THE NEED FOR HEIGHT MODERNIZATION IN ILLINOIS
EXECUTIVE SUMMARY

Illinois Height Modernization Committee
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Every engineering project and many land-use planning efforts require accurate measurements of heights. To accomplish this we need a datum-consistent vertical and horizontal statewide network of survey benchmarks and a statewide high-resolution digital elevation model (DEM) of the earth's surface. Unfortunately, Illinois currently falls far short of both goals and is ranked in the bottom ten regarding the quality of its elevation data. The National Geodetic Survey (NGS), part of the National Oceanic and Atmospheric Administration, provides funding to states through the Height Modernization program to improve the quality of elevation data using global positioning satellites (GPS) technology in conjunction with traditional leveling, gravity, and modern remote sensing. We recommend that Illinois utilize this program to upgrade the statewide network of survey benchmarks and develop a statewide high-resolution digital elevation model (DEM) of the earth's surface.

Illinois has two major networks of benchmarks, NGS and U.S. Geological Survey, which are supplemented by several other networks. Each benchmark is tied to a different known elevation marker, called a datum. These networks are not integrated into a single database, and approximately half of the benchmarks can no longer be located. Perhaps the principal area where the geodetic control network is deficient is the Chicago metro area. Because of the different datums, numerical conversions between networks are approximate, which lowers the accuracy of elevation data. In the Mississippi Valley in northern Illinois, for example, levee-top surveys and water level measurements are based upon two different datums, making accurate predictions of levee over-topping during flooding more difficult. Average annual flood damage is estimated to exceed $700 million in Illinois, yet our accuracy in predicting flooding is hampered by inconsistent datums.

Illinois' DEMs (large-scale, digital topographic maps are the most common example) are mainly based on 5- or 10-foot contours, depending on local relief and original map resolution. Many of them contain elevation information acquired in the 1920s and 1930s. Modern techniques allow for better resolution and some new DEMs are being developed based on 2-foot data. Cook, Kane, Lake and Will Counties have all developed 2-foot resolution models using local governmental funding. In low relief areas, the comparison between the old low-resolution and new high-resolution data shows remarkable improvement in visible detail.

Nearly every engineered design of structures needs current and accurate elevation data for the immediate site and its surroundings. However, vertical reference benchmarks are scarce, and vertical datums and topographic information are inconsistent throughout Illinois. This affects all engineering projects, natural resources studies and modeling, and even routine surveying. To accurately and efficiently predict the extent and depth of flooding, coastal erosion, or natural disasters; monitor landscape changes due to artificial improvements; plan for roadway improvements; develop evacuation routes; and minimize environmental impacts, it is critical to have one current, consistent vertical datum on which field surveys and a statewide DEM can be based. A National Geodetic Survey report concluded that "the potential for financial benefits was found to be staggering".

Illinois became part of the NGS Height Modernization Program in FY08, through a $352,500 appropriation. This project needs to be continued to improve the number and accuracy of benchmarks, which are the foundation of all surveying efforts, and to improve the accuracy of DEMs, which are needed for the large number of land-use planning applications that require accurate and detailed elevation information. The cost of the project is estimated at $35 million over ten years, with higher levels of funding in the first four years to complete the DEM portion of the project.

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WHAT IS THE HEIGHT MODERNIZATION PROGRAM?

Height Modernization is the establishment of accurate, reliable heights using global positioning satellites (GPS) technology in conjunction with traditional leveling, gravity, and modern remote sensing. The National Geodetic Survey (NGS), part of the National Oceanic and Atmospheric Administration, provides funding to states for this effort through grants to organizations or agencies in states which are identified in the Congressional budget. The goal of the Illinois Height Modernization Program (IL-HMP) is to establish (1) a datum-consistent vertical and horizontal statewide network of survey benchmarks and (2) a statewide high-resolution digital elevation model (DEM) of the earth's surface based upon the updated network of survey benchmarks. Illinois currently falls far short of both goals and is identified by the NGS as being in the bottom ten U.S. states with regard to the quality of its elevation information. In the upper Midwest, Minnesota and Wisconsin rank above Illinois in the quality of elevation data. In a 1998 report to Congress, the National Geodetic Survey noted that "the potential for financial benefits was found to be staggering, even based on conservative estimates".

All types of property and engineering surveying rely on benchmarks. A benchmark is a relatively permanent object whose elevation above an adopted datum is known. Illinois has two major networks of benchmarks – the NGS and U.S. Geological Survey (USGS) – which are supplemented by several other networks. Illinois has been unable to replace benchmarks that are destroyed due to ongoing construction, farming, or other activities. Nearly half of all benchmarks have been destroyed. Efficiency and good engineering require that all elevations be tied to a single datum, but Illinois has several vertical datums. These datums are not easily related to each other, further confounding large-area surveys. These include two well known national datums, NAVD88 and NGVD29, and numerous municipal datums, the best known of which is the City of Chicago datum. Two different datums are used by the U.S. Army Corps of Engineers (USACE) Rock Island district for management of the Mississippi and by the USACE Louisville district for management of the Ohio River. These datums are particularly important because they affect the management of substantial parts of the two largest rivers in the state and because conversions between them and the national datums are not precise. IL-HMP is needed both to replace lost benchmarks and resolve the conversion between datums.

The second component of the program is improvement of DEMs, which are grids of elevation data. A topographic map is a representation of a DEM. Modern techniques, such a LiDAR (Light Detection And Ranging) allow mapping with an accuracy of 2 feet or better. In areas of low relief, such as floodplains, 5-foot data are of limited use, because a small change in flood height can affect a large area. Figure 1 shows a comparison of USGS DEM elevation data and LiDAR data. Figure 1a is a shaded relief image created from the USGS 7.5-minute formatted digital elevation model data, which have a grid spacing of 30 meters (98.4 feet). The vertical resolution of the USGS DEMs represent the contour interval from the original source 7.5-minute quadrangle maps, which is typically 10 feet (as in this example) or 5 feet. This represents the best statewide elevation data currently available. Figure 1b is a shaded relief image produced from LiDAR elevation data, which has a grid spacing of 10 feet and a vertical resolution of 2 feet. The area depicted corresponds to the central portion of the USGS DEM shaded relief image. Because of the much higher vertical and horizontal resolution of the LiDAR elevation data, both cultural and physical features are revealed in significantly higher detail. .

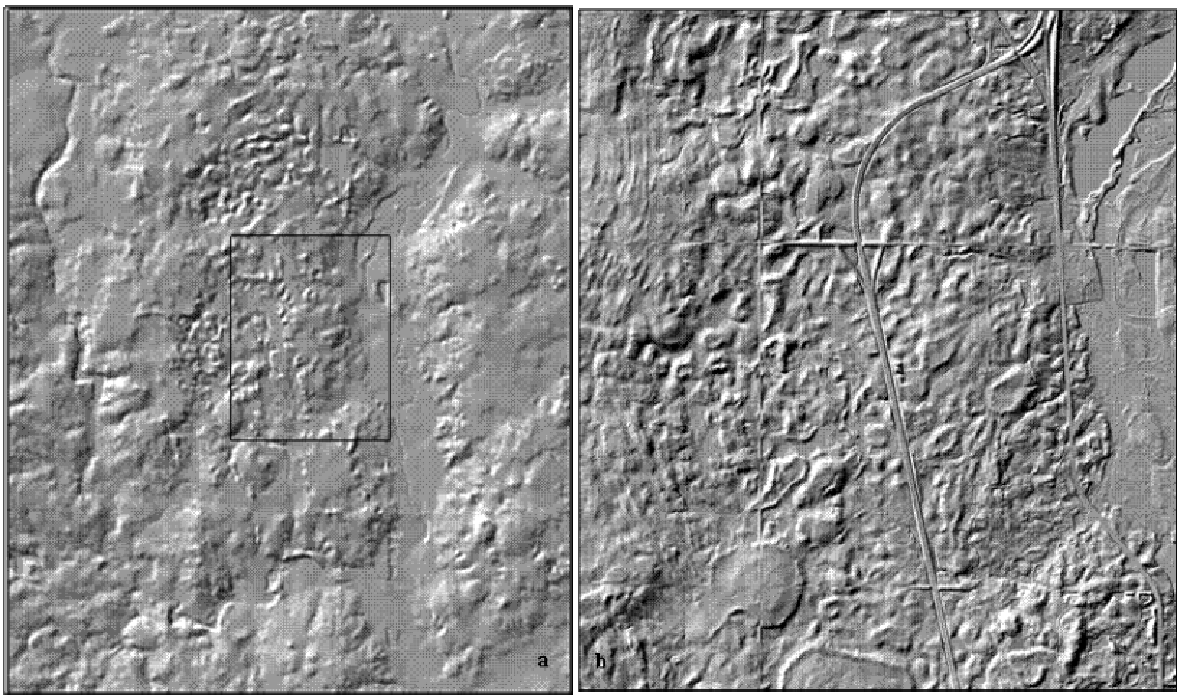

Figure 1. Comparison of digital elevation data for Lake County. On the left, (a) is a shaded relief image created from the USGS 7.5-minute formatted digital elevation model data, which have a horizontal grid spacing of 30 meters (98.4 feet). The vertical resolution represents the contour interval from the original source 7.5-minute quadrangle maps, which is 10 feet for this image. The box is the area covered by (b), which is a shaded relief image produced from LiDAR elevation data which has a horizontal grid spacing of 10 feet and a vertical resolution of 2 feet.

Illinois should become part of the NGS Height Modernization Program to take advantage of available federal funding to resolve these problems, which can cost lives, damage property, and increase the cost of building projects. Details on the impact of better data follow.

EXISTING CONDITIONS IN ILLINOIS

Illinois has the fifth largest population in the United States. Population growth has greatly changed the landscape through construction of roads, residences and other buildings, industry, and commercial ventures. Illinois currently has a roadway network (interstate, state, and local) of 139,930 miles, including 26,347 bridges and more than 2,100 miles of interstate highways. Although primarily an agricultural state, Illinois contains some of the fastest growing urban areas in the nation. It also has one of the largest inland systems of rivers, lakes, and streams in the United States; has numerous surface and underground mines; is affected by sinkhole development in karst areas; and has a history of earthquakes. Development is increasingly encroaching upon areas with greater natural hazards or sensitivities to disturbance. Development has changed the landscape, affecting property nearby and downstream, so that areas that were less susceptible to flooding, landslides, and other hazards now face increased risk.

HOW BETTER HEIGHT INFORMATION WILL BE USED

Because of natural and human processes, Illinois' topography is constantly changing. To accurately and efficiently predict the extent of flooding, monitor landscape changes due to artificial improvements, natural processes, or natural disasters, plan for roadway improvements, develop evacuation routes, and minimize environmental impacts, it is critical to have a statewide vertical datum upon which field surveys and a statewide DEM can be based. It is difficult to plan access and evacuation routes in response to a natural catastrophe (earthquake, flood, etc.) or other calamity (e.g., dam failure, chemical release, wildfire, etc.) and to determine the extent of damage with inaccurate data or with data from differing datums.

Flood Modeling and Prediction

On average, floods cause more deaths each year than any other natural disaster (USGS, 12/30/99 news release), and the ensuing damage is the most costly of natural hazards. With surface water from 24 states entering or flowing along Illinois' boundaries, flooding is a common occurrence in the state. Since the flood of 1993 alone, the state has had state or federally declared flood disasters in six years. While Illinois used to rank in the top ten states for flood insurance claims, strong state regulations to protect property in potential flood damage areas and efforts to move homes and businesses out of harm's way have knocked it out of the top ten. Even so, flood damage is estimated to exceed $700 million per year in Illinois. With Illinois' large and growing population, rapid incorporation of elevation data is critical to successful floodplain management in the urbanizing areas of the state.

Flood modeling and prediction in Illinois is a challenge. Not only is water from 24 states entering or flowing along Illinois' boundaries, but the water level information is tied to several different datums established by a variety of agencies. The USACE utilizes three different vertical datums to measure and model water levels on the Mississippi, Ohio, and Illinois Rivers. In addition, river stages are forecast at a very limited number of river gages. The area flooded between the gages is not forecast. The fieldwork required to determine stream channel shape for computer modeling of a river system can also be very time consuming. Field surveys begin with locating suitable survey benchmarks for a study area, which often requires days of research and extensive travel. Transferring the vertical elevation from a suitable benchmark to a study area may also require days of leveling before the field survey of stream channels can begin. Solving these problems efficiently will require a substantial investment in the geodetic control network.

To address flood modeling and prediction, the Illinois Department of Natural Resources (IDNR), State Water Survey (SWS), and the Office of Water Resources (OWR) have launched a joint effort to work with the Federal Emergency Management Agency (FEMA) on floodplain map modernization in Illinois. This effort began in 2005 with a five year program to convert existing paper flood panel maps to a digital GIS format. Height Modernization will benefit future updates of the digital GIS flood panels by providing a topography that will more accurately map floodplains. Illinois has taken an aggressive step to fully participate in floodplain map modernization, recognizing that participation benefits the people of Illinois by providing state expertise for the best mapping product.

Recent floodplain mapping in North Carolina based upon 2-foot contour data (Figure 2) shows a greatly expanded area expected to be covered by a 100-year flood, than did older maps based upon the same type of elevation data currently available in Illinois. Information about the federal program, which has recently included Illinois for multiyear floodplain mapping, can be found at http://www.fema.gov/fhm/mm_main.shtm. Flood-prone areas will be better delineated, and the improved DEM data will enhance modeling for flood prediction and designation of

escape/access routes for emergency workers. Nationally, the value of high resolution DEMs for flood hazard mapping has been estimated at more than $225 million (NGS, 1998). Savings of hundreds of thousands of dollars have been documented for a single county in Wisconsin (Winnebago) as the result of the completion of improved floodplain maps based on more accurate elevation data (Moyer and Henkel 2004).

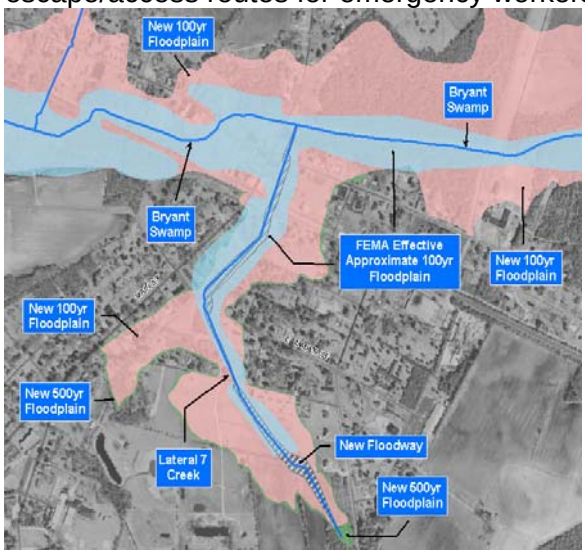

Figure 2. New 100-year floodplain delineation (shown in pink) compared with previous delineation (shown in blue) for part of North Carolina

High resolution DEMs can also be used for designing detention basins for flood control, which is required of many commercial and residential development projects. The DEMs provide better estimations of drainage boundaries, which allow better calculations for the size and placement of retention basins to assure that they perform as required.

Cost Savings in Building Projects

Nearly every engineered structure needs current and accurate elevation data for the immediate site and its surroundings. However, vertical reference marks are scarce, and vertical datums and topographic information are inconsistent throughout Illinois. The lack of sufficient, accurate benchmarks, in almost all cases, requires a significant level line run (in many cases several miles) to the nearest NGS benchmark. It is estimated by one engineering firm that at least $2,000 to $5,000 must be added to each building project in order to tie and utilize associated data (soils, topography, etc.) referenced to NGS benchmarks. Having a current statewide DEM will reduce the time and expense of creating and modifying DEMs for individual projects.

In the article “More Accurate Elevation Data for Users of Geospatial Data,” published in the Winter 2004/2005 issue of Arc News, Moyer and Henkel state, “This benefit of saving time and cost for field surveying activities is so large that WisDOT was able to cost justify the entire WI-HMP plan based on transportation planning, design, and maintenance activities alone.” Indeed, Moyer and Henkel estimate annual savings of over $1 million for surveying of photogrammetric targets from highway design/mapping projects alone. Given the much larger highway network present in Illinois compared to Wisconsin (with nearly 3 times the number of miles of interstate highways) and the large amount of photogrammetric projects undertaken in the state (approximately 250 miles mapped per year), potential savings are substantial.

Mapping for Regional Planning

Geologic maps and their derivative products, including aquifer maps, geologic hazards maps, construction suitability maps, and aggregate and mineral resources maps are necessary so that land- and water-resource planning can be most effective. These maps are based on test borings and well records filed with the state and supplemented by field observations, including test holes drilled for specific projects. The most numerous data, and least expensive to a given mapping project, are those records already on file with the state. Frequently, well location accuracy can be improved from plat maps, etc., but elevations, which are estimated by extrapolation from existing large-scale USGS topographic maps, are no more accurate than the mapped contour interval. Verifying well locations and elevations is a labor-intensive task, impeding the progress and quality of geologic mapping. Vertical error adds uncertainty to the boundaries between

landforms and their associated geologic materials, making maps of aquifers, coal, and other mineral deposits less accurate. Landforms are a principal tool for finding sand and gravel resources for local construction projects. Precise delineation of the boundaries between geological materials is critical for accurate modeling of groundwater, including the determination of available supply and the movement of contaminants. If the elevation at a particular location on a geologic map or 3-D model is inaccurate, the boundary between two units—one an aquifer, the other a non-aquifer—may be portrayed considerably higher or lower than actuality. Subsequent land-use planning decisions could result in actions requiring costly and unnecessary cleanup, or worse, a decision not to clean up contaminants over a susceptible aquifer.

Accurate elevation data is needed for mapping geologic hazards. There is no detailed, statewide model of location and elevation to which landscape changes can be compared after a hazard event. Subsidence beneath buildings, homes, bridges, and roads is problematic in communities developed over former underground mines. Health and fire hazards resulting from subsidence endanger communities and cause destruction of property and injury to livestock. Accurate DEMs show where subsidence has occurred and is most like to expand.

Karst (sinkhole) development and slope instability (landslides) pose risks to many types of built infrastructure. Karst development is a natural process in western Illinois where it is a hazard to surface and groundwater quality. As sinkholes and caves develop, enlarge, and deepen, surface drainage can be diverted directly into groundwater and threaten its quality, especially where sewage treatment lateral lines, sewers, and drainage tiles carry wastes and agricultural chemicals. Finally, slope steepening caused by sinkholes and stream meandering can be exacerbated by earthquake vibrations and can lead to landslides threatening surface drainage and stability of artificial structures, especially lifelines such as roads and bridges. Mapping surface rupture of poorly known and unknown faults in the Wabash Valley Seismic Zone is important for identifying and reducing risk to facilities such as hospitals, bridges, and roads. Landslides and changes in depth and meandering of streams are largely undocumented, or are available only for small sites. Accurate elevation and location data on a statewide basis are critical for evaluation of all natural hazards.

Agriculture and Ecosystems

Agriculture is critical to the economy of Illinois, where two-thirds of the land is farmed. Precision agriculture can greatly impact the industry and the environment. Soil development, as well as the effectiveness of fertilizer, pesticides, and herbicides is partly dependent upon topography. Variable rate application of agricultural chemicals – as determined by topography – yields significant cost savings and a reduction in agricultural pollution. Because of the lack of high-resolution DEMs, the full benefits of precision agriculture cannot be realized. The national value of Height Modernization to precision farming was estimated at $1.7 billion in 1998 (NGS, 1998).

High resolution DEMs are also valuable for examining erosion and determining where best to place erosion control structures. Erosion is a problem both because of the loss of valuable topsoil, and because it degrades the streams into which the eroded material enters. Because of the negative impacts of erosion, the Illinois River 2020 program emphasizes erosion control as part of river ecosystem restoration and navigation improvement. Wetland reconstruction and species habitat prediction will also benefit from high resolution DEMs.

PROBLEMS WITH THE CURRENT VERTICAL CONTROL NETWORK DATA

Accurate and high resolution height and elevation data is critical to nearly every aspect of life in Illinois. Unfortunately, Illinois suffers from a lack of benchmarks, multiple vertical datums, and DEMs with low vertical resolution and outdated elevation data.

Problems with the Current Network of Benchmarks.

Leveling remains the most accurate method of determining heights for a wide variety of engineering applications including planning, design, construction, hydrologic studies, and maintenance of roads, residences, industry, and commercial ventures. Leveling requires tying the survey to a network of known points or benchmarks with reliable heights. Because they are a necessary component of nearly every development project, benchmarks play a critical role in the economic development of Illinois. Geodetic benchmarks also fill a critical role in facilitating economic development and response to emergencies like flooding. These known points are from the USGS network, NGS network, or other monuments set by government or private surveyors. Illinois has lost nearly half of its benchmarks and continues to lose them, because no funding is available for replacements.

Illinois' deteriorating network of benchmarks is also problematic because the various benchmarks are not contained in a single database and are not all on the same geodetic datum. The NGS maintains the most comprehensive database of benchmarks, which are adjusted to ensure that the heights assigned to benchmarks are consistent with each other. Other important benchmarks, such as those of the USGS and the USACE, are not currently included in this network. Despite the multiple benchmark systems, not all parts of Illinois are well covered. Figure 3 shows all of the benchmarks currently in the NGS database for Illinois. While most parts of Illinois are reasonably well served by the current network of benchmark lines, there are significant gaps in the western part of the state, requiring long level lines to bring vertical control to projects there.

The geodetic control network is clearly deficient in the Chicago metro area (Figure 3). While the density of control points in this region is comparable to other parts of the state, the need is far greater in this dynamic, rapidly growing urban environment with a very high density of critical infrastructure to support. Density of control is quite good in central and southern Cook County, but northern Cook County and Lake County have only one line of benchmarks along the lake shore. Rapidly urbanizing McHenry County also has only a single line of benchmarks; and Boone County does not contain a single NGS benchmark.

Benchmarks continue to be destroyed by construction and other activities. Although the NGS and the Illinois Department of Transportation (IDOT) make every effort to replace benchmarks that will be disturbed by construction activities before they are lost, frequently notification is not received in time. This is shown in Figure 3, where the benchmarks shown in blue have no reported recoveries in the last ten years and, thus, have a significantly higher probability of having been destroyed than those benchmarks shown in red. Benchmark loss is especially a problem in the Chicago area due to rapid development and high rate of construction, particularly road construction, in the area. The benchmark recovery data shown in Figure 3 represents the best measure of benchmark survival available from the database; however, some benchmarks that are in good condition may have received no reports, and some benchmarks reported in good condition may have subsequently been destroyed.

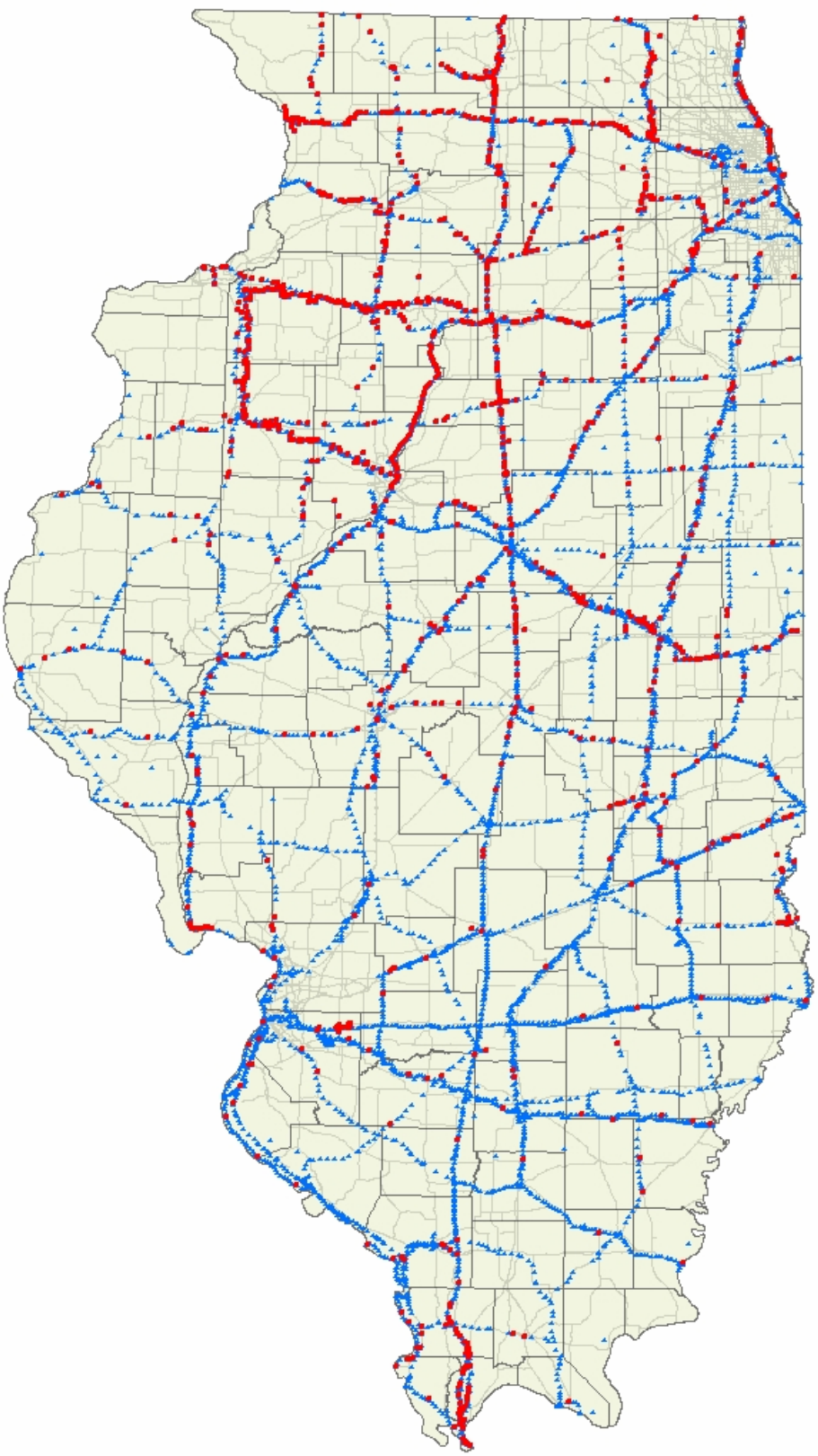

Figure 3. NGS benchmarks for Illinois. In the past ten years, benchmarks shown in red were reported in good condition while those depicted in blue had no reported recoveries.

Table 1. Surviving IDOT benchmarks in each IDOT District.

IDOT District	% Benchmarks Surviving
1	50
2	60
3	na
4	na
5	48
6	66
7	35
8	60
9	75
Statewide Average	56

Another measure of the rate of loss of benchmarks can be developed by polling the IDOT Chief of Surveys for the nine IDOT districts. Because these individuals are responsible for a wide range of surveys in their respective areas, they are well positioned to estimate the rate of benchmark loss in their areas. Results of polling the districts (Table 1) suggest that just over half of the original benchmarks are still in place. The greatest loss of benchmarks seems to have occurred in District 7 (south-central Illinois), where analysis of recovery data indicated major loss of benchmarks. District 1 (Chicago metro area) shows a loss of fifty per cent of its IDOT benchmarks, which is similar to the benchmark recovery data shown in Figure 3.

In summary, nearly one-half of Illinois' original benchmarks are already lost and threats to the surviving benchmarks are increasing. This problem is compounded by the lack of an ongoing program to develop new level lines that can replace lost benchmarks and densify the network in rapidly urbanizing parts of the state, such as the Chicago metropolitan area.

The Problem of Multiple Datums

All benchmark elevations are measured with respect to a reference surface, called a datum. Illinois has a variety of datums in common use, which results in elevations being produced that are inconsistent with elevations from nearby surveys that used a different datum. The principal vertical datums for Illinois are the national datums NAVD88 and NGVD29, which are supplemented by several older datums that are still in use in limited areas such as the City of Chicago datum. A definition of this datum established by city ordinance exists as a static shift with respect to NGVD29. However, there are inconsistencies between this and values adopted by various city departments. Two other legacy datums are also important in Illinois. These are NGVD12, used by the USACE Rock Island district for management of the Mississippi, and the Ohio River datum, used by the USACE Louisville district for management of the Ohio River. These datums are particularly important because they affect the management of substantial parts of the two largest rivers and their floodplains in the state. Approximate conversions between these legacy data and NAVD88 exist, but their use degrades the precision of the measurements. During emergencies, these inconsistencies can cause confusion and waste valuable time. Multiple datums also make it virtually impossible to create useful, accurate, seamless maps and supporting flood data for the state. An example of the problems that multiple vertical datums can cause can be found in the Mississippi Valley in Northern Illinois, where levee top surveys are in NAVD88 and water level measurements are in NGVD12.

Deficiencies in the Current Digital Elevation Model

The current statewide DEM was obtained from USGS topographic maps. The maps were compiled at 1:24,000-scale (1 inch on the map equals 2,000 feet on the ground), with contours derived by plane table surveying and photogrammetric methods using benchmarks and triangulation stations surveyed over several decades by a variety of classical methods and instruments. USGS National Map Accuracy Standards (NMAS) specify one-half contour interval accuracy for 90% of points of well-defined features, such as road intersections, bridges, and monuments. Some USGS topographic maps for Illinois do not meet NMAS. Consequently, the

current statewide DEM possesses inadequate elevation resolution and accuracy for modern detailed maps and models.

Modern techniques, such as LiDAR imaging can greatly improve DEMs. To date, Cook, Kane, Lake, and Will Counties are the only Illinois counties with local high-resolution DEMs. The Lake County LiDAR DEM dataset (+/- 2-foot vertical accuracy; 10-foot square pixel) provides higher accuracy elevations than common GPS measurements and even rivals differentially-corrected GPS (DGPS) measurements. For Cook County LIDAR DEM (Alan Hobsheid, personal communication), the LIDAR cost was about $500K of a $1.4 million purchase for imagery of 1,000 square miles. The County is pleased with the filtered digital surface model (DSM) that was generated by LiDAR and their digital terrain model (DTM), which is a DSM enhanced with break lines, water body delineation, and road crowns to make the elevation model more "sensible." Cook County is pursuing funding to make 2-foot contours from the DTM, which has accuracy of +/- 1-foot (0.6 feet in open terrain).

These new DEMs allow much more accurate floodplain (e.g., Figure 2) and other mapping. The underpinning for an accurate DEM is a stable reference system of horizontal and vertical datums. Without accurate benchmarks to register flight information for orthophotography and topography, the data cannot be accurately interpreted much less used to improve floodplain mapping.

GOALS FOR THE ILLINOIS HEIGHT MODERNIZATION PROGRAM

Products: Benchmarks and DEMs

The Height Modernization Program would allow Illinois to update and densify its existing network of benchmarks. The "Standards and Specifications for Geodetic Control Networks" specifies the spacing should not exceed 3-kilometers along a level line for all leveling, regardless of order. For all first order and second class 1 surveys, the average benchmark spacing should be 1.6 kilometers, while for second class 2 and third order surveys the average benchmark spacing is 3 kilometers. The actual benchmark spacing will also depend on the spacing of the level lines. Spacing of level lines depends on the infrastructure that we are trying to support. A denser network is needed in rapidly developing areas, such as the Chicago metro area and the St. Louis metro east area, than in predominantly rural areas.

The resulting statewide network would consist of points that are all GPS accessible, are accurate both horizontally and vertically, and are on one consistent datum. Height modernization will provide the opportunity to standardize the horizontal and vertical control used in the measurement and/or modeling of all the various watersheds, rivers, roadways, floodplains, farm fields, landscape changes, landslides, well locations, and so on throughout the state. The program would also support the use of GPS for accurate determination of heights (Zilkoski, D'Onofrio, and Frakes 1997), which would result in significant savings in costs for services to the public.

Two by-products of the height modernization program would include a CORS (Continuously Operating GPS Reference Station) network and LiDAR imagery or similar technology that may be developed in the future. Over the past year, many individual CORS have been set up in Illinois. Completing the network statewide would be a great benefit to all surveyors. LiDAR imagery offers an economical method for acquiring digital elevation data. This data would be widely used in various modeling programs. With a denser network of geodetic monuments, a CORS network, and LiDAR-generated DEM, Illinois could truly maximize the benefits of the

latest GPS and digital technologies. It would also provide a geodetic control foundation, which could be used to provide interdependent linkage among geographic information systems (GIS) data layers.

An updated, densified, statewide network of combined horizontal and vertical benchmarks, along with a CORS network, will greatly affect field-surveying activities for many applications. The time and cost of field surveys used for computer modeling of river systems, for roadway designs, for floodplain mapping and management, and so forth will be significantly reduced. With more benchmarks available, less field time will be spent researching and locating acceptable reference marks to base surveys on, and less field time will be spent running miles of levels to bring control to a project site. In addition, with current GPS equipment and technology and a CORS network, the latest methods can be used to obtain the required survey data. Often, the time or human labor required to complete fieldwork can be cut in half with the use of a CORS as the base station.

LiDAR provides a grid of elevations that blanket the earth. The densified network of benchmarks resulting from the Height Modernization Program will provide the foundation on which the high-resolution DEM product will be based. The benefits of these projects are listed below.

Benefits: Flood Prediction and Floodplain Mapping

The network of benchmarks resulting from the Height Modernization Program can be utilized to make elevation measurements along rivers in and around Illinois consistent, rather than based on three different vertical datums. This will increase accuracy and facilitate cooperation between agencies during emergencies. Height modernization will provide the opportunity to standardize the horizontal and vertical controls used in the measurement and modeling of watersheds and rivers in the state. An improved network of benchmarks will also reduce the costs of FEMA surveys used to estimate the elevation of building sites located within flood planes.

LiDAR will provide an accurate elevation model that can be utilized for many applications that are currently not available to the state. An accurate elevation model is a key component to forecast river flooding in real time. Presently, river stages are forecast at a very limited number of river gages, and the area anticipated to be flooded between the gages is not forecast. With the advancement of LiDAR technology and computer hydraulic models, applications have been developed that map the flood extent of a river system as it is forecast in advance of the flood event. Illinois has developed such an application for “real-time” river forecasting of the Upper Des Plaines River, where both LiDAR and a hydraulic model are available. Emergency management at the community, county, and state levels will benefit greatly from a real-time river forecast system by reducing the amount of surveying needed to run levels from the current widely scattered network of benchmarks

Floodplain mapping requires good base maps on which to depict flood hazard areas. The new standard for floodplain mapping is fully-digital with digital orthophotographs serving as the base map. Depicting flood hazards on high quality accurate base maps is a significant improvement over cartographic renditions of aged paper-map features. Use of orthophotography for floodplain maps has the advantage that maps can be readily updated using newer orthophotographs as they become available. GIS technology provides the tools to improve floodplain mapping by integrating spatial data sets such as digital topography (DEMs and DTMs) with flood-study data to accurately interpolate floodplain boundaries.

Benefits: Economic Development

Orthorectification of aerial photography, an important step for removing the radial displacement and distortion for large- and small-scale imagery, will be greatly improved by a more highly detailed elevation model of Illinois. The elevation model is used to rectify the image based on elevation differences of the topography. Having a current statewide DEM will help to reduce the time creating and modifying DEMs for individual projects. The resulting improvement of orthophotography (photo-maps) will benefit all—private and public clients and government agencies—by improved accuracy and reductions in cost and production time.

In addition, the Height Modernization Program and its various by-products will improve land-use planning, groundwater modeling, landscape change measurement, precision agriculture, ecosystem restoration, and validation of surface mine maps. Groundwater models are used for pollution prevention and contaminant cleanup and to determine qualities of aquifers. Groundwater models use geologic data, but require accurate well elevations which can be derived from high-resolution DEMs. As yet, there is not a detailed, statewide model of location and elevation data for which landscape changes can be compared. Landslides, changes in depth and meandering of streams, coastal erosion and accretion, and even massive earthworks are largely undocumented or are available only for small sites. Measurements of landscape, coastal, and stream change could be compared with large area high-resolution DEMs to document changes. High-resolution DEMs will provide improved elevation data for farms, greatly improving the effectiveness of variable rate application of fertilizer, pesticides, and herbicides, resulting in cost savings to the farmer and reductions in agricultural pollution. They can also be used for determining where to place erosion control and document its effectiveness and are valuable for determining where wetland and other types of habitat can be restored. Validation of surface mine maps will be improved with and the extent of settlement and drainage diversion in surface mined areas, as well as subsidence and surface drainage disruption over undermined areas, will be depicted in the DEM.

Benefits: Homeland Security

Illinois' Homeland Security efforts will be enhanced as a result of the Height Modernization Program and related by-products. In managing an emergency, first responders need timely access to accurate elevation data. This is obvious in flood emergencies where emergency management staff may have to advise the public on safe evacuation routes, which can only be done if the elevation of the road surface and the predicted flood levels are both known. Errors caused by inaccurate DEM's or confusion about vertical datums can cause loss of time and potentially loss of lives. In other types of emergencies, the enhanced survey system (particularly the CORS network) will allow first responders to accurately position assets and engineers to monitor movement of buildings or other structures. To protect Illinois and its citizens, it is critical to have documentation of the location and elevation of all major structures, rivers, cities, and so on. These data are helpful in locating and identifying the settings in which damage or contamination has occurred, determining safe evacuation routes as well as access routes for emergency personnel. Accurate elevation models are key components of simulations of contaminant dispersal in surface waters as well as in selection of suitable staging areas for evacuation and emergency relief. The CORS network can be used to help monitor movement of buildings and other structures before, during, and after a catastrophe. Having current data on a consistent datum would greatly enhance the ability to perform these and other unforeseen activities under crisis conditions when there is no time to establish baseline data.

CONCLUSION

Illinois will greatly benefit from the Height Modernization Program. The current network of benchmarks is on various datums, is filled with gaps throughout the state, and continues to

diminish through benchmark loss. This network is the foundation for numerous activities that are critical to the environmental, social, and economic well-being of our state. It is paramount that this network be updated and improved and be sustainable for future generations. While considerable effort has gone into improving the network of horizontal control stations, including the 1998 and 2001 HARN (High Accuracy Reference Network) surveys and local densification projects conducted by IDOT districts and county administrators, few if any benchmarks have been added to Illinois's vertical network in the last 20 years. Various IDOT districts have completed densification projects in their counties. Many counties are also working to obtain countywide imagery for their GIS systems, which requires a countywide network of benchmarks from which to work.

An updated, densified statewide network of combined horizontal and vertical benchmarks, such as produced by IL-HMP, along with a CORS network, will streamline field surveying activities for many various applications. This will reduce the time and cost of field surveys of all kinds, from rights-of-way and parcel maps to computer modeling of river systems. The Wisconsin Height Modernization Program produced significant savings. In his article "More Accurate Elevation Data for Users of Geospatial Data," published in the Winter 2004/2005 issue of Arc News, David Moyer states, "This benefit of saving time and cost for field surveying activities is so large that WisDOT was able to cost justify the entire WI-HMP plan based on transportation planning, design, and maintenance activities alone." This network will also provide the foundation for high-resolution DEMs. The Height Modernization Program will include any improvements to existing or construction of new vertical reference marks and any leveling work that would be required in preparation of obtaining high-resolution DEMs. High-resolution DEMs have multiple uses which can improve safety and security and can bring economic and ecosystem benefits. The cost of the project is estimated at $35 million over ten years with higher levels of funding during the first for years to complete the DEM portion of the project. Illinois received an appropriation of $352,500 in FY08 to begin the project, with funds expected in the summer of 2008. Given that the National Height Modernization found "the potential for financial benefits was found to be staggering, even based on conservative estimates" (NGS, 1998), this program should be an excellent investment in Illinois.

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