Business Plan
for
Developing Statewide Elevation & Bathymetry Data for Connecticut

Developed for the:

The Connecticut Geospatial Information Systems Council (CGISC)

September, 24 2008

Prepared by:

The CGISC Data Inventory and Assessment Working Group
Elevation & Bathymetry Subcommittee

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Connecticut Geospatial Information Systems Council

The Connecticut Geospatial Information Systems Council (CGISC) was established by Public Act 05-3 of the June Special Session. The enabling legislation directs the CGISC to coordinate a uniform GIS capacity amongst the State, Regional Planning Organizations, municipalities, and others. Additionally, the CGISC is required to administer a program of technical assistance to these entities. The CGISC consists of 21 members representing state agencies, municipalities, a regional planning organization, and a GIS practicioner.

Data Inventory and Assessment Working Group

The CGISC has created of four working groups: Data Inventory and Assessment, Education and Training, Financial, and Legal and Security. The Data Inventory and Assessment Work Group has identified 12 framework datasets for Connecticut, and established individual subcommittees tasked to evaluate, document and provide recommendations for each framework dataset. This includes establishing policies, standards and general procedures for the submission, evaluation, maintenance, on-line access, and dissemination of all geospatial data within the purview of the Council.

Elevation & Bathymetry is one of the twelve Framework Data layers. Subcommittee members are:

Kevin O’Brien, CTDEP, Chair
Dr. Tom Meyer, University of Connecticut
Bob Barron, CTDOT
Capt. Mike Alfultis, USCG
Beth Doran, CTDEP
Howie Sternberg, CTDEP
Dr. Roman Zajac, Univ. of New Haven

For more information on this plan, contact:

Kevin O’Brien
Department of Environmental Protection
Email: Kevin.obrien@po.state.ct.us
Phone: 860-424-3432

1. EXECUTIVE SUMMARY

In 2007, through grant funding provided by the Federal Geographic Data Committee CAP grant program, Applied Geographic, Inc. was hired by the Connecticut Geospatial Information Systems Council to develop a Strategic and Business Plan for Connecticut GIS Program. Under these plans, through a series of planning and information gathering sessions and an on-line survey, several clear strategic goals were identified. One of these was the goal of developing a core set of framework data layers that can be shared across state agencies and with local government.

The purpose of this document is to provide a detailed business plan for achieving the goal of developing statewide **elevation** and **bathymetry** framework data layers. Put simply, elevation and bathymetric data provide vertical measurements for the topography (land) of Connecticut and bathymetry (water) of both Long Island Sound and land based waterbodies such as lakes and ponds and are applicable to a wide variety of uses ranging from environmental, transportation, public safety and urban planning, as well as the processing of orthophotography, a specifically identified 'priority' framework data layer for the State.

Elevation Data:

There are several cost-effective technology options to capture improved digital elevation data that is essential to modernize the most current elevation models that (from a statewide perspective) are decades old and too coarse (i.e., 100 to 30 foot resolution) for most of the above mentioned applications.[1] It is worth noting, however, that while many (but not all) of Connecticut's municipalities do have their own elevation data, it is not always the case that they are necessarily more accurate or more recent than the current statewide data; further in many cases the collection and processing methodologies are largely unknown.[2] Therefore, it would be advantageous for Connecticut to plan for the creation of a uniform elevation data layer available to everyone. Experience in other states has shown that financial return on investment is high from applying modern technologies to develop high-resolution contours (i.e., two-foot interval or better), which are significantly more useful and accurate than currently available elevation data.

Bathymetric Data:

For the purposes of this document, references to bathymetry will be relegated to addressing the current status of bathymetric data. In Fall 2007, the Connecticut Department of Environmental Protection (DEP) Office of Long Island Sound Programs (OLISP), in partnership with the University of Connecticut and the EPA Long Island Sound Study, hosted a Long Island Sound Seafloor Mapping Workshop. Attendees from Federal, State and Private sectors spanning natural resource managers, scientists, and planners identified mapping needs and geographic

[1] The specific data referenced here is the USGS National Elevation Dataset (NED) for CT. A more recent and accurate statewide layer based on elevation data collected in 2000 is currently being processed but has not been fully completed or deployed to support anything other than basic display or research. The focus of this document is to facilitate, in part, the update and upgrade to the 2000 elevation data.

[2] CT DEP Digital Flood Map Modernization Program. Refers directly to communities in Fairfield and New Haven counties, but can be extrapolated across the state.

locations to address key management and research goals. The results of the workshop are currently being compiled into a strategic planning document for seafloor mapping for the State of Connecticut. Once completed, the needs and recommendations from that document will be examined and where appropriate referenced here. Until then, rather than duplicate and existing effort, this business plan will wait to incorporate the majority of bathymetric data layer planning.

In Connecticut, no single department is currently responsible for statewide acquisition of elevation and bathymetric data. Historically, the DEP was the primary steward of statewide elevation and bathymetric data, though not necessarily active in acquiring or processing it. In 2000, the Department of Transportation (DOT) in partnership with the Department of Public Safety, (DPS) and the DEP, arranged for a statewide flight to collect elevation data – the original data was not contracted to be in the public domain, but a derivative set is and through cooperation with the University of Connecticut, will be made available for public use shortly. In the absence of a dedicated CTGISC led effort, a collaborative approach between experienced and/or interested state agencies would be required for the planning and implementation of providing elevation and bathymetric data layers.

Generally speaking, the acquisition of improved elevation data for a state the size of Connecticut from initial project planning to distribution of deliverables requires a multi-year effort. A phased approach is described in this plan, spanning a three-year period for program development activities and milestones.

For budgeting purposes, the essential base data assumes a cost of $90 per square mile for acquisition, or roughly $150K for the entire state. Additional data products can be derived from the base data, adding to the total investment. For example, improving from the current 10-foot elevation contours to the two-foot contours needed for flood map modernization would add another $95 per square mile, bringing a total project cost of roughly $725K. This and other options, however, can be implemented in a prioritized, task order basis to spread costs over time. It is also worth noting that any budgetary estimates are based upon a self-contained elevation-centric project. Cost reductions can likely be achieved if, for example, elevation data flights are coordinated with statewide aerial orthophotography flights or if Connecticut were to partner with neighboring states to collect regional elevation data.

2. PROGRAM GOALS

2.1. Statewide Elevation Data

The current status, requirements, recommended approach and funding considerations for developing a statewide elevation data layer are discussed below.

2.1.1 Current Status

What follows is not intended to be an exhaustive inventory but rather a listing of notable examples of the breadth and scale of elevation data for Connecticut.

10m Statewide National Elevation Dataset DEM: (USGS)

- The USGS maintains nationwide elevation data known as the National Elevation Dataset (NED). These datasets are available publicly for free download from the USGS Seamless Data Distribution System. NED 1/3 Arc-Second products are available for 70% of the country, including complete coverage for Connecticut. The NED is a derived product from the 7.5 minute topographic map series. Through a process of complex linear interpolation, the contour elevation information is re-sampled onto 10-m interval postings so that elevation is represented as a continuous coverage. The NED is sometimes referred to as a "high resolution" Digital Elevation Model (DEM), but it is not truly suitable for detailed studies at the large-scale (i.e. local) level.

20m Statewide Hypsography: (CT Dept of Environmental Protection)

- This data layer was compiled from 1:100,000 scale DLG hypsography data in order to create topographic contour lines suitable to use as part of a digital base map for the Quaternary Geologic Map of Connecticut and Long Island Sound Basin, USGS I-2784, Stone and others, in press. The vectors (20 meter intervals) were edge-matched, edited, and attributed for the purpose of developing a topographic base for the Quaternary Map, but may be useful with other maps of similar scale (1:125,000).

20' 2000 Statewide LiDAR data: (CT Dept. of Transportation)

- This statewide dataset is comprised of LiDAR elevation points collected during April - July 2000 and January – April 2001. These data have been re-sampled from the original set to display points at an approximate posting interval of 20'. These data are currently used by DOT staff to perform blunder detection in their surveys and to check areas of obscured photogrammetry.

10' 2000 Statewide DEMs – *DRAFT SUITABLE FOR EDUCATION, PRESENTATION AND GENERAL RESEARCH ONLY*: (University of Connecticut Center for Landuse Education and Research)

- This statewide dataset consists of LiDAR-based interpolated gridded elevation provided on a quadrangle basis, over-edged by 500-feet. Elevation data are at a 10-foot horizontal by 1-foot vertical resolution. The data are derived through the spatial interpolation of airborne LiDAR collected in the year 2000. The point files have been edited to remove anomalous observations, but given the volume of data, there are likely errors still present in the point data as well as in the interpolated surface. This is a Beta product and intended for research and demonstration purposes.

1m 2004 Central CT Coastal LiDAR: (University of Connecticut Center for Landuse Education and Research / CT Dept. of Environmental Protection)

- Flown in October 2008 from the Quinnipiac River marshes east along the coastline and up the lower CT River to approximately Haddam. The data was collected according to FEMA LiDAR collection specifications, is classified into several land-type categories, and is primarily being used for wetland classification and analysis.

2m 2004 CT Coastal DSM: (University of Connecticut Center for Landuse Education and Research / CT Dept. of Environmental Protection)

- This Digital Surface Model of elevation data was collected in October 2004 as part of an orthophotography flight of the 36 coastal communities in CT. This data derives elevation values by photogrammetric methods, not by LiDAR collection methods.

<u>1m 2006 CT Coastal LiDAR & DEMs: (FEMA/CT Dept. of Environmental Protection)</u>

- This LiDAR project covered approximately 40 sq miles along the coastline of Connecticut approximating the boundaries of the 100-year flood zones and was acquired in December of 2006 providing a mass point dataset with an average point spacing of 3 ft. The data is tiled, stored in LAS format and LiDAR returns are classified into ground and non-ground classes. DEMs were also provided as bare earth representations. Data were collected to support Digital Flood Insurance Rate Map (DFIRM) Modernization and conformed to FEMA's LIDAR collection specifications.

<u>1m 2004 CT River LIDAR: (FEMA/CT Dept. of Environmental Protection)</u>

- This data was collected in the Spring of 2004 by FEMA to support Digital Flood Insurance Rate Map (DFIRM) Modernization and conformed to FEMA's LIDAR collection specifications. The data runs from the mouth of the Connecticut River to the CT/MA border and spans the approximate area of the 100-year flood zone.

2.1.2 Future Requirements

<u>Data & Deliverable Products:</u>
A fully implemented statewide elevation data project should include the following as deliverables:

- Original, unprocessed, categorized data in a standardized digital format (ASCII, LAS, etc.)
- Derived products
    - Required
        - Bare Earth Digital Elevation Models (DEMs)
        - Bare Earth elevation points
        - Contour lines
    - Optional
        - Breaklines
        - Full – feature (unprocessed) DEMs
        - 3-D infrastructure (buildings, bridges, etc.)
- FGDC compliant metadata for all spatial data deliverables
- Project QA/QC and accuracy assessment reports.

Due to the potentially large size of the original elevation data and its derived products, breaking them up into smaller elements will be a necessity. The means to represent these (US National Grid, USGS Quad or Quarter-Quads, etc) should be carefully investigated.

<u>Methodology Considerations:</u>
While the dynamic nature of technology prevents a comprehensive assessment of all possible methodologies that will stand the test of time, the following table illustrates several popular options available at this juncture.

Table 2.1.2-A: Examples of methodology options

Option	Technology	Strengths/Benefits	Caveats/Limitations
Photogrammetry	Uses several views from multiple images of the same point on the ground from two perspectives to create a 3-D image	• Mature, perfected technology; well established best practices	• Compromised by foliage and cloud cover • Expensive and time-consuming, especially for large areas
Airborne Light Detection and Ranging (LiDAR)	Laser affixed to an aircraft scans the ground and returns points with horizontal and vertical position values	• Significant cost reduction in collection of data over large areas • Can be collected in adverse environmental conditions (cloud cover, and at night)	• Careful calibration of equipment needed to achieve high accuracy levels • Millions of returns can lead to the production of large data files
Interferometric Synthetic Aperture Radio Detection and Ranging (IFSAR)	Using sophisticated antennae, airborne Radar (radio detection and ranging) sensor measures echos from targets	• Well suited to very large collection areas	• Accuracy dependent on careful calibration of equipment needed to achieve high accuracy levels and the quality of the target's reflectivity • Typically less Accurate than photogrammetry or LiDAR • Requires sophisticated post processing techniques
LiDARgrammetry	Hybridization of photogrammetry and LiDAR	• Cost efficiencies gained by blending imagery and elevation acquisition into one process	• New approach, best practices not well established • Accuracies are not well documented

Option	Technology	Strengths/Benefits	Caveats/Limitations
Terrestrial LiDAR	Laser affixed to an elevated ground based device scans the ground at oblique (side) angles and returns points with horizontal and vertical position values	• Well suited for capturing volumetric data • Well suited for smaller project areas	• Impractical for larger survey areas • Accuracy dependent on careful calibration of equipment needed to achieve high accuracy levels
Airborne Topographic/Bathymetric LiDAR	The technology functions the same as standard airborne LiDAR, but different lasers are used to penetrate the water column and scan the bottom of waterbodies.	• Allows for the seamless collection and integration of topography and bathymetry • Ideal for modeling hydrodynamics, hydrology, etc	• Similar to airborne LiDAR, but with the added note that water clarity conditions (excessive turbidity, sedimentation) can hamper bathymetric data collection.

<u>Guidelines:</u>

A. National Digital Elevation Program Guidelines

A treatment of all the standards related to digital elevation data is beyond the scope of this document. Elevation data acquisition is a highly technical subject, and available technologies are evolving quite rapidly. The National Digital Elevation Program has published comprehensive guidance and recommendations for acquiring high-resolution digital elevation data in any of its various forms.[3] Content in this work includes discussion of surface models, data sources, derived products and file formats in the context of specific application areas.

B. National Standards for Spatial Data Accuracy (NSSDA)

In 1998, the Federal Geographic Data Committee (FGDC) published the National Standard for Spatial Data Accuracy (NSSDA), which is a statistical approach for characterizing positional accuracy that is appropriate for digital map products.[4] The NSSDA is defined such that:

- Removal of systematic error will leave error that is normally distributed
- Study dataset should be compared to a reference dataset that is three times more accurate

[3] National Digital Elevation Program (NED). 2004. Guidelines for Digital Elevation Data, version 1.0. Available at: http://www.ndep.gov/NDEP_Elevation_Guidelines_Ver1_10May2004.pdf

[4] Federal Geographic Data Committee: 1998. Geospatial Positioning Accuracy Standards Part 3: National Standard for Spatial Data Accuracy. Available at: http://www.fgdc.gov/standards/projects/FGDC-standards-projects/accuracy/part3/chapter3

- Root mean square error (RMSE) between study and reference reported at an established confidence level.
- Accuracy may be reported as "equivalent contour interval accuracy." For example, for two-foot contours, 90 percent of tested points will fall within one foot of the reference, or one-half the contour interval. In other words, the proposed elevation project must achieve one-foot equivalent contour interval accuracy for two-foot contours (Association of State Floodplain Managers Mapping & Engineering Standards Committee, 2004).

Technology-Specific Guidelines
The State of Connecticut should expect that elevation data acquisition proposals to adhere to existing standards relevant to the proposed technology and mapping application (e.g. flood maps). For example, FEMA has published specifications for LiDAR data collection for flood hazard mapping .[5] LiDAR file format specifications should refer to the most current industry standards, notably the *.LAS format.[6]

2.1.3 Recommended Approach

The baseline objectives to successfully implement an elevation data layer are summarized in the following table:

Table 2.1.3-A: Recommended Approach Objectives

Overall Goal:	**Develop an improved statewide elevation data layer that will support detailed and accurate topographic mapping needed for Connecticut.**
Objective 1:	Identify elevation program management team to move program forward
Objective 2:	Gather core requirements/expectations from stakeholders
Objective 3:	Analyze past, current and potential elevation data collection efforts to determine geographic extent
Objective 4:	Evaluate available and potentially available technology options for suitability
Objective 5:	Determine data storage, management, and dissemination strategies. Include assessment of potential methods for data promotion to raise awareness of availability/applicability
Objective 6:	Identify cost estimates and acquire funding sources
Objective 7:	Develop project technical specifications, criteria, and procure services
Objective 8:	Conduct data acquisition
Objective 9:	Conduct post-acquisition assessment
Objective 10:	Advertise and make deliverables available

[5] Federal Emergency Management Agency (FEMA). 2002. Appendix B to FEMA 37: Guidelines and Specifications for Flood Hazard Mapping. Lidar Specifications for Flood Hazard Mapping. Available at: http://www.fema.gov/plan/prevent/fhm/lidar_4b.shtm

[6] American Society of Photogrammetry and Remote Sensing (ASPRS). 2006. Common Lidar Data Exchange Format - .LAS Industry Initiative. Available at: http://www.asprs.org/society/committees/lidar/lidar_format.html

2.1.4 Anticipated Funding Requirements

Regardless of choice of technology, the elevation data project would have the following general line items that must be considered in a detailed cost proposal:

- Acquisition activity
- Infrastructure to store and distribute data
- Data management and handling, including quality control
- Project administration
- Derived products, including a digital elevation model, terrain model, and contours

<u>Range of Costs</u>

Elevation data costs vary considerably according to technologic approach, geographic extent of coverage, and requirements for deliverables. On the least expensive end of the spectrum, using airborne LiDAR for the entire state of Connecticut and estimating approximately $90 per square mile for FEMA grade 1.4 meter post spacing, results in a approximately $150K. On the opposite end of the cost spectrum, a traditional photogrammetric approach from aerial imagery could increase costs significantly. Deriving contours from aerial imagery using photogrammetry is many times more costly than using LiDAR.

The addition of two-foot contours would increase the per-square mile costs to $185 per square mile, or $725K for both base LiDAR and two-foot contours, statewide. Breaklines, which would prevent contours from crossing waterbodies, roads, bridges, etc., could also be added for an additional $140 per square mile bringing the total cost to approximately $1.75 million. However LiDAR data can provide high definition of roads and other features and breaklines are arguably not necessary in most cases. The state can use the base LiDAR intensity to generate breaklines in the future if they are needed.

Generally, there exist economies of scale with respect to statewide digital elevation data capture; in other words, the per-area cost decreases with increasing geographic coverage extent. Therefore, it is desirable to establish a program of capital investment in a statewide base layer, repeated at a regular interval (e.g. repeated every seven years as advised by FEMA elevation guidelines for detailed study areas). By partnering with neighboring states, further cost savings may also be realized. Further, by working closely with other statewide data plans, other savings can be achieved – for example coordination with statewide aerial photography projects can leverage one flight to cover both photography and elevation data.

The reader will find an initial Implementation Plan for Connecticut in Section 4 of this document, including a “Budget Plan and Schedule” which suggests a project schedule with estimated costs split-out by year.   Due to the comparatively small size of the state it may be possible, both logistically and financially, to implement an elevation data project in a single phase. However, a potential approach for phasing is to divide the state into project areas, as suggested in Section 4, “Consideration of Project Areas.”

<u>Return on Investment Potential – State of Iowa Example:</u>

With funding from the State’s Department of Transportation (DOT), Department of Natural Resources (DNR), Department of Agriculture, and the Natural Resources Conservation Service (NRCS), the State of Iowa has been conducting LiDAR data acquisition for the entire state because improved elevation data would improve government efficiency and achieve significant cost savings. For example, the DNR identified $390K annual cost savings for planning level surveys. The NRCS estimated that they might achieve $3-5 million annually in their efforts to conduct Water Quality Best Management Practices (BMPs) activities, and the DOT estimated that with LiDAR data they could shave 1-3% off their billion dollar budget for applications such as cut and fill, preliminary design, road grading, new roads, and line of site studies for passing lanes. Iowa broke down the acquisition project into three distinct phases. As of November 2007, approximately 28% of the entire state (56,343 square miles) has been collected in part or in full (Iowa Department of Natural Resources 2007).

2.2 Statewide Bathymetric Data

As noted in the executive summary, information related to bathymetry is pending the completion of a strategic planning document for seafloor mapping for the State of Connecticut. At present this section will primarily focus on Current Status.

2.2.1 Current Status

What follows is not intended to be an exhaustive inventory but rather a listing of notable examples of the breadth and scale of bathymetry data for Connecticut.

<u>30m NOAA Long Island Sound Bathymetric DEM: (CT Dept. of Environmental Protection)</u>

- National Ocean Service Estuarine Bathymetry for Long Island Sound was derived from fifty-five surveys containing 562,596 soundings. The average separation between soundings was 77 meters. The fifty-five surveys used dated from 1931 to 1990. Approximately 40 percent of the surveys were from 1931 to 1939. The total range of sounding data was 2.1 meters to -113.4 meters at mean low water. Mean high water values between 0.6 and 2.3 meters were assigned to the shoreline.

<u>CT Lake Bathymetry Contours: (CT Dept. of Environmental Protection)</u>

- This is a 1:24,000 scale datalayer of lake bathymetry for over 100 lakes and ponds throughout Connecticut. Depth is in feet. The method of data collection involved one of the following three methods: manual soundings, depth finder, or GPS (global positioning system) and depth finder.

<u>1m LIS Bathymetry Contours: (USGS/Long Island Sound Resource Center)</u>

- The Long Island Sound Study (LISS) compiled data from a number of different sources, integrated new data, and assembled a comprehensive spatial database for areas of the States of Connecticut, New York, and portions of Rhode Island which border Long Island Sound. The original compilation was done in 1992. The data was published by the United States Geological Survey (USGS) and CT DEP in 1998.

<u>Various Scale NOAA Nautical Charts for LIS and Coastal CT: (CT Dept. of Environmental Protection/ Long Island Sound Resource Center)</u>

- These Nautical Charts are graphic portrayals of the marine environment showing the nature and form of the coast, the general configuration of the sea bottom including water depths, locations of dangers to navigation, locations and characteristics of man-made aids to navigation and other features useful to the mariner. They are created and maintained by the National Oceanic and Atmospheric Administration Office of Coast Survey.

Various USGS/NOAA sonar surveys for parts of Long Island Sound - Six Mile Reef, the Race, North Central Long Island Sound, offshore Milford, offshore Hammonassett: (USGS/ Long Island Sound Resource Center)

- These bathymetric contours were produced as part of series of side-scan sonar studies in Long Island Sound conducted through a cooperative mapping program between the USGS and the Connecticut Department of Environmental Protection, Connecticut Geological and Natural History Survey. Contours intervals are generally 2 meters.

Multibeam surveys for parts of Long Island Sound - Six Mile Reef, the Race, North Central Long Island Sound, offshore Milford, offshore Bridgeport, offshore Roanoke: (NOAA/USGS/ CT Dept. of Environmental Protection)

- These gridded data sets were produced form multibeam surveys conducted by the National Oceanic and Atmospheric Administration (NOAA). They were processed by USGS as part of the cooperative mapping program between the USGS and the Connecticut Department of Environmental Protection. The grids are generally 2 meter.

2.2.2 Future Requirements

Guidelines:

While most future Connecticut requirements are still being developed, national data collection standards are being developed by the National Oceanic and Atmospheric Administration (NOAA) Integrated Ocean and Coastal Mapping (IOCM) concept.[7] The IOCM goal is to “map once, use many times” by creating a preliminary set of standards that will permit seafloor mapping data acquired for any NOAA program to be used confidently by all other NOAA programs as well as outside user groups.[8]

An additional consideration, due to the fact that Connecticut has elevation and bathymetric needs that share a common boundary along the shoreline, is an integrated approach that seamlessly blends these two regions into a single datalayer (or two complementary ones.) The NOAA Coastal Services Center has developed some preliminary information in a technical report that begins to address this.[9]

A preliminary recommendation for this business plan to examine the information provided by these organizations, as well as that of the U.S. Geological Survey, Coastal and Marine Geology Program, Woods Hole Science Center (WHSC)[10] in order to more fully develop requirements for Connecticut bathymetric data needs.

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[7] National Oceanic and Atmospheric Administration. January 2008. About the National Oceanic and Atmospheric Administration. Available at: www.csc.noaa.gov/iwg/docs/NOAAProfileJan08.doc

[8] Parson, Roger, Co-Chair, Inter-Agency Working Group on Ocean & Coastal Mapping. September, 2007. National Integrated Ocean and Coastal Mapping. Available at: www.mapps.org/SupportingFiles/documents/JOST_RogerParsons.ppt

[9] National Oceanic and Atmospheric Administration Coastal Services Center. March 11, 2008. A Roadmap to a Seamless Topobathy Surface. Available at: http://www.csc.noaa.gov/topobathy/

[10] WHSC-Sea Floor Mapping Technology. December 19, 2007. Available at: http://woodshole.er.usgs.gov/operations/sfmapping/index.htm

2.2.3 Recommended Approach
TBD

2.2.4 Anticipated Funding Requirements
TBD

3 POTENTIAL INITIATIVES

Having standardized and comprehensive elevation and bathymetric data will benefit many potential areas of need. Examples are listed in the tables below:

3.1 Elevation Initiatives

Table 3.1-A: Initiatives & Applications for elevation data

Initiative	Application
Flood Prediction & Mitigation	• *Floodplain delineation & Flood Map modernization** • Identification of flood prone property • Risk determination and insurance assessment • Flood modeling • Evacuation planning ** highlighted as a case study example following this table*
Dam Safety Assessment	• Dam Hazard rating • Site selection • Dam Flood stage rating and structural analyses • Levee integrity & capacity • Emergency management planning
Orthorectification of Aerial Imagery	• Correction of aerial photos with DEMs • Topographic feature identification (spot elevations & breaklines)
Transportation	• Transportation corridor planning • Landslide risk • Environmental impact analyses • Drainage analyses • Bridge safety assessments • Subsidence monitoring • Site suitability analyses • Airport Obstruction Mapping
Habitat Characterization	• Vegetation classification • Landscape ecology • Stream channel change

Initiative	Application
Urban/Environmental Planning	• Slope hazard studies • Hillside development • Facility permitting • Structure characterizations • Impervious surface studies • Site suitability analyses • Change detection • Construction planning • Stormwater management • Vieshed/Viewscape analysis
Watershed Planning	• Total Maximum Daily Load (TMDL) best practices • Spill containment flow • Run-off calculations
Emergency Response	• Vulnerability assessments for critical infrastructure • Staging area/command center siting • Hazardous Material spill containment • Line of sight analysis

<u>Case Study – Flood Map Modernization:</u>
Flooding can result from natural and man-made causes. Melting of winter snow and spring rain can cause river flooding, when water from a river basin fills up overflows into the neighboring areas. Events such as tropical storms and nor'easters can bring large quantities of rainfall over several hours or even days causing waterbodies to crest over flood stages. A flash flood is distinguished by onset of six hours or less. Like a river flood, a flash flood may occur after substantial rainfall. In a flash flood, the saturated ground cannot absorb the fallen water, and the runoff quickly collects and pools in low-lying areas. Man-made surfaces that are impervious, such as pavement, increase the speed of runoff. Another type of flash flood follows the failure of a water barrier such as an ice dam or a man-made dam. Flooding poses risks to people and property; business and government operations; and cultural, historic, and natural resources, as well.

Accurate floodplain characterization relies on high quality elevation information to map the shape of the land surface in three dimensions, which is critical in determining the likely direction, velocity, and depth of flood flows. To reduce the risk of damage to private property, communities develop floodplain management programs that consider both preventative and corrective measures. Early, accurate identification of flood-prone properties inform flood preparedness measures such as elevating structure or construction of levees. During emergencies, floodplain maps allow public safety organizations to establish warning and evacuation priorities. Requiring homeowners to obtain flood insurance through the National Flood Insurance Program (NFIP) for properties within the floodplain offsets a portion of the cost resulting from flooding.

To support the NFIP, the Federal Emergency Management Agency (FEMA) coordinates flood hazard mapping efforts. Nationwide, FEMA floodmaps are an average of 35 years old. In 2003 FEMA instituted the national Map Modernization Program to answer the nationwide call for better quality, newer flood hazard maps. Connecticut is currently using LiDAR elevation data to update Digital Flood Insurance Rate Maps (DFIRMS) for the portions of the following four counties: Fairfield, New Haven, Middlesex and New London. In doing so, flood zone elevations are being delineated over more accurate elevation data and thus providing a better flood map product. For example, in most cases flood zones were originally delineated using the USGS NED data. Due to its relatively coarse level of accuracy, exact locations of elevation values were difficult if not impossible to define. With more accurate LiDAR data, these same elevation values are more readily identifiable, which means flood zones will be more reflective of on-the-ground-conditions. The LiDAR data, however, does not span the geographic extent of all of the counties - it is mainly near the coastline of Long Island Sound and the Connecticut River. Consequently, some areas will have more accurate maps while others will not. This is a result of not having a consistent, statewide dataset that meets FEMA's flood mapping requirements for detailed study areas, which are:

- Two-foot contour accuracy in flat areas
- One-foot contour accuracy in extremely flat areas
- Data acquisition should be within the last seven years to account for the effects of land development on flood elevations
- Flood depth at structures should be known for detailed study areas when flood insurance is obtained; the flood insurance rate for detailed study areas is based on the height of the first finished floor with respect to Base Flood Elevation (BFE), or the elevation to which floodwater is anticipated to rise during a flood; in other words, a modern flood map view should be three-dimensional, rather than just planar extent of a flood plain on a flat map

The National Flood Insurance Program is seriously undermined without accurate, current flood maps. Homeowners may be required to purchase flood insurance for properties incorrectly identified as within the flood zone, whereas at-risk homes remain uninsured and unprotected. Benefits of improved elevation for floodplain mapping include:

- Cost savings to homeowners, including accurate insurance assessments and reduction in expenses incurred from land surveys normally required for map revisions
- Improved siting of flood protection measures such as dams, levees, and bypass channels
- Improved floodplain regulation efficiency

3.2 Bathymetry Initiatives

Table 3.2-A: Initiatives & Applications of bathymetry data

Initiative	Application
TBD	• TBD

4 IMPLEMENTATION PLAN

Consistent with the recommendations from the CGISC's Strategic Plan, an Elevation & Bathymetry sub-committee was established under the Data Inventory and Assessment Working Group with role of inventorying Connecticut's elevation and bathymetric data and providing recommendations necessary to provide for a more enhanced standardized resource for all in Connecticut to use. The Subcommittee has worked to draft a plan for the developing comprehensive elevation & bathymetry for the State of Connecticut.

4.1 Elevation Implementation Schedule

4.1.1 Activities & Milestones

Objectives for achieving the programmatic goal of improved elevation data were defined in Section 2 of this Business Plan. These objectives are further broken down into activities and milestones on a tentative schedule, assuming a three-year window.

Table 4.1.1-A: Elevation Implementation Details

Activities & Milestones	Year 1	Year 2	Year 3
1. Identify elevation program management team to move program forward			
1a. Develop short, medium, and long term coordination and planning objectives	X		
1b. Assign priorities and develop management protocols	X		
1c. Obtain GIS Council Approval	X		
2. Gather core requirements/expectations from stakeholders			
2a. Identify & meet with relevant state agency representatives to discuss partnerships, needs requirements	X		
3. Analyze past, current and potential elevation data collection efforts to determine geographic extent			
3a. Conduct analyses to determine data gaps in past, current, or anticipated near-future data holdings	X		
3b. Finalize coverage area	X		
4. Evaluate available and potentially available technology options for suitability			
4a. Perform cost-benefit analyses of data acquisition approaches	X		
4b. Evaluate technology options against user needs	X		
5. Determine data storage, management, and dissemination strategies. Include assessment of potential methods for data promotion to raise awareness of availability/applicability			
5a. Establish/maintain website for sharing elevation related news and information	X	X	X
5b. Create/maintain data portal	X	X	X
5c. Locate/purchase hardware/software as needed	X		
6. Identify cost estimates and acquire funding sources			
6a. Communicate expectations/requirements to cost estimate providers	X		
6b. Identify potential funding sources	X		
6c. Secure funding (project specific minimally, sustainable ideally)	X	X	

Activities & Milestones	Year 1	Year 2	Year 3
7. Develop project technical specifications, criteria, and procure services			
7a. Develop technical specifications		X	
7b. Determine acquisition criteria		X	
7c. Select contractor(s)		X	
8. Data Acquisition			
8a. Schedule/Conduct acquisition		X	X
9. Conduct post-acquisition assessment			
9a. Review/QC project deliverables			X
10. Advertise and make deliverables available			
10a. Load data deliverables onto web portal			X
10b. Announce deliverables to user base/stakeholder groups			X

Consideration of Project Areas:
The State of Connecticut could adopt an incremental approach for developing the data products (e.g. two-foot or better contours) from the base LiDAR data. This approach would entail prioritizing areas of the state and, for example, defining project areas based on geographic criteria, such as according to watershed, along major streams, or perhaps according to expansions of metropolitan areas, with cost-sharing by project or area

4.1.2 Budget Planning

The CGISC Finance Working Group, working with the Program Team will develop a budget based on this plan and will determine appropriate methods of funding. Rough Order of Magnitude (ROM) numbers are provided in Section 4, earlier in this document. Decisions need to be made on the most viable approach to funding, which may include breaking the project into phases, and setting-up cost-shares for the program amongst major stakeholders. The following is an outline of some of the important considerations to the budget plan.

Legislative Appropriation:

- Synchronize timing with state budget cycle and Fiscal Year
- Identify political champion

Agency Cost-Share:

- Cost-sharing breakdown
- Lead agency identification
- Need agency contract agreements

Municipal Cost-Share:

- Municipal buy-in and/or buy-up program
- Municipal by watershed cost-sharing

Federal Funding Sources:

- FEMA Map Modernization funds

- Geodetic control modernization
- USGS Cost Sharing

Funding Availability:

- Sustainable vs. project specific allocations

Requirements Across Time:
The implementation schedule offered here assumes a three-year project horizon to begin planning and take delivery of final product(s). The frequency recommended by FEMA for updating contour data is seven years. Thus, seven years after the data has been delivered, Connecticut should be poised to repeat the process. It can reasonably be assumed that technology will continue to improve, and costs will continue to come down, so cost estimates for the second collection should certainly be revisited during the project cycle. Further, a majority of the planning effort invested in the initial collection effort can likely be reused or modified with relative ease, potentially shortening the overall subsequent collection projects to less than three years.

4.2 Bathymetry Implementation Schedule

4.2.1 Activities & Milestones

Table 4.2.1-A: Bathymetry Implementation Details

Activities & Milestones	Year 1	Year 2	Year 3
1. TBD			
1a. TBD			

4.2.2 Budget Planning

TBD

5 REFERENCES

Applied Geographics, Inc. May 2008. State of Kansas Geographic Information Systems Business Plan: Improved Elevation Data for Statewide Applications. Available at: http://www.da.ks.gov/gis/documents/KS_ImprovedElevationData_BusinessPlan.pdf

6 GLOSSARY

Breaklines: linear features in a data model that describe a change in the smoothness or continuity of the surface. Hard breaklines define interruptions in surface smoothness such as streams, shorelines, dams, ridges, and building footprints. Soft breaklines are used to ensure that known "Z" (elevation) values along a linear feature (such as a roadway) are maintained in a TIN.

Digital Elevation Model (DEM): a digital representation of ground surface topography or terrain.

Digital Flood Insurance Rate Map (DFIRM) Database: a digital version of the FEMA flood insurance rate map that is designed for use with digital mapping and analysis software.

Interoferometric Synthetic Aperture Radar (InSAR or IfSAR): technique for topographic map generation using two or more synthetic aperture radar (SAR) images.

Light Detection and Ranging - LiDAR (also known as laser altimetry): Remote sensing technologies whereby properties laser echoes are measured off a distant object. For topographic mapping, the distance to an object, or *range*, is determined by measuring the time delay between transmission of a pulse and detection of the reflected signal. The range is then compared to a geodetic earth model to determine absolute elevation.

Orthoimagery: digital or film earth imagery with an orthogonal (straight-down) ground view. Features are displayed in their true correct position, and geographic distances, angles, directions, and areas are preserved.

Orthorectification: image processing technique to remove geometric and displacement errors in an aerial or satellite image.

Photogrammetry: remote sensing technique whereby geometric features are read from photographs. Measurements made in two or more photographic images taken from different positions can be compared to derive three-dimensional coordinates (see stereoscopy).

Planimetric: two-dimensional (planar) representation of geographic features in three dimensions. In Geographic Information Systems (GIS), the term also refers to geographic features interpreted from imagery.

Radio Detection and Ranging (RADAR): remote sensing technology that uses the echo of radio electromagnetic waves (backscatter) to identify the range, altitude, direction, or speed of targets. This is especially suited to detection of metal objects, which create distinctive radar backscatter patterns.

Resample: to alter the size of a digital image by changing the pixel size. Information in the pixels from the original image is then remapped to pixels in the resized image using computer algorithms.

Spot Elevations (also known as Spot Heights): point data features that represent locations on the ground in three dimensions, typically created individually through photogrammetric or survey methods and placed at specific locations in a digital elevation model that may not be accurately represented by mass points.

Stereoscopy: an optical technique by which two images of the same object are blended into one, giving a three-dimensional appearance to the single image.

Synthetic Aperture Radar (SAR): type of radar technology distinguished by a relatively narrow effective beam, achieved through sophisticated data processing methods.

Topobathy DEM: A topobathy digital elevation model (DEM) is a single surface that combines the land elevation with the seafloor surface and which can be used to examine processes that occur across the coastal and nearshore areas.

Triangular Irregular Network (TIN): line-based representation of the physical land surface or sea bottom, made up of irregularly distributed points and lines with three dimensional coordinates (x, y, and z) that are arranged in a network of non-overlapping triangles.