for larger numbers of houses to be processed. However, it still costs an estimated $50 per structure for surveyors to measure offsets and collect the ancillary information, unless done so by individual homeowners working with their Insurance Agents. With various assumptions, methods 17 and 15 cost $57.50 to $62.50 on average per structure for high quality data; method 18 costs $15 for high quality data; and methods 14 and 13 cost $7.50 to $12.50 per structure for mid to low quality data, with quality largely depending on the availability of building footprints linked to street addresses. Method 16 is ineffective.

Conclusions. When a community already has LIDAR data equivalent to 2' contours or better, LIDAR Method 17 (with on-site offset measurements) can achieve elevation accuracy of ±1.2 ft or less at the 95% confidence level for the lowest floor, LAG and HAG at an average estimated cost of $57.50 per record. Method 14 (without offset measurements) can achieve elevation accuracy of ±1.2 ft for the LAG and HAG only, suitable for mass LOMA determinations.

Strategy B — Airborne Remote Sensing — IFSAR

IFSAR method 19 assumes that a county or state has IFSAR data suitable for generating digital elevation data equivalent to 10' contours and this data can be further processed by IFSAR specialists to determine LAG and HAG elevations.

Advantages. The major advantage of IFSAR is that it is the least expensive way to collect elevation data of large areas, often entire states rather than individual counties or communities. IFSAR provides accurate latitude and longitude information plus ortho-rectified radar images that can be interpreted by radar analysts. Where there is little or no vegetation, IFSAR data can provide bare-earth elevations comparable to 10-foot contours.

Disadvantages. Of all methods evaluated for this study, IFSAR is the least accurate way to collect LAG/HAG elevations. IFSAR collects digital surface models (DSMs) of top surfaces, trees and rooftops; procedures for generating bare-earth elevations are not yet reliable. New IFSAR technology, designed to provide better penetration of vegetation, has not yet been proven to provide accurate bare-earth elevations near buildings and other vertical surfaces. IFSAR also needs on-site measurements and data collection to complete other information required for ECs. As shown in Figure 7 (bottom), IFSAR imagery is noisy and more difficult to interpret than film or digital images commonly used.

Costs. When counties already have IFSAR datasets and footprints, entire counties can be post-processed to determine LAGs of all buildings for a total cost of approximately $5,000, regardless of the number of buildings involved. If assuming 1000 ECs are produced per average community, the unit cost comes to $5 per structure. If footprints are not available, a radar image analyst will need to manually interpret the images in order to estimate building footprints, around which LAG and HAG elevations are extracted. It costs an estimated $50 per structure to measure offsets and collect other ancillary information needed, unless done so by individual homeowners working with their Insurance Agents. With various other assumptions, Method 19 costs an estimated $57.50 per house to mass produce low-quality records. Until IFSAR is better able to penetrate vegetation to acquire accurate bare-earth DTMs adjacent to buildings, there is no IFSAR option that produces high-accuracy elevation records.

Conclusions. We conclude that this method is unreliable for its intended *e*Rating purpose. IFSAR methods combined with on-site offset measurements can achieve elevation accuracy of ±6 ft at the 95% confidence level for the lowest floor, LAG and HAG. FEMA's criteria determined that methods having elevation errors larger than 4 ft were of no value for *e*Rating purposes.

Strategy C — Vehicular Remote Sensing

Method 20 assumes that imagery from VISAT or other photogrammetric van is available for a community.

Photogrammetric Van Advantages. For communities that already have imagery from VISAT or other photogrammetric vans, accurate ECs can be produced therefrom provided shrubbery does not block the needed views of target points to be surveyed in stereo. Elevations tested in Pinellas County, FL were accurate to 1.5 ft at the 95% confidence level. When LAG and HAG elevations are available from another source (e.g., photogrammetry, LIDAR, IFSAR) and address numbers are visible, photogrammetric vans could be used to collect addresses, building diagram numbers, vertical offset measurements for top of bottom floor and other elevations, and vent information, but not elevation of lowest machinery if air conditioner pads, for example, are in the back yard where they can't be seen from the street.

Photogrammetric Van Disadvantages. The sample tests in Pinellas County concluded that the bottom of front door and other target points could only be seen in stereo for about 20% of the houses; the remaining 80% were unsuitable for data extraction because of foliage that blocked stereo views of features to be surveyed. Latitude and longitude measurements could be made on all houses, but not the critical elevations. Also, imagery from the street cannot see in back yards to detect the possible existence of walk-out basements.

Photogrammetric Van Costs. Estimated $35 per building extracted plus $2.50 per building for batch entry of records into the registry.

Photogrammetric Van Conclusion. Because landscaping blocks stereo views, photogrammetric vans are not a reliable alternative for generating complete ECs. With reconfiguration of the cameras, this method could become a cost-effective alternative to hiring a surveyor to measure vertical offsets and provide other ancillary information needed to complete ECs, but only in areas that do not have dense vegetation surrounding the front and side views of homes.

LIDAR Van Advantages. LIDAR vans, recently introduced, may be better than photogrammetric vans at measuring elevations of features such as front or side porches, decks and patios, from which top of bottom floor elevations are derived because only a single line of sight is needed to survey target points with LIDAR. LAG and HAG elevations should also be relatively simple to measure.

LIDAR Van Disadvantages. LIDAR van technology is totally new and untested on applications such as ECs. The sensor is unable to see into back yards to detect the possible existence of walk-out basements.

LIDAR Van Conclusions. Unreliable at this time.

Strategy D — Future Web-Based Elevation Certificates

Strategy D pertains to future ECs presumed to be entered into the elevation registry using a new web-based system that would help surveyors correctly prepare ECs for conventional printing, but then remove the owner's name (Privacy Act consideration) and record the remaining information in the registry. See Methods 5 and 6.

Advantages: The web registry helps the surveyor to correctly complete ECs. It automatically enters all data, except for owner's name, into the registry without any further need for digitization. Records are of high accuracy and quality, generated at no cost to FEMA beyond the cost of developing the registry.

Disadvantages: The cost of developing and maintaining a user-friendly web-based registry is the only disadvantage. Obviously, the system must be extremely user-friendly to the surveyor, or else the system will be by-passed in favor of completing a conventional paper EC form.

Costs: Dewberry assumed a maximum cost of $4 million over a 5-year period, to include Oracle and/or other license fees, to develop the web-based registry. Assuming this system is used to generate 50,000 ECs per year for 5 years, the amortized cost at $10 per individual web entry would be $2.5 million. Assuming this system is also used for batch entry of 1,000,000 ECs currently held by CRS communities, the amortized cost at $1.50 each would be $1.5 million. This same $4 million is assumed to also provide functionality for batch entry of other large databases into the registry, including databases from Policies in Force, LOMA 2000, ISO, Dewberry, and the Corps of Engineers. For batch entry of records, Dewberry assumed the cost would be $2.50 per record; for the known 162,360 digital EC records that already exist, this could subtract $405,900 from the cost basis presumed to apply to individual EC functionality. In actuality, Dewberry does not know if $4 million is a good cost estimate for such a system, but believes $4 million to be at the high end of all cost options. For this reason, Dewberry conservatively pro-rated the cost at $10 per individual EC entered, and $2.50 each for batch entries.

Conclusions: Conventional or GPS survey methods used for future ECs can achieve elevation accuracy of ±0.5 ft at the 95% confidence level for the lowest floor, LAG and HAG. Web-enabled entries of new ECs into the registry are key to the updating and maintenance of the registry. Assuming the pro-rated cost at $10 per EC, the cost-effectiveness ratio is on the order of 30:1 when full valued ECs are produced using GPS. FEMA should remove the word "optional" next to the latitude/longitude entry on the EC form 81-31 and encourage surveyors to use GPS technology which, when properly utilized, is both more accurate and also provides accurate geographic coordinates needed for future updates of BFEs and other registry information pertaining to revised flood risks.

Strategy E — Leverage Alternative Data Sources

For Strategies A and D, GPS ECs provide the highest quality records, with conventional ECs being nearly as good except for the lack of geographic coordinates; but ground-surveyed ECs are the most expensive to produce. For Strategy B, assuming the airborne remote sensing costs have already been paid for, the additional costs are minimal for provision of geographic coordinates plus LAG and HAG elevations, but "ancillary information" including street addresses, building diagram numbers, top of bottom floor and other elevations, and vent information are not provided from airborne remote sensing. Commercial georeferencing services were determined to lack the accuracy necessary for geocoding or reverse-geocoding of structures for the registry.

Although various Federal, state, and local agencies, as well as commercial organizations such as map determination companies and real estate firms, may possess some of the ancillary data needed, the alternative data sources for this study focused on the following: (1) community building footprint files or building centroids, preferably linked to street addresses, (2) community-provided vertical offset measurements, photos, and other on-site information provided by a surveyor, GIS technician, summer intern or other person hired to make simple measurements community-wide, and (3) measurements and information on individual structures provided by homeowners to their insurance agents. Item (1) is already available in many communities; item (2) could be provided by communities if motivated with proper incentives to do so; item (3) is a newly-proposed alternative that would enable insurance agents to enter ancillary data when presented with measurements, "yardstick photos" and other appropriate information from homeowners seeking flood insurance, but this proposal is expected to encounter resistance because of implementation issues. Although there are other sources of ancillary information, these are reasonable standard alternatives that could be used nationwide.

Advantages. For all study methods that utilize footprint files (Methods 9, 14, 17, 18 and 19) the total value of the ECs and their CE ratios increase significantly when footprints are available; in many communities, footprint files are already available or could be produced at relatively low cost, even if digitized off of digital orthophotos. For all study methods that utilize surveyor-provided or equivalent on-site ancillary data (Methods 8, 11, 15, 17 and 19), the total value of the ECs and their CE ratios again increase significantly, especially when simple vertical offset measurements (from a yardstick or steel tape) are provided between LAG and HAG and top of bottom floor or LHSM elevations. For all study methods that utilize owner-provided ancillary data (Methods 9, 16 and 18), the value stays the same as when a surveyor takes the measurements, but the CE ratios increase dramatically because the $50 per structure cost is saved by not having to hire a surveyor or someone else to take simple measurements. The homeowner options only pertain to individual houses where the homeowner and insurance agent see an individual need, whereas the surveyor options pertains to surveys performed community-wide and address community-wide needs.

Disadvantages. One disadvantage of using community-based alternative data sources is in the need to establish incentives that are successful in motivating communities to take multiple steps necessary to acquire all data needed for batch entry of EC data into the registry. Not only would they need to provide their photogrammetry or LIDAR data to FEMA for use in establishing geographic coordinates and LAG/HAG elevations, but they would also need to take additional steps to provide building footprints, vertical offset measurements and other on-site information necessary for mass production of EC data. The second disadvantage is that the process is complicated; extraction of geographic coordinates and LAG/HAG elevations from LIDAR data is highly technical and should be performed by specialized FEMA or Regional contractors, whereas the ancillary information is less technical and could be added to the community's EC database by either the community or by FEMA contractors.

Costs. The cost of digitizing building footprints (either from stereo photogrammetry or from digital orthophotos) is very low (perhaps $1 per house) but the complicated part is linking these footprints to the correct street addresses. Such addressing can be done relatively inexpensively where the community already has georeferenced tax parcels in a GIS database; communities without a GIS would consider this option only when it becomes GIS-enabled. The cost of hiring a surveyor to take vertical offset measurements community-wide and to collect other on-site ancillary information is estimated at $50 per house, although summer GIS interns or others could undoubtedly do a satisfactory job at lower cost. Presumably, homeowners could do this at no additional cost to the government, but this only pertains to individual structures, not community-wide.

Conclusions. When a community already has elevation data from photogrammetry or LIDAR equivalent to 2' contours, on-site offset measurements can convert LAG and HAG elevations into lowest floor elevations, all of which are accurate to ±1.2 ft at the 95% confidence level. Although new GPS-surveyed ECs are preferred (Strategy D), aerial survey data (Strategy B), supplemented with additional information from the community, is the next best alternative for acquisition of community-wide structural elevation data.

Although it is doubtful that FEMA will ever be able to offer adequate CRS credits to cover community costs of collecting and maintaining elevation data, several communities have already funded the acquisition of the highest accuracy (and more expensive) ECs using GPS ground surveys throughout community flood plains. Other communities that feel they cannot afford such ground surveys, but have already borne the cost of photogrammetric or LIDAR surveys, may find that CRS credits will at least help to offset a portion of the overall costs of acquiring the additional information necessary for development of structural elevation data community-wide.

STRATEGY RECOMMENDATIONS

All five of the technical strategies have advantages and disadvantages for populating an elevation registry. There is no "one size fits all" solution. Flexibility is required in order to maximize the advantages and minimize the disadvantages of the various strategies, recognizing that capabilities and limitations vary by individual community, depending on the availability of existing survey data, accurate photogrammetric and/or LIDAR data, GIS-based building footprints linked to street addresses, or alternatives such as building centroids or tax parcels linked to street addresses.

Strategy A: Maximizing the use of existing ECs.

Recommendation A.1: Assemble as many ECs in the registry's database format as possible. Known existing sources include the following:

- ISO ECs. ISO has over 50,000 ECs of 352 CRS communities entered into the database explained in section A.1 of the Part I Report; these have been received to date from communities and have been transmitted via the Elevation Certificates in Computer Format element over the years and/or entered by ISO through a special project in 1995. This database already has each address separated into the required multiple data fields as required for automated address matching.[1] ISO's database includes the most important data fields required by the registry. However, some programming will be required to eliminate records that have neither Top of Bottom Floor elevation nor Lowest Adjacent Grade (LAG) elevation.

- Dewberry and URS Digital and Hardcopy ECs. These two firms have approximately 19,560 ECs, of which 16,381 are already in a database format suitable for importing into the elevation registry. Additional EC records should come available as a result of Dewberry's ongoing surveys.

- Susquehanna River Flood Warning and Response System. The Philadelphia District of USACE has the street address and elevation of the basement, top of next higher floor, and lowest adjacent grade for approximately 1,200 structures, plus elevation data with partial/incomplete address information for approximately 1,400 additional houses, with elevations produced from photogrammetric spot heights supplemented with vertical offset measurements. At least 1,200 of these structures should be suitable for the elevation registry. The Philadelphia District has

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[1] It must be noted that Dewberry and ISO share concerns about populating a new database with old information that has known quality problems. As noted previously, many of the ECs are incomplete and need additional information. Furthermore, since there were so many different versions of the EC and in various states of quality for scanning, there will be many that are missing much of the pertinent data such as top of bottom floor and HAG since this type of information was not required on many of the earlier forms or named differently (e.g., "top of bottom floor" versus "reference floor" on earlier versions).

already indicated its willingness to share this data with FEMA. These were tested by Dewberry to be accurate to 1.2 ft at the 95% confidence level, i.e., equivalent to 2 foot contour interval accuracy.

- Other Corps of Engineers Data. The Philadelphia District is probably not the only Corps district or laboratory that collects structural elevation data. If and when a registry is implemented, FEMA should seek cooperation from the Corps' Director of Civil Works and officially solicit input from the Corps' various districts, divisions, and R&D laboratories that may have elevation data on structures surveyed in the past, or surveys planned in the future.

- Community ECs. ISO estimates that there are 4.5 million flood policies in three approximately equal categories: (1) 1.5 million outside the SFHAs, normally having no ECs, (2) 1.5 million pre-FIRM, normally having no ECs, and (3) 1.5 million post-FIRM, normally having ECs that should be archived by local communities.[2] Of the 1.5 million ECs, ISO could potentially obtain as many as 1 million of them from the 1000 CRS communities that have two-thirds of the total policies — assuming that these communities have these ECs — but incentives will be required to reach out to get them. (Under the CRS, communities are only required to maintain those ECs from the date of application to the CRS. This number presumes these communities have all the post-FIRM and pre-FIRM ECs available and can provide them. Since many CRS communities do not receive full or partial credit for post-FIRM or pre-FIRM ECs, it is doubtful that 1 million such ECs actually exist. Furthermore, as with ECs collected by ISO, many of these would probably be missing various pieces of data. ISO commented: "The reason we don't see more credit [for post-FIRM and pre-FIRM ECs] is that these ECs are not available or are not fully completed.") Regardless, this may be a formidable task because considerable incentives may be required to get communities to collect, photocopy and send their ECs to FEMA or ISO. The data from each of these certificates could be scanned and/or manually digitized into standardized databases for entry into the registry. The cost would depend upon whether communities (A) gather and digitize their own records or (B) provide their ECs to FEMA or ISO for scanning and digitization.

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[2] Before digitizing any community ECs, it would be advisable to check the BureauNet database to determine if these elevation records are already part of the policies-in-force database maintained by CSC. When a community's ECs are already digitized in another database, it would be wasteful to digitize them again. For this reason, the BureauNet database needs to be accessible to anyone entering EC data. If an address, when entered, duplicates an address already in the database, dates would need to be checked to see if the EC is a duplicate or perhaps supersedes an existing record. Data conversion specialty firms, when paid a negotiated unit fee to digitize records, do not want to be encumbered by decisions as to whether or not each record needs to be digitized. Furthermore, community personnel are better able to determine if addresses are truly duplicates. For these reasons, it would be best if the communities themselves could decide which records need to be digitized, avoiding decisions required by digitization firms. For these reasons, Dewberry will assume that communities themselves will determine which of their ECs to digitize.

- LOMA 2000. Data already residing in the LOMA 2000 database could help to "seed" an elevation registry consistent with Method 1. LAG elevations should be usable, but FEMA has raised concerns about the reliability of other data in this database. Some human intervention will be required in order to convert each LOMA 2000 single Street Address field into multiple fields for address number, street name, address suffix; apartment, unit, suite and/or building number; and post office box and route numbers. Some manual addressing will be required. Dewberry has about 130,000 LOMA 2000 records, of which 80,000 have elevation data and approximate/imprecise geocoordinates; very few have accurate coordinates from GPS surveys. Michael Baker Jr., Inc. has about 12,000 records, of which 4,200 have elevation data and approximate geocoordinates. PBS&J has about 21,000 records, of which 7,400 have elevation data and approximate coordinates.

Recommendation A.2: Convert as many as possible of the hardcopy ECs to the registry's database format. FEMA may choose to centralize the scanning and conversion of hardcopy ECs held by ISO, Dewberry and URS into the registry's database format. With sufficient quantities, such conversions can be performed for $5 per EC. Communities could either provide their hardcopy ECs to FEMA for centralized conversion or they could choose to convert the records locally, consistent with FEMA guidelines and examples.

Recommendation A.3: After hardcopy ECs are digitized, communities should attempt to geocode their registry records using the best of the options below and recording the horizontal accuracy code for the method used (see item 21 at APPENDIX R).

- Communities that already have geocoded building footprints or centroids linked to street addresses have the best and most accurate methodology for geocoding ECs using their existing GIS tools.

- Communities that have geocoded parcel polygons linked to street addresses and/or Assessor Parcel Numbers (APNs) can overlay their parcel polygons over digital orthophotos (available nationwide), manually identify the centroid of the main structure visible in each parcel polygon, and extract the accurate geographic coordinates. The APN can be used only on those ECs for which the APN number (normally the Assessor's tax book number, page number, and parcel number) are included in the Property Description block on the EC form. APNs are more commonly referenced in rural areas without standard street addresses.

- Alternatively, the centroid of each parcel polygon could be generated, without overlay on digital orthophotos. This would provide estimated coordinates that could be reasonably accurate and acceptable for small lots with single structures, but which would become less accurate as parcel sizes increase.

- The least accurate method is to use commercial geocoding services which can be reasonably accurate for some addresses, but which were found to have errors of hundreds of feet at the 95% confidence level because of interpolation procedures used. Also, commercial geocoding services often fail to match addresses queried, especially PO box and RR addresses.

- The latitude and longitude fields may be left blank if no method works for address matching, but such records cannot be automatically updated in the future as new flood studies are implemented.

Recommendation A.4: Where other records are incomplete, get communities to help in filling in missing information. Communities are best for resolving issues from missing or confusing addresses and for providing the correct FIRM and BFE information needed for Section B on the current EC form, for example.

Recommendation A.5: Do not duplicate on-line databases already developed by communities. When communities already have their ECs digitized and available online, Dewberry recommends that the elevation registry provide a link to such sites, without attempting to duplicate and maintain a database already being maintained by communities. This would justify CRS credits (under CRS Section 310) for these communities and would encourage other communities to do the same.

Recommendation A.6: Provide additional CRS credits to communities that digitize their ECs, provide addresses linked to accurate geographic coordinates for the universe of floodprone structures in their communities, and assume "ownership" of their records in the registry by taking effective steps to quality control their data, complete missing information, and resolve potential discrepancies. More CRS credits should be awarded for provision of accurate coordinates and few credits for providing approximate coordinates from automated geocoding of EC records.

Strategy B: Maximizing the use of existing LIDAR or photogrammetric data (when equivalent to 2 ft contours or better).

Recommendation B.1: Process existing LIDAR data to extract LAG and HAG elevations and geographic coordinates of structures. This is best performed by intersecting a bare-earth LIDAR triangulated irregular network (TIN) with building footprint files, then using GIS software to determine the LAG and HAG elevations along the intersection polygon for each structure. Provide accurate latitude and longitude for the approximate centroid of each footprint.

Recommendation B.2: If LIDAR data is not available, process existing photogrammetric data to extract corner spot heights, LAG and HAG elevations and geographic coordinates of structures. This is best performed by hiring a photogrammetric firm to use photogrammetric aerial triangulation data to reset the stereo models and compile LAG/HAG elevations and spot heights on the ground at all visible corners of each structure in or near the community's SFHA. Normally, only 2 or 3 corners are visible of the ground in stereo, immediately adjacent to each building. If building footprints do not already exist, compile 2-D footprints in addition to the 3-D spot heights. Provide accurate latitude and longitude for the approximate centroid of each footprint.

Recommendation B.3: Hire a surveyor or utilize trained government employees to locate and travel to each of the structures in or near the SFHA in order to collect ancillary information and make on-site measurements.[3]

For Methods 8 and/or 17, the on-site surveyors or specialists should perform the following tasks, recording data onto a hand-held computer if possible to complete a database that "mirrors" the data dictionary at APPENDIX R:

- Complete all entries required for the data dictionary — except for the geographic coordinates (items 18 and 19) and elevations (items 43, 44, 45, 46, 47, 48 and 49) which are determined by other means. Ensure that the following items are completed: street address (items 4 through 14), building diagram number (item 40), and number and area of flood vents (items 50 and 51).

- Locate the LAG point for each structure; measure and record the vertical offset measurement from the LAG to the Top of Bottom Floor and the Top of Next Higher Floor (TNHF) in A-zones, or the Lowest Horizontal Structural Member (LHSM) in V-zones. Also measure and record the vertical offset measurements to the Lowest Elevation of Machinery (LEM) and garage floor elevation for an attached garage.

- Using the LAG values from photogrammetry or LIDAR for each structure, use the vertical offset measurements to compute and record the elevations of the top of bottom floor, top of next higher floor, lowest horizontal structural member, lowest elevation of machinery and/or garage floor, as applicable. Also record the LAG and HAG elevations in the database.

If communities have collected LAG and HAG elevations from either photogrammetry or LIDAR, but cannot afford the additional cost of the on-site surveys, the LAG and HAG information alone may be acceptable for mass

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[3] It is extremely important that the person taking these measurements be fully trained to understand the correct elevation points to be measured. Often, licensed surveyors do not understand the correct elevation points, partly because they may rarely survey ECs. For these reasons, it is imperative that anyone taking measurements for hundreds of alternative EC records be fully trained in the correct process to be followed.

production of LOMAs, or for advising owners of some pre-FIRM homes when it would be advisable for them to acquire a conventional EC to determine if actuarial rates might be less expensive than pre-FIRM rates. LIDAR Method 14, which collects LAG/HAG elevations without additional on-site surveys, is very cost effective (15.76:1) in determining structure addresses for which the purchase of flood insurance should be mandatory, based solely on the elevation of the LAG compared with the BFE.

Recommendation B.4: Perform quality control and reformat the database as necessary to fit the data dictionary. Quality control steps are recommended for the community that generates the database and again by the registry's administrator responsible for resolving any database conflicts.

Recommendation B.5: We recommend that data from Pictometry imagery not be used to populate the elevation registry for the following reasons:

- All elevations are relative, rather than absolute, requiring other data sources to provide the basis for all elevation comparisons

- Although the technology could be used to view an insured structure from all sides, it has an unacceptably high error rate in detection of the presence or absence of basements.

- On-site data collection is still required for other missing information.

Recommendation B.6: Provide additional CRS credits to communities that utilize their existing LIDAR and/or photogrammetric data to generate spot heights, LAG and HAG elevations for all structures in or near floodplains; perform on-site surveys to provide lowest floor elevations and other data required for EC records; rigorously assess the accuracy of their data; provide their data for the registry in the correct format; and assume "ownership" of their records in the registry by taking effective steps to quality control their data, complete missing information, and resolve potential discrepancies.

Strategy C: Utilizing data from mobile photogrammetric vans

Recommendation C.1: We recommend that data from mobile photogrammetric vans not be used to populate the elevation registry for the following reasons:

- This technology was rated poor in its ability to produce ECs because of the high number of target points (top of bottom floor, lowest horizontal structural member, LAG and HAG points, and vents) that could not be surveyed because of landscape shrubbery that blocked stereo views from the street
- This technology was rated poor because of its inability to see and survey key features in backyards such as walk-out basements and air conditioner pads.

Strategy D: Web-entry of future ECs.

Recommendation D.1: The web-based elevation registry should have a *front-end* portal with functionality to: (1) tutor the surveyor on correct survey procedures to be followed for completion of an EC, and (2) receive individual online submissions of new ECs needed to maintain/update the registry.

Recommendation D.2: FEMA should web-enable the generation of new ECs, not allowing them to be finalized until mandatory data fields are completed, including latitude and longitude and the surveyor's use of a benchmark with Permanent Identifier (PID) number listed in the National Spatial Reference System.

Recommendation D.3: When all mandatory items are complete, and the surveyor or engineer enters his/her name and state registration number, the certificate should be recorded as final, printed in hardcopy for sealing and signature as at present, but with the data automatically transferred into the elevation registry, excluding the homeowner's name because of Privacy Act considerations. FEMA may also consider the use of electronic signatures for this process.[4]

Recommendation D.4: The registry should provide immediate feedback to the surveyor, acknowledging receipt of input. If the name and/or registration number is inconsistent with records from the state licensing Board, follow-up action should be required to ensure data certification.

Strategy E: Leveraging alternative data sources.

Recommendation E.1: Import relevant BureauNet data into the registry. There are currently 4.5 million active policies in force which include such information as date of construction; LAG, HAG and lowest floor elevation; approximately geo-referenced coordinates, and policyholder information. FEMA's NextGen project is in the process of updating the system to an Oracle database environment and revamping the analysis tools and policy rating engine. Excluding the policyholder information, other information relevant to the registry's data dictionary should be imported for initial population of the registry

Recommendation E.2: Import relevant NEMIS data into the registry. There are currently over 400,000 structures in the NEMIS database of structures damaged by Presidentially-declared disasters. NEMIS automates federal disaster programs including incident activities, preliminary damage assessment, declaration processing, human services, infrastructure support, mitigation, and associated administrative and financial processing. NEMIS includes a structure's address, type (basement, no basement), and approximate UTM coordinates. Although it does not include structural elevation information, NEMIS information

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[4] Although it is technically feasible, the concept of also including electronic seals for engineers and surveyors is not realistic at this time because state licensure boards would need to develop, operate and maintain such systems. There are no such initiatives known to be in progress at this time.

could be used to populate items 70 and/or 71 of the registry's data dictionary, i.e., the depth(s) and/or date(s) of prior interior flooding.

Recommendation E.3: Consider buying needed data.

First American Flood Data Services (FAFDS) provided pricing to Dewberry/FEMA of $2.50 per "hit" for GIS automated geocoding of addresses and $3.02 per "hit" for automatic flood zone determinations from their database. Lower unit costs pertain to transactions involving over 10,000 addresses. Higher unit costs pertain when manual look-up procedures are used and FAFDS provides guarantees for the accuracy of their determinations. However, a FAFDS official indicated that they could not provide FEMA or anyone else a list of all addresses in or near to floodplains, to define the total universe of floodprone structures, because that would jeopardize their market advantage.

Although not yet truly nationwide, the National Parcelmap Data Portal (NPDP) was considered because it has nearly 60 million geocoded parcels linked to addresses and/or Assessor Parcel Numbers (APNs) in about 200 major metropolitan areas, and they plan to compile 800-900 of the most highly populated counties by the end of the current decade. However, this is just a fraction of the 3,150 counties nationwide and would therefore not include the total "universe" of structures desired. The cost to FEMA for this service may be $1 to $2 million per year for access to all records, but NPDP's Dynamic Server option would be less expensive if, for example, only 1 million records were "hit" at 25 cents each. Because the NPDP purchases digitized parcel data from communities that update their records periodically, an argument could be made that FEMA should receive such data free from these same communities. The counter argument is that FEMA would only have to deal with NPDP to receive normalized data, rather than with thousands of communities each providing data with different data formats and technical issues to be resolved.

Whereas FEMA would have difficulty justifying commitments costing FEMA millions of dollars per year, it is possible that arrangements could be made with either of the above-listed services so that FEMA is charged on a "per hit" basis, with costs paid by registry users who utilize the registry and provide credit card numbers or have active draw-down accounts for routine servicing. Users could be charged a slightly higher mark-up fee to help reimburse FEMA for its expenses in maintaining agreements with FAFDS or NPDP.

Recommendation E.4: Award additional CRS credits to those communities that provide up-to-date geocoding or reverse geocoding of all structures in or near floodplains. CRS administrators should determine if this recommendation is feasible or not, and the number of credit points warranted. As with many of Dewberry's CRS credit recommendations, this could be a larger one-time credit for geocoding all existing structures, followed by a small annual credit for maintaining and updating the data.

Although not mandatory, it is desirable for the registry to include the universe of addresses in or near to floodplains so FEMA/CRS would have a way to track progress towards a goal of having all such addresses completed with elevation data in the registry. Attempts to leverage data from the U.S. Census Bureau and the U.S. Postal Service were unsuccessful. Because of Title 13 limitations, the Census Bureau is not allowed to share its geocoded Master Address File (MAF), either with or without geocoding, and Postal Service addresses are not georeferenced. Ultimately, the best source of floodprone addresses is from the communities themselves. This would require that thousands of communities take actions to populate the registry with such addresses in a standard format. This could be a formidable task, and most communities would expect some incentive for performing this task, preferably in the form of additional CRS credits.

Recommendation E.5: When feasible, "piggy-back" on other FEMA initiatives, to include Housing Inspection Services and the Map Modernization Program.

FEMA conducts thousands of housing inspections annually in disaster areas nationwide. Personnel from FEMA's housing inspection service contractors could be trained to make vertical offset measurements and collect other data needed to leverage the photogrammetric and/or LIDAR data so as to complete high quality EC records for damaged structures. Before FEMA deploys teams for housing inspections, they would need to coordinate with the Mitigation Division or check the registry's web site to determine if offset data are needed to upgrade the mid-value data from Method 14 to high-value data from Method 17, for example. This would cost FEMA only an estimated $5 more per house, rather than $50 per house for on-site surveys described above.

FEMA's Map Modernization (MAPMOD) Program is working towards the goal of having DFIRM Databases (i.e., floodplain and flood elevation data in GIS format) within 5 years for all NFIP communities, and to have DFIRM Database coverage for 98 percent of the U.S. population by the end of FY2008. When developing the implementation plan for the elevation registry, it would be prudent to review the MAPMOD schedule. Phased implementation of the elevation registry following the MAPMOD schedule would ensure that any *e*Rating tools that depend on DFIRM Databases for BFE and flood zones would have the appropriate data available. The National Service Provider (NSP) plans to store DFIRM Databases in Geodatabase format, making them available online through the Multi-Hazard Information Platform (MIP).

PART II — PROVIDING STRUCTURAL ELEVATION DATA

Purpose

Insurance agents and WYO companies have long affirmed that the requirement for Elevation Certificates (ECs) is a major impediment in selling flood insurance. The purpose of this study is to determine if it is appropriate, feasible, and legally possible for FEMA to obtain the elevation data on individual structures and to make this elevation information available in an elevation registry to properly rate the structures for flood risks and flood insurance premiums so that ECs costing hundreds of dollars each would not be needed in most cases for insurance rating. Part I of this study addresses the legal and technical issues in implementing an elevation registry, whereas Part II addresses feasibility issues.

Summary of Part I Requirements for *e*Rating

For *e*Rating purposes, insurance agents need to know if a structure is Pre-FIRM or Post-FIRM, and they need information traditionally included on ECs:

(1) street address and FEMA building diagram number
(2) elevation of the top of bottom floor in A-zones or bottom of the lowest horizontal structural member in V-zones
(3) elevations of the next higher floor, lowest adjacent grade (LAG), highest adjacent grade (HAG), attached garage floor slab, and lowest elevation of machinery or equipment servicing the building
(4) base flood elevation (BFE) and flood zone
(5) number, area and location of flood openings (vents).

The latitude and longitude of each structure is desired for long-term maintenance and update of records but these geographic coordinates are not required for rating of structures. Whereas the highest accuracy elevation data from ground surveys is preferred (±6 inches), FEMA can accept lesser accuracy for eRating by implementing a system of "judgment ratings," but with no elevation errors larger than 4 ft at the 95% confidence level.

Summary of Part I Legal Findings

The Dewberry/FEMA Law Associates/EOP Foundation "Final Report on Legal Issues" identified no legal issues that would preclude FEMA from establishing, maintaining and making available to insurance companies and agents, or to the general public, an elevation registry containing this required information so long as personal information is not included. As such the registry would not be a "system of records" regulated by the Privacy Act. This legal analysis assumed that the registry includes specific property addresses, but does not include personal identifiers of individuals such as names, policy numbers, or social security numbers. FEMA may maintain individual identifier information in separate data bases, and link to those separate databases for purposes authorized for those data bases. Other legal findings, relevant to implementation of an elevation registry, are summarized as follows:

- The National Flood Insurance Act clearly authorizes FEMA to obtain and distribute to the public information about flood risk and information relevant to the determination of premiums under federal flood insurance policies. Questions regarding ownership of ECs have no bearing on FEMA's right to obtain elevation data and place it in the registry.

- FEMA is not restricted by the Privacy Act or other privacy policy principles from making elevation registry information available to the insurance companies and agents, which are the intended audience of the registry. The registry would contain all addresses for which FEMA had elevation data, from a number of sources, and hence the registry would not disclose any company's customer list or disclose whether a listed property is insured by FEMA directly, insured by a competitor, or whether the property is insured at all.

- FEMA would be obligated by the Freedom of Information Act to make information in the registry available to any person on request, and to make it available in an electronic format to anyone who asks, if it is made available to companies in that format. FEMA may, but need not, design the elevation registry to be publicly available and accessible to any person on the Internet.

- FEMA and any FEMA contractors establishing and maintaining the elevation registry would not incur any significant increased liability exposure from creation of the elevation registry. FEMA can reduce any potential liability exposure by: (a) using the registry only for the purpose of rating insurance policies, and continuing to require communities to obtain Elevation Certificates to support construction permits and other floodplain management purposes; (b) amending FEMA's regulations and manuals to allow WYO Companies and agents to rely on the elevation registry for rating of policies thus supporting the argument that reliance on the registry's data satisfies the professional standard of care; and (c) including in the elevation registry a warning notice that the information in the registry has been developed solely for purposes of determination of premiums for insurance policies and that more accurate elevation determinations may be required for purchase and development decisions by property owners.

- FEMA should design and implement the quality control standards, processes, and documentation for populating the registry with data. These processes will specify the types of data sources and the documentation and certification requirements for data before it can be incorporated into the registry.

Summary of Part I Technical Findings

Whereas ground-surveyed ECs are the best, having elevations accurate to ±0.5 ft at the 95% confidence level, aerial surveys, including photogrammetry and LIDAR, can cost-effectively provide elevations accurate to 1.0 to 1.5 ft at the 95% confidence level when the lowest and highest adjacent grade (LAG and HAG) are visible from the air; then, vertical offset measurements could be made on-site to compute the other elevations required in a registry.

Federal Geographic Data Committee (FGDC) standards require all geospatial data accuracy, including aerial survey data accuracy, to be reported in ground distances at the 95% confidence level in accordance with the National Standard for Spatial Data Accuracy (NSSDA). For example, 2 foot contours, or equivalent digital elevation datasets, have 1.2 ft vertical accuracy at the 95% confidence level; statistically, this is the same as 1.0 ft vertical accuracy at the 90% confidence level used by the National Map Accuracy Standard published in 1947, a standard now obsolete for digital elevation data since publication of the NSSDA.

For quality control purposes, there are several acceptable methods for certifying the accuracy of elevation data:

- When an elevation dataset is tested against checkpoints of higher accuracy, vertical accuracy is reported as: "Tested __ feet vertical accuracy at 95% confidence level." This method is routine for LIDAR data because production procedures have not yet been standardized by the immature LIDAR industry.[5]

- When an elevation dataset is not tested against checkpoints of higher accuracy but produced according to procedures that have been demonstrated to produce data with particular vertical accuracy, vertical accuracy is reported as: "Compiled to meet __ feet vertical accuracy at 95% confidence level." This method is routine for photogrammetric data for which industry production procedures are standardized and mature.

- Either of these methods would be suitable for a community to certify the accuracy of its elevation data if used by FEMA to establish LAG/HAG elevations and vertical offset measurements for lowest floor and other elevations in the registry.

Although they have some limitations, existing hardcopy ECs could easily and cost effectively be digitized into the registry's database format. Highest quality

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[5] When LIDAR data is used for floodplain mapping purposes, FEMA standards require the data to be tested and reported separately for each of the major land cover categories representative of the floodplain, e.g., open terrain, weeds and crops, scrub, forests, and built-up areas. Nevertheless, a consolidated vertical accuracy statistic is normally quoted for all land cover categories combined.

ECs could be more easily acquired in the future if FEMA develops and encourages surveyors to use a FEMA on-line tutorial to prepare and print hardcopy ECs and automatically populate the registry with selected EC information. The owner's name would be excluded for Privacy Act considerations. This tutorial would encourage the use of National Geodetic Survey benchmarks and global positioning system (GPS) surveys that provide geographic coordinates in addition to required elevation data — helping to ensure that new ECs are accurate and complete and will support spatial queries by users.

BFEs are best determined from Flood Insurance Study (FIS) profiles, but Dewberry suspects few are actually determined by this method. Most BFEs are probably estimated by interpolating between BFEs shown on FIRMs, and BFE values can be in error by up to 0.5 ft since they are rounded to the nearest whole foot on the effective FIRM. FEMA's new DFIRM databases include BFE values at all cross sections. When DFIRM databases become available nationwide (2007-2009), these cross section BFEs can be interpolated to determine BFE values at other locations; these values will be superior to BFEs interpolated from the FIRMs but may still be inferior to FIS profiles. Accurate geographic coordinates for structures are needed to track changes to flood zones and BFEs.

Elevation Registry

The registry could be available to all via the web. The registry should focus on structure EC data used by insurance agents, floodplain managers, realtors and potential owners to determine flood risks. Registry information, including a downloaded copy of a "virtual EC" produced from registry records, but excluding owner names, could be free to some but available to others for a fee, similar to the way that users pay a fee to FEMA's Map Service Center for downloading flood maps and DFIRM databases. Selected users would be able to query the registry for all records in a community that satisfy certain criteria.

Ideally, to avoid data redundancy, the registry could be hosted by FEMA's NextGen data warehouse. However, for administrative simplicity, FEMA may want to ensure that the registry avoids potential Privacy Act issues. To do this, names and other personally identifiable information should not be included in the registry and cannot be permanently linked to a system containing these items. Therefore, despite some inefficiencies of storage, FEMA may prefer to implement the registry as a standalone database that would merely feed data into the NextGen data warehouse.

Depending on the strategies chosen by FEMA, the registry could be populated by several means: (a) digitization of existing ground-surveyed ECs from communities, ISO and others; (b) web entry of future ECs by licensed surveyors using an on-line tutorial on how to correctly prepare ECs; (c) reformatting of existing FEMA databases (BureauNet, NEMIS and LOMA 2000), including deletion of personal information; and (d) batch entry of elevation records provided by communities using their existing LIDAR or photogrammetry data to determine LAG/HAG elevations and offset measurements to determine other needed elevations. Each of these data sources have different levels of accuracy and reliability that would be tracked in the registry.

It is recommended that the registry be developed as a Geodatabase or other comparable spatial database. A spatial database would include the locations of structures as geographic features (in this case, geographic point features) along with the attributes as described in the data dictionary shown in APPENDIX R. Use of a spatial database will facilitate display of the elevation registry data with other GIS data such as topographic data or DFIRMs. Additionally, it will facilitate spatial queries, allowing users to more easily see all records within a community or all records near another feature.

To be effective for *e*Rating, the elevation registry would need to have a web portal with interfaces for security-controlled input of data to the registry's database, and output of information needed for *e*Rating. In addition to insurance agents and WYO companies, this portal should also be available to others involved in the NFIP, e.g., floodplain managers who may need to review all records for his/her community, or an individual user who may need to review only a single address record at a time. The registry must identify the source of the elevation information, its accuracy and effective date, and have the ability to track multiple records per address that may differ and/or change over time. An administrator who can resolve data conflicts should monitor the registry.

For maintenance of the information, the elevation registry requires the following capabilities:

- Accept community Master Address Files (MAFs) of addresses to be included in the registry for communities participating in the NFIP, with provisions for community NFIP coordinators to update their MAFs to track new construction in or near floodplains. This is needed to help communities track the percentage of total structures for which elevation data are available, with the goal of achieving 100% availability.

- Allow for batch entry of new or existing elevation databases, reformatted for consistency with the data dictionary.

- Allow for on-line preparation of ECs both for hardcopy printing and for automated entry of individual ECs into the registry by surveyors or other authorized personnel, with provisions for feedback to surveyors and validation of credentials. This capability would build upon the functionality of the latest NFIP/CRS Elevation Certificate software. It would require the surveyor to enter the latitude and longitude of the structure and indicate the source of the coordinate information from a *pick list*.

- The "front end" web portal would provide a How-To Guide to tutor surveyors through the correct process to perform EC surveys to higher levels of accuracy than at present and require them, for example, to enter the PID number of the NGS benchmark on which elevations are based.

- Allow for updating registry data and tracking the source of new data, while archiving historical data.

- Ability to compare files/records and perform address matching to determine if two or more records pertain to the same structure; ability to correlate addresses that differ slightly, e.g., 123 5th St, 123 5th St., 123 5th Str., 123 5th Street, 123 Fifth St., 123 Fifth Street, etc.; ability to correlate addresses that have changed zip codes for otherwise-unchanged addresses or have multiple community names for the same zip code.

Web Services

Dewberry's detailed recommendations for the web-based registry are documented at APPENDIX S.

For all recommended strategies, it will be necessary to establish a web-based elevation registry, preferably with a Geodatabase (or comparable spatial database) that includes the attributes in the data dictionary at APPENDIX R. XML data format is recommended for all input and output protocols to minimize interoperability issues. Before ESRI's Geodatabase or alternative spatial database format is adopted, other NextGen stakeholders should be consulted to ensure a common or compatible approach to FEMA's database(s). Dewberry was informed by Mr. Jack Way of Optimal Solutions & Technologies (OST) that a Geodatabase is compatible with the NextGen database design.

Publication of the elevation registry data through a Web Map Service (WMS) and/or Web Feature Service (WFS) would be required to allow users to view the elevation registry data within their GIS application. Elevation Certificate (EC) spatial data (i.e., structure points) could be used in conjunction with FEMA DFIRM data (ideally also made available through WMS and/or WFS) and/or local GIS data.

- A WMS would provide the data in the form of a map, generally in a static pictorial format such as PNG, GIF, or JPEG. The user could specify what portion of the earth to view, the coordinate system, and the map size. The map could be overlaid on data from other WMSs (e.g., a DFIRM Database or a USGS DOQ) or data stored locally on the user's system. However, a WMS provides little ability to customize the symbolization of features in the map and no ability for users to make updates to the maps. Therefore, a WMS is not recommended when changes are anticipated to the geographic coordinates of structures such as when approximate coordinates are upgraded to precise coordinates.

- The alternative WFS is recommended because it would provide the data as geospatial features that could be manipulated by FEMA and authorized users. This would include the ability for users to set symbology for features and optionally to create, update, or delete features. As with the WMS, the user could specify what portion of the earth to view and the coordinate system. In addition, a WFS would allow users to filter data by user-defined conditions (e.g., view all ECs within a particular community; all ECs for structures with lowest floor elevations below the BFE; or all ECs within a particular community for structures with flood insurance — if the source of this information came from the policies-in-force database). A WFS would provide a mechanism for spatial updates to the latitude and longitude fields of the elevation registry to be provided to FEMA by local communities or surveyors. However, a validation process would need to be developed before such updates are loaded into the main spatial database.

Populating the Registry

Community Input**.** During population of the registry, the data will be "spotty," depending on each community's ability and willingness to support the overall objectives. The following initiatives should be taken (voluntarily) by communities to help populate the registry:

- Digitize their hardcopy ECs and/or reformat their digital elevation records to fit the registry's data dictionary format.
- Digitize building footprints from digital orthophotos and link each footprint to its address, whether floodprone or not.
- For communities with existing LIDAR or photogrammetric data equivalent to 2 ft contours or better, determine LAG and HAG elevations for each structure in or near floodplains. Measure vertical offsets on-site and complete other elevations relative to the LAG/HAG. While on-site, complete other information required for a complete EC record.
- Provide tax assessor data to enhance registry records.[6]

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[6] Existing tax assessor records typically have value for the elevation registry, especially when tax parcels (or building footprints or centroids) are digitized in a GIS with each parcel linked to a street address, PO box or rural route address, and/or APN number. Even though these records do not include elevation data, they include georeferenced parcel polygons that can be overlaid on DFIRMs to determine the universe of structure addresses within each county that are located in or near to floodplains. This is needed to help determine how complete the registry records are for each county or community, or alternatively, how many EC records are missing. Furthermore, tax record square footage and assessed values of structures enhance an elevation registry so that proactive floodplain management initiatives can be applied.

- Inform FEMA of typical database queries expected to be made by the community so that the registry is developed to satisfy user query requirements.

FEMA Support. The following actions should be taken by FEMA to develop and populate the registry:

- Develop a user-friendly, web-based registry with functionality described in APPENDIX S.
- Digitize hardcopy ECs not digitized by communities; reformat digital EC records from ISO, Dewberry, Corps of Engineers, and LOMA 2000; and populate the registry with records from the BureauNet and NEMIS databases.
- Develop efficient procedures and tutorial for professional land surveyors, and mandate their on-line preparation and submission of future ECs.
- Award additional CRS credits for communities that take initiatives described above.
- Evaluate options for cost-sharing with communities willing to pay a major portion of costs involved.
- Encourage and promote wide support of the registry as a benefit to all.

Registry Maintenance and Updates

The registry can be maintained and updated by on-line preparation and submission of new ECs by surveyors. Cooperating communities could maintain and update their datasets by EC surveys or through an acceptable airborne remote sensing option combined with on-site measurements. Communities could also help to maintain the registry by volunteering to track their permit files and input new ECs into the registry if not done so automatically by the surveyors; and communities would be encouraged to add additional information such as assessed value and square footage of the structure as needed for other floodplain management purposes. All community input to the registry should be voluntary, with no FEMA mandates. Alterations to structures are difficult to identify from the air or even from the street. Insurance agents should obtain owner certifications, during the insurance application process, to verify no significant structural changes since the last EC was entered into the registry.

Accuracy Verification. With high resolution LIDAR, FEMA and communities now have a tool for verifying the accuracy of old EC records in the registry. When new LIDAR data becomes available for a community that has building footprint files, FEMA could pay the additional $5,000 estimated per community to generate LAGs and HAGs for addresses community-wide. These LAGs and HAGs could then be compared with EC records in the registry to see if they are logical or not, and LAG/HAG errors are a good indicator of other elevations that might also be in error. For example, Dewberry used LIDAR data of Prince George's County, MD and found two ECs for which LAGs and other elevations were in error. When building footprint files are available for areas with LIDAR data, either FEMA or communities could verify the accuracy of LAG and HAG elevations. Also, FEMA occasionally surveys structures and compares elevations with ECs on file at communities. CAV visits could also be used to help ensure that communities act appropriately to maintain the quality of their elevation information in the registry; additional CRS credits could be earned for conscientious execution of these responsibilities.

<u>Addition of New Structures to the Database</u>. It would be ideal if communities would initiate a new record in the registry at the time that a building permit is approved, and then update the record when an "as built" EC is received. However, FEMA should not make this a community requirement but instead rely upon CRS credits for motivating communities to do so voluntarily.

<u>Alteration to Structures</u>. There are several questions involving structure alterations that need to be answered for insurance rating at the time an applicant applies for renewal. "Since the last EC was entered into the registry:

- "Was habitable space constructed in garages, basements or crawl spaces previously used for storage only?
- "Was habitable space constructed beneath elevated structures in V-zones?
- "Were rooms added or enlarged? Were rooms deleted?
- "Was new heating, ventilating and/or air conditioning equipment installed below the BFE?
- "Were flood vents removed or closed during remodeling (e.g., garage door replaced with a new one that has no vents; new siding that covered prior openings)?
- "Were breakaway panels in V-zones replaced with permanent walls?"

Whereas CRS credits could be awarded to communities that track such alterations, illegal construction is rarely visible from the air, or even from the street, but requires interior access. For these reasons, structure alterations are best addressed by the insurance agent, requiring the owner to complete a certification form answering the above questions. Then, if the owner submits a claim for flood insurance, the agent would have the opportunity to determine if this certification is true or false. The above questions/answers have been added to the bottom of the registry's data dictionary at APPENDIX R, items 75-80.

<u>Changes to Flood Zones and BFEs</u>. Once a DFIRM database is available for a community, it will be easy to update SFHA boundaries and BFEs and track

changes to DFIRMs including the history of BFE and flood zones for a given study area. New BFEs will be interpolated from cross sections rather than from BFE lines and values. One reason for being adamant that latitude and longitude are required in the registry is because geographic coordinates are necessary to enable a GIS to automatically identify address records that need to be updated with changes in SFHA boundaries and BFEs. The other reason is that latitude and longitude are essential for spatial queries from users of the registry.

Community Rating System (CRS) Credits. FEMA does not intend to require communities to populate, maintain or use the elevation registry. If a community agrees to enter information into the registry to get CRS credit, then FEMA would presumably need to ensure the community was doing this properly. APPENDIX T provides full details of CRS credits currently authorized in all relevant categories.

APPENDIX T summarizes CRS credit points used to encourage communities, by the use of flood insurance premium adjustments, to initiate activities beyond those required by the NFIP to reduce flood losses, facilitate accurate insurance rating, and promote the awareness of flood insurance.

CRS communities currently prepare and implement those activities which best deal with their local problems, whether or not they are creditable under the CRS. Few, if any, of the CRS activities will produce premium reductions equal to or in excess of their implementation costs. In considering whether to undertake a new floodplain management activity, a community must consider all of the benefits the activity will provide (not just insurance premium reductions) in order to determine whether it is worth implementing.

Dewberry recommends that the CRS consider awarding additional CRS credit points for the following community activities:

- Identification of all addresses, assessor parcel numbers (APNs) and accurate geographic coordinates (from digital orthophotos or GPS surveys) for all structures in or near to floodplains.

- Development of building footprint (GIS) files linked to the building addresses and APNs.

- Processing of community high accuracy photogrammetric or LIDAR data to identify accurate LAGs and HAGs for all geocoded structures in or near to floodplains.

- On-site measurements, community-wide (by a person qualified to determine the correct points to be surveyed) to determine elevations of the top of bottom floor, lowest horizontal structural member, lowest machinery and garage floor relative to LAGs and HAGs, and to collect vent and other information required by the elevation registry.

- Comparison of photogrammetry or LIDAR LAGs with those on existing ECs to identify and isolate existing ECs that have major errors.

Each of these initiatives would appear to warrant a larger one-time CRS credit, followed by a small annual credit for maintaining and updating the data in the elevation registry.

To implement these recommendations, much work is needed to be completed by communities to address the issues cited above. It is not certain that the CRS could provide enough incentives (credit points) to make it worth the communities' efforts. For some communities the task is not unreasonable, but for large communities this may be a problem. The small incentives (current credit points) already in the CRS have not motivated a large number of CRS communities to provide the older ECs for credit (ECPO and ECPR) to date. Adding large incentives for this type of activity may cause an imbalance in the program. The bigger credit items are in the 400 and 500 series where good mitigation results are received from community actions. The 300 series has low CRS credit points because it is harder to justify the mitigation results from these types of projects. Dewberry realizes that EC data alone doesn't result in better mitigation. Therefore, to increase the credits to where it is an incentive for communities to provide the information requested (either to correct old ECs or to provide information in the future as it becomes available) may be difficult to justify.

If FEMA concurs with these recommendations, they will need to be discussed with the CRS Task Force for consideration in future changes to the CRS Manual.

Registry Use by Insurance Agents

From our prior legal analysis at APPENDIX A, we understand that elevation information required for use in determining premiums for an actuarially sound flood insurance program need not be as accurate as information required for evaluating the true flood risk of individual structures. An actuarially sound program can average out modest positive and negative errors in elevations of individual buildings, whereas those same errors could hide true flood risk for the owner of a particular structure.

To ensure that potential users of the registry are aware of its limitations, the registry should include a prominent notice stating that it may be used in lieu of ECs in rating or writing flood insurance policies but that the information may not be sufficiently accurate for other purposes, particularly in determining whether to purchase a structure in the flood plain or to permit new construction or renovation in the floodplain.

Judgment Ratings

Based on the cost model developed for this report, the registry could be populated by several means that are cost effective. However, not all of these strategies provide the same level of completeness or accuracy as the current ECs. FEMA could choose to build the registry based only on ECs produced by surveyors or could choose to include alternative, less accurate elevation methods. If FEMA chose to include alternative EC records that are less accurate than conventional ECs, having errors of 1.2 ft at the 95% confidence level, for example, when photogrammetric or LIDAR data are equivalent to 2 ft contours, FEMA could implement a system of "judgment ratings" that would increase premiums proportionally to the increased uncertainty in the true flood risk. Owners could always choose to pay for a normal EC to reduce uncertainty and premiums, but they will probably do so only if they believe their true elevations should be higher, which should result in lower premiums.

Insurance analysts use judgment to create and modify the mathematical models used to assess risk and determine premiums. The following example will be used to demonstrate how increased uncertainty in the accuracy of structural elevation data could be offset by increased flood insurance premiums.

The following example was cited previously in this report, using NFIP premiums as of May 1, 2004. For a post-FIRM building in the SFHA, annual premiums shown below are for $150,000 in building coverage and $75,000 in contents coverage for a one-story building with no basement and a $500 deductible. Assuming the top of bottom floor elevations are known with vertical accuracy of 0.5 ft at the 95% confidence level:

- When the top of bottom floor is 2 ft above the BFE: $418
- When the top of bottom floor is 1 ft above the BFE: $595
- When the top of bottom floor equals the BFE: $892
- When the top of bottom floor is 1 ft below the BFE: $3,201
- When the top of bottom floor is 2 ft below the BFE: $4,040

If we assumed the top of bottom floor elevations instead have vertical accuracy of 1.0 ft (instead of 0.5 ft) at the 95% confidence level, the above rates might be increased by 5%, if such an increase is consistent with actuarial logic. Similarly, if we assumed the top of bottom floor elevations instead have vertical accuracy of 1.5 ft at the 95% confidence level, the above rates might be increased by 10%; and if we assumed the top of bottom floor elevations instead have vertical accuracy of 2.0 ft at the 95% confidence level, the above rates might be increased by 15%.[7]

For this same example, we will next assume that the top of bottom floor elevations are derived from either photogrammetry or LIDAR data tested as equivalent to 2' contours, with on-site vertical offset measurements. This

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[7] These increases of 5%, 10% and 15% are totally theoretical on Dewberry's part, used for demonstrating the concept of higher premiums based on uncertainty, and do not represent actuarially-sound increases based on the true risks.

equates to vertical accuracy of 1.2 ft at the 95% confidence level. For the cited example, the flood insurance premiums could be interpolated between 1.0 ft (5% increase) and 1.5 ft (10% increase) so that structures without conventional ECs but with alternative aerial surveyed ECs accurate to ±1.2 ft at the 95% confidence level would pay a 7% increase in premiums to compensate for the elevation uncertainty. The annual premiums on the same valued structure would then be as shown in Table 30 under the column depicting ±1.2 ft at the 95% confidence level:

Table 30 — Theoretical Flood Insurance Premium Increases

Top of bottom floor elevation	**Assumed annual premiums when the top of bottom floor elevation has this accuracy at the 95% confidence level**			
	When ±0.5 ft at 95% conf level, assume no increase	**When ±1.0 ft at 95% conf level, assume 5% increase**	**When ±1.2 ft at 95% conf level, assume 7% increase**	**When ±1.5 ft at 95% conf level, assume 10% increase**
2 ft above the BFE	$418	$439	$447	$460
1 ft above the BFE	$595	$625	$637	$655
Equals the BFE	$892	$937	$954	$981
1 ft below the BFE	$3,201	$3,361	$3,425	$3,521
2 ft below the BFE	$4,040	$4,242	$4,323	$4,444

The conclusion from this example is that judgment ratings could be used to handle elevation data that is less accurate than the best ECs, and FEMA could apply higher premiums to compensate for increased risk. For EC data equivalent to 2 ft contours (1.2 ft at the 95% confidence level), for the example structure determined to be 2 ft above the BFE, the 7% increased cost of uncertainty in this example is only $29 per year ($447 - $418), but for the home estimated at 2 ft below the BFE, the 7% increased cost of uncertainty is $283 per year ($4,323 - $4,040) for this example, almost covering the cost of a ground-surveyed EC when mass produced community-wide.

Dewberry believes that having higher premiums for poorer quality data is an incentive for getting owners to acquire higher accuracy elevation data. Education will also be needed to help communities and home owners realize the benefits of normal EC data, but actions must also be taken to ensure that future ECs are more accurate than in the past. Users should be able to see the Judgment Rating on the web portal and be able to evaluate different insurance premiums if rated by a surveyed EC or by available alternatives such as photogrammetry, LIDAR, or NEMIS data, for example.

Unfortunately, this logic could encounter arguments that flood insurance studies themselves do not all have the same accuracy and rigor in computation of BFEs and delineation of SFHAs. Detailed studies do not all have the same level of accuracy; and limited detailed studies and approximate studies are less accurate as well. At some point, the variables become too complex in determining premium increases or decreases justified by alternative methods used to derive the key parameters in flood risk determinations.

Homeowners themselves may decide to apply their own judgment as to whether or not it is desirable to pay for a higher accuracy ground survey. If they believe that a survey will help their premiums to decrease, they may well decide to pay for a new EC. However, if they feel that alternative aerial surveys yielded elevations that are favorable to them (higher than true elevations, indicating lower flood risk), they will probably not choose to pay for a survey that would document their premiums should be higher. Thus, elevation corrections to the registry by homeowners will be most likely to occur when owners believe their aerial surveyed elevations are too low, and less likely to occur when owners believe their aerial surveyed elevations are too high. In the latter case, errors that support lower premiums are more likely to remain in the registry indefinitely.

Registry Use by Others

Community Floodplain Managers. When registry records are enhanced to include accurate geographic coordinates, street addresses, assessed values, square footage, and elevation data for all floodprone structures in a community, floodplain managers can implement *proactive floodplain management* principles. HAZUS models can be used to accurately estimate the damages to individual buildings from past or from predicted future flood events, and sum the total damages to all flood-prone buildings in the community so that the floodplain manager can quantify the potential cost to the community from such predictable flood events. This risk assessment helps to identify and prioritize the need for subsequent steps to mitigate flood risks: (1) drainage improvement projects, (2) floodproofing projects, (3) public education and flood insurance marketing, (4) flood warning systems, and (5) post-flood rapid damage assessments. Charlotte-Mecklenburg, NC already does this with great cost-effectiveness, and their lessons learned could be used to encourage other communities to do the same.

FEMA. Immediately following a riverine flood or a hurricane tidal surge, FEMA seeks to know the total losses to a community. The same information described above for *proactive floodplain management* is vital for accurate and rapid damage assessments by FEMA. When the elevation of flood waters are known for a flood event, information in the enhanced registry will provide (1) depth of interior flooding, (2) square footage, and (3) assessed value — the three parameters required by HAZUS for accurate damage assessments.

FEMA might also use the registry for checking insurance policies and community compliance. Georeferenced ECs and policies-in-force data can be plotted on top of digital orthophotos to determine floodprone structures that are currently uninsured, but this will only be effective when all addresses are accurately geocoded. LIDAR data can be used to determine if existing ECs have accurate or inaccurate LAGs and HAGs and whether a LAG is above or below the BFE, for example, but remote sensing alone cannot determine the accuracy of lowest floor elevations. Airborne remote sensing can be used to count the total number of structures in floodplains and determine those structures for which ECs are available and non-available — the goal being to maintain ECs on all such structures if possible; but aerial survey products can not determine if structures are pre-FIRM or post-FIRM since dates of construction are unknown. LIDAR and/or photogrammetry alone will not be able to identify the majority of non-compliance issues. For example, aerial survey products can not determine the following: (1) lowest floor elevations surveyed to the wrong story, (2) illegal construction below elevated structures, (3) illegal finishing and use of crawl space or storage space, (4) elevations of basements below the BFE, (5) lowest elevation of machinery below the BFE, (6) non-breakaway walls in V-zones, and/or (7) inadequacy of flood vents. All of these require on-site inspections to verify compliance.

A broader FEMA database of structures could include all structures, not just those determined to be floodprone, for the following reasons:

- The NFIP has a vested interest in understanding the numbers and elevations of structures outside the SFHA, and their proximity to floodplains, for the purpose of marketing preferred risk policies and estimating the impacts of map revisions that raise BFEs and increase the size of SFHAs within communities. SFHA buffers, used to identify candidates for preferred risk policies, would change as new flood studies are completed or future conditions are taken into account.

- An expanded database could also support other FEMA programs that require structure data on a broad basis. As part of the Department of Homeland Security (DHS), it is important for FEMA to have an inventory of all structures in the U.S., both floodprone and non-floodprone, to support individual and public assistance following all natural and technical disaster. For example, multi-hazard response and recovery activities routinely need accurate geographic coordinates linked to street addresses. Computer models that predict the spread of wildfires also utilize elevation data.

- For all forms of pre-disaster mitigation planning, DHS needs to maintain current information and GIS-based imagery on all structures that could be impacted, to include address, geographic coordinates, assessed value, and information about each structure such as used by realtors and insurance agents. A complete and up-to-date geocoded inventory of all structures is needed to determine where to send inspectors for preliminary damage assessments following natural and technical disasters. This inventory would help to identify legitimate claimants and reduce fraudulent claims. The U.S. Census Bureau, U.S. Postal Service, state emergency management centers, local communities and E-911 services all have similar requirements.

> Recognizing Title 13 constraints on the Census Bureau, the challenge for DHS is to develop effective incentives for working with other federal agencies, states, counties, and communities to satisfy common needs.

Individuals. Individuals such as real estate agents and potential home buyers could benefit by accessing the registry for an approximate assessment of flood risk for a specific address. Increased public awareness of flood risk will ultimately result in smarter decisions by those who build, sell and buy structures in or near to floodplains. However, all users must be warned that the registry was designed for determination of insurance premiums and that more accurate elevation determinations may be required for purchase and development decisions by property owners, especially when alternative methods were used to determine lowest floor elevations.

FEMA Implementation Costs

Dewberry estimates that it would cost approximately $4 million to develop a web-based registry supported by a geodatabase or comparable spatial database, assuming the registry is an enhancement to a current FEMA web site such as that of the Map Service Center which is already geared to provide web-based products and services and receive cost reimbursements. In part I of this report, these start-up costs were artificially recouped by applying pro-rated charges of $2.50 each for records that are batch processed and $10 each for records that are individually entered. Strategies A and D alone would account for more than $4 million in cost-effectiveness calculations.

In addition to the estimated $4 million *ramp-up* cost for developing the web-based registry with front-end portal for individual users and individual data providers and back-end portal for the system developer and administrator, other short-term estimated costs to FEMA include the following items that total $392,000 to populate the registry and provide linkage to other FEMA databases:

- $16,000 for scanning, digitization and quality control of nearly 3,200 hardcopy ECs from URS, at $5 each
- $44,000 for reformatting and quality control of nearly 17,600 digital ECs from Dewberry and USACE at $2.50 each
- $50,000 for reformatting and quality control of an estimated 50,000 digital records in the ISO database
- $50,000 for reformatting and quality control of an estimated 91,600 digital records in the LOMA 2000 database
- $100,000 cost to FEMA for extracting and reformatting data for the registry from an estimated 400,000 digital records in the NEMIS database and an estimated 4,500,000 records in the BureauNet database, 80,000 of which include elevation data.

Additional costs to FEMA would include an estimated $350,000 per year for operation of the registry, plus additional costs incurred to reformat and quality control data provided by communities. Dewberry estimated $2.50 per record to reformat and quality control data batch processed by communities, but costs truly depend on FEMA's ability to train communities how to correctly format their data from the beginning so that FEMA's subsequent role is minimal.

Cost Recovery

For maximum cost effectiveness, the elevation registry could "piggy-back" onto FEMA's existing Map Service Center web site at www.msc.fema.gov. The MSC already offers products and services available for a fee to users with a credit card or *draw-down* account. Some current users are *fee-exempt* customers. Scanned images of LOMCs, for example, are available for free on-line viewing, or customers can purchase digital images for downloading on-line. Similarly, the web site provides free How-To Guides online on how to use Map Search and how to download FIRMettes for printing. FEMA already owns the hardware, has established "firewalls," has a web site that is fully certified and accredited, and has the eCommerce account in place to collect fees that go directly into the Treasury. Dewberry sees no need to establish a totally new web site when this existing site could be expanded to include new EC products and services.

Scanned and digitized EC records could be treated as new products or services. Communities that scan and digitize their ECs and provide them free to the registry could, in turn, be fee-exempt when needing to download EC data from the registry. Regular customers such as flood insurance agents or WYO companies could establish draw-down accounts and pay a standard fee for EC records that they download, unless they too submit their total holdings of EC records to become fee-exempt. Individual inquirers would be the ones most likely to use their credit cards to pay for the service; there would be no fee to individuals if FEMA simply provides a link back to a database operated and maintained by a community. If approved by FEMA, a working group would need to be established to work out the technical details and develop cost estimates. Also, procedures would need to be developed to delete or blacken the owner's name from scanned EC images.

If it actually costs $350,000 per year to operate, maintain and upgrade the registry, FEMA should attempt to recover at least this much annually with user fees. For example:

- $10 each for a copy of a virtual EC that looks like a regular EC except that it would be generated from the registry's database and would exclude the name of the owner and the name and seal of the Land Surveyor who produced the original EC. (FEMA would have the scanned image of the original EC on file, with the file name and path included in the database record (see APPENDIX R, items 68 and 69) but FEMA would not make the scanned EC available to the public.)
- $5 each for an alternative record from remote sensing that lists elevations needed for insurance rating, but without certification by a Land Surveyor.

- $2 each for an alternative record from remote sensing that lists LAG/HAG elevations that could be usable for a LOMA, but without certification by a Land Surveyor.

Each of these costs compare favorably with the alternative of paying hundreds of dollars for a new EC survey. These alternative EC costs are admittedly higher than the $1.50 that users pay for a scanned FIRM image from the Map Service Center, but alternatives to scanned FIRM images are paper FIRMs that might cost $10 should they be sold commercially at a map store. Thus, getting a scanned EC for only $10 would be a real bargain compared with the much higher cost of an individual EC.

Dewberry has no way to accurately estimate how many individual users would seek to purchase ECs from the registry because much depends on FEMA policies to be developed as well as marketing initiatives to promote the registry. Currently, FEMA receives about $1 million annually from Map Service Center products, much from the sale of scanned FIRM images at $1.50 each.

Community Implementation Costs

Nothing is mandatory for community participation with any of the Strategies. It will cost communities an estimated $5 for each of their hardcopy ECs that they voluntarily digitize, quality control and insert in the registry, but it will cost very little if ECs are already digitized. It will cost communities an estimated $55 to $60 per structure (primarily for on-site vertical offset measurements) to voluntarily convert their existing LIDAR or photogrammetric data into alternative EC records suitable for batch processing into the registry. Community costs to digitize building footprints linked to street addresses are normally borne by GIS-enabled communities using this information for tax assessment purposes.

Incentives

Community Rating System (CRS) credits are FEMA's primary incentive to encourage communities to support the registry, but it is questionable whether CRS credits alone would be sufficient to make a community willing to spend an estimated $55,000 to $60,000, for example, to convert their existing LIDAR or photogrammetric data into 1,000 alternative EC records for the registry. They will need to be convinced of a "greater good" such as demonstrated by Charlotte-Mecklenburg whose development of a local EC database allows them to implement *proactive floodplain management* principles.

FEMA's Cooperating Technical Partner (CTP) program encourages communities to acquire LIDAR data for general mapping purposes, made available to FEMA for hydrologic and hydraulic modeling for a FIS, in exchange for FEMA giving higher priority to Map Modernization funding for such CTPs. Community tax records can provide assessed values and structure square footage needed to complete records for *proactive floodplain management* initiatives summarized above.

Insurance firms could voluntarily provide EC files for the registry, but they too would need to be convinced of a "greater good" by sharing their data with others including competitors. Overall, since the basic purpose of the registry is to help insurance agents and WYO companies who have long affirmed that the requirement for ECs is a major impediment in selling flood insurance, they must be convinced of the benefits of supporting the registry or else there is no point in proceeding.

Advantages and Disadvantages

Dewberry concludes that it is appropriate, feasible, and legally possible for FEMA to obtain the elevation data on individual structures and to make this elevation information available in an elevation registry. However, in addition to cost factors, FEMA and its major constituencies must support the registry for it to be successful.

- FEMA itself might use the registry for checking policies, community compliance, post-disaster response and recovery, and to help insurance agents and WYOP companies sell more flood insurance by helping everyone recognize true flood risks and simplify the flood insurance application process. The major disadvantage to FEMA is the estimated $4+ million start-up cost, $5 each for digitizing hardcopy ECs into the registry, and $350,000 annual operating costs.

- With an elevation registry, the insurance industry should ultimately find it easier to sell flood insurance; but until the registry matures, they may still complain that the registry is incomplete or unreliable for its intended use. The insurance industry may be reluctant to provide elevation data to the registry if they believe it negates a competitive advantage.

- With an elevation registry, communities could be more-proactive floodplain managers, and increased CRS credits would result in lower insurance premiums. Yet, the major disadvantage is the time and money (potentially $60,000 per community) necessary to collect data needed to populate the registry. Thus, success may be spotty, successful in communities that provide strongest support, and less successful elsewhere until they learn from other communities that demonstrate strong benefits.

Summary

Dewberry recommends that FEMA open a dialog with the insurance industry and the floodplain management community -- to promote the concept of the registry. Efforts with these constituencies must succeed before FEMA begins attempts to implement an elevation registry. Only then can steps be taken to implement a registry that is as affordable, accurate, reliable and as useful as possible.

Once the decision is made by FEMA to proceed in development of a registry:

- FEMA should proceed with implementation plans to obtain needed funding and contract for the development of the web-based registry as described above. This would include plans for ways the stand-alone registry could feed data into the NextGen data warehouse.
- FEMA should design and implement quality control standards, processes, and documentation for populating the registry with data. These processes will specify the types of data sources (with different accuracy levels) and the documentation and certification required for data before it can be incorporated into the registry.
- FEMA should obtain structural elevation data from all potential sources following the various strategies described above. This includes incentives to encourage cooperation and active support from floodprone communities and the insurance industry itself.
- FEMA would need to amend regulations and manuals to allow WYO Companies and agents to rely on the registry for rating of policies, thus supporting the argument that reliance on the registry's data satisfies the professional standard of care.
- The FEMA general counsel should determine if there are any prohibitions to nominal user fees for access to data in the registry, especially if FEMA provides scanned copies of ECs originally paid for by others, but deletes the names of the owners.

All must recognize that the registry will have modest gains at first, but will grow in utility and value as the registry becomes fully populated with reliable data and has effective means for updates.