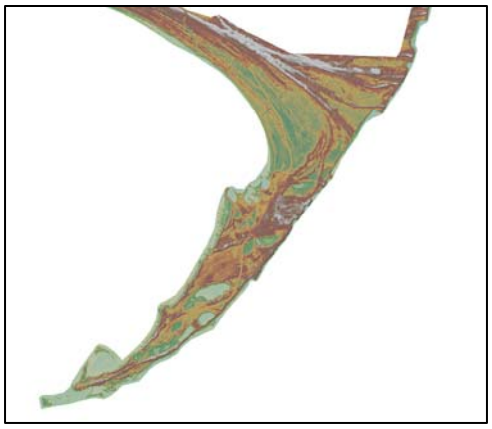
# 2004 Connecticut Lidar Data Validation Report

*Prepared by IM Systems Group and Perot Systems Government Services for the NOAA Coastal Services Center*



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# 2004 Connecticut Lidar Data Validation Report

## Introduction

The National Oceanic Atmospheric Administration (NOAA) Coastal Service Center Topographic Change Mapping (TCM) project seeks to aid coastal managers with their topographic needs. This can include issues ranging from beach geomorphologic change to storm surge inundation to determination of invasive species habitat. Additionally, the TCM project creates derived information products and analysis tools to facilitate the coastal resource manager's decision-making process. The TCM project received Light Detection and Ranging (Lidar) data collected along the coast of Connecticut in April 2004 and will distribute the data from its web-based Lidar Data Retrieval Tool (LDART).

Woolpert LLP collected elevation point data derived from multiple return (first and last) lidar measurements along a section of coast between New Haven and Old Lyme, Connecticut on October 8, 2004. Final data was delivered in the LAS format with several embedded attributes: return number, number of returns, intensity, classification ("bare ground" or "not bare ground"). Average ground sample distance was 0.9 meters. The survey area covered approximately 300 square kilometers (*Figure 1*). The survey was conducted under tidally controlled conditions to ensure maximum shoreline exposure during the data collection. The contract with Woolpert LLP specified a vertical accuracy requirement of ±0.15-meter root mean square error ($RMSE_{(z)}$).

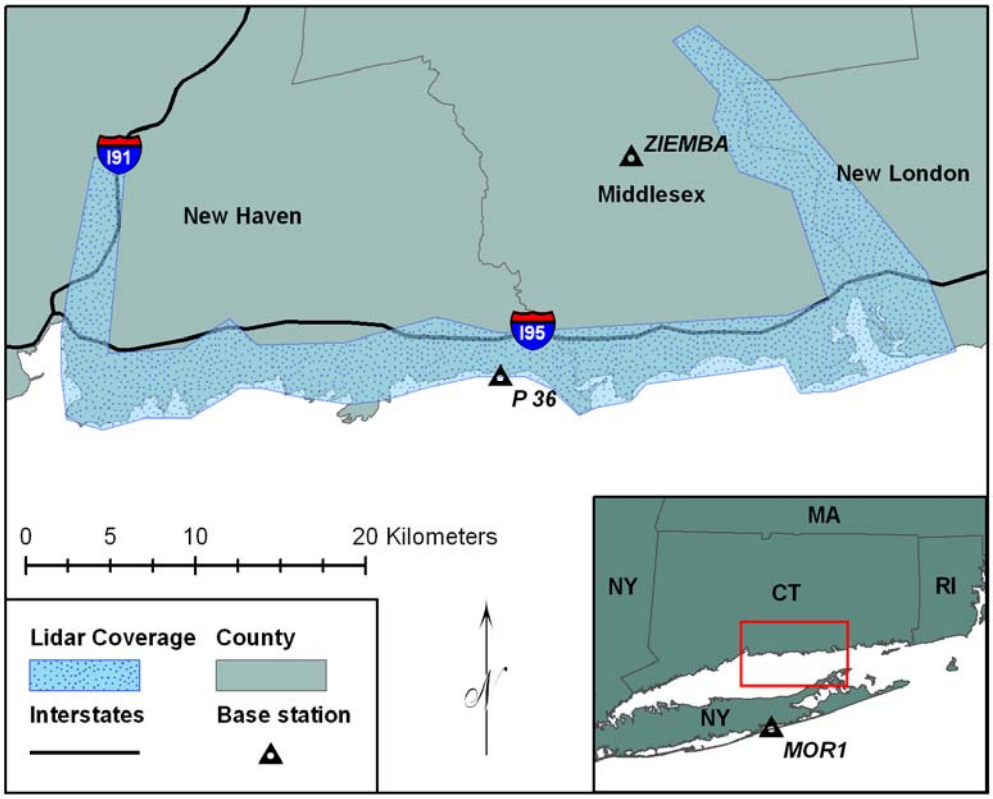


*Figure 1. Extent of the Connecticut lidar survey with base station locations.*

This report presents the results of a quantitative error assessment conducted to verify the vertical accuracy of the lidar data in open terrain using the independent ground control points as validation points. This assessment followed procedures and recommendations presented in the *Guidelines for Digital Elevation Data* prepared by the National Digital Elevation Program (NDEP) and the *ASPRS Guidelines for Vertical Accuracy Reporting for Lidar Data* prepared by the ASPRS Lidar Committee.

## Methods

The Center conducted a ground control point survey March 14-17, 2005. A ground control network was established with NGS HARN points P36 (PID LX0452), ZIEMBA (LX2642), and Moriches CORS 1 ARP (PD AH5048) (this station is located on Long Island, New York). Points in flat, open terrain distributed throughout the study area were selected for occupation. Two Thales Z-Max dual frequency GPS receivers were operated in static differential mode to collect vector information. The vector data was post-processed and adjusted using GNSS Studio (Thales Navigation). The final independent ground control data set consisted of thirty control points that were believed to have an absolute accuracy of ±0.03 meters.

The post edited bare earth lidar data were used by the Center to perform this data validation. The nature of topographic lidar data collection limits the ability to survey precise horizontal (xy) locations; therefore, a form of interpolation of lidar data is required to accurately compare ground control points and lidar derived elevation models. The Guidelines for Digital

Elevation Data by NDEP recommends interpolation from a surface generated from a triangulated irregular network (TIN) derived from the lidar point data for assessing the accuracy of mass points. This method was employed in this evaluation. Elevation values at the location of each of the 30 ground control points were interpolated from the triangulated bare earth point data. The vertical error at each ground control point location was calculated by subtracting the interpolated lidar elevation value from the control point elevation value. After calculating the error at each control point, the overall root mean square error ($RMSE_{(z)}$) for the survey was calculated. The overall vertical accuracy at the 95th percentile was then calculated with the following equation:

**Vertical Accuracy at 95% confidence level = 1.9600 * $RMSE_{(z)}$**
**(assuming errors were normally distributed)**

## Results

The overall $RMSE_{(z)}$ error was ±0.06 meters which is based on 30 samples (i.e., n = 30). A Shapiro-Wilk statistical test performed on the errors for the quantitative assessment indicated the errors were normally distributed (W = 0.97; p = 0.53). The Shapiro-Wilk test was chosen because it works well with a small sample size as long as there are not identical values.

*Figure 2* shows the elevation difference calculated at each of the ground control stations. A mean error of 0.05 meters and a standard deviation of 0.04 meters were reported. The greatest elevation difference was 0.12 meters at station 1029 (see *Appendix A*). This point was located in a relatively flat and open area, but there were tall buildings in the vicinity which may have induced multipath interference.

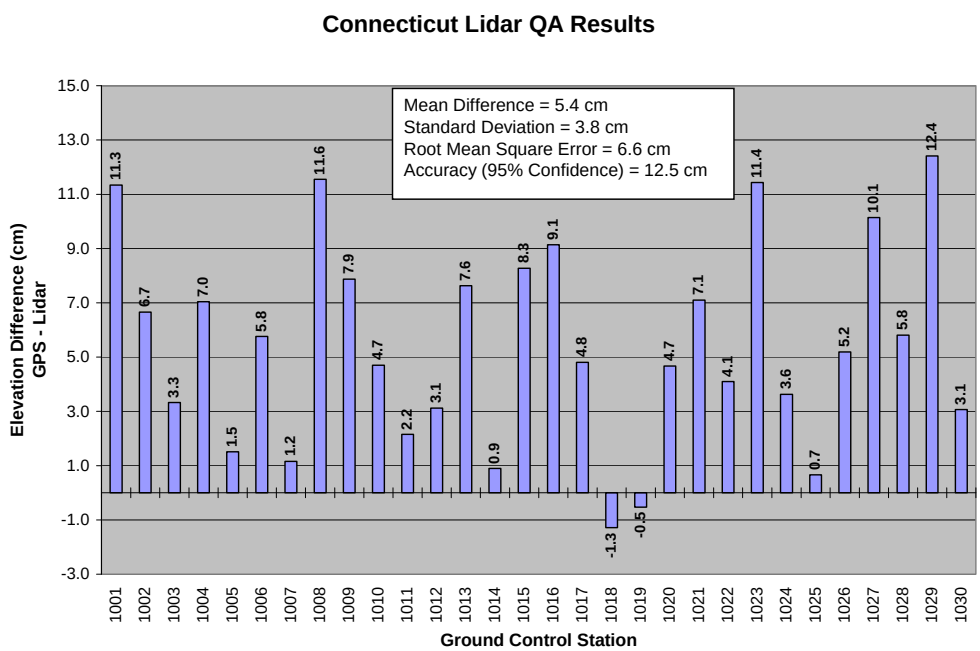


*Figure 2. Elevation differences at each control station (Control point elevation – Lidar elevation).*

The spatial distribution of the elevation differences is presented in *Figure 3* and the actual values are presented in a table in *Appendix A*. Each ground control point is colored according

to the magnitude of the error identified for the lidar elevation calculated at the station's horizontal (xy) location.

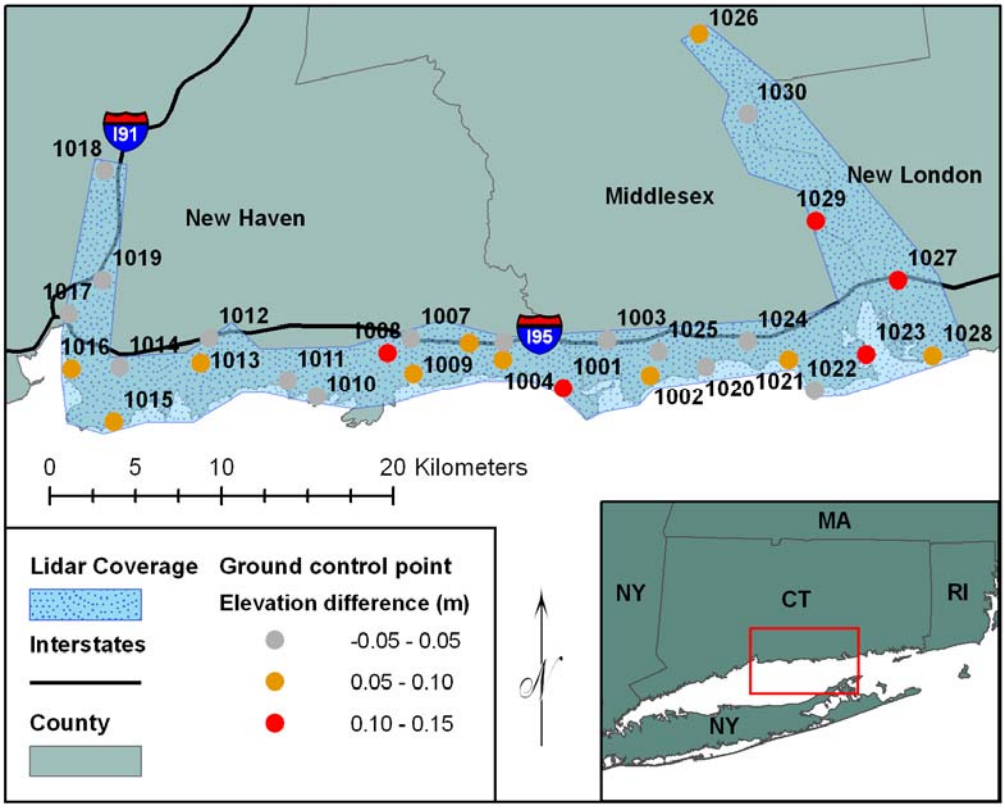


*Figure 3: Map showing the spatial distribution of elevation differences between ground control point elevations and interpolated lidar elevations (Ground control point elevation – Lidar elevation).*

## Discussion

The overall vertical error calculated from the collection of ground control points is within the prescribed accuracy limits. Given that the control stations were located in flat and open terrain, these errors are generally believed to be random errors in the lidar sensor system as opposed to systematic errors generated from vegetated areas.

The horizontal accuracy of this lidar data was not assessed. The high vertical accuracy is indicative of good horizontal accuracy, though slight horizontal inaccuracies are difficult to detect using these ground control points because they were located in relatively flat terrain.

Based on this assessment, the 2004 Connecticut lidar survey data meet the prescribed vertical accuracy level since more than 95% of the measured positions have an error less than or equal to 29.4 cm (equivalent to root mean square error of 15 cm for normally distributed data).

> **"Tested 0.13 meter fundamental vertical accuracy at 95 percent confidence level in open terrain using $RMSE_{(z)}$ x 1.9600."**

## Appendix A

The following table shows the elevation difference calculated at each of the ground control stations. The differences (Delta Z) were calculated by subtracting the interpolated (via tinning) orthometric lidar heights (meters) from the coincident ground control point heights.

| Station | Longitude (dd) | Latitude (dd) | Delta_z (m) | Delta_z2 (m) |
|---|---|---|---|---|
| 1001 | -72.560101 | 41.263779 | 0.113 | 0.013 |
| 1002 | -72.500046 | 41.270681 | 0.067 | 0.004 |
| 1003 | -72.529937 | 41.289313 | 0.033 | 0.001 |
| 1004 | -72.602135 | 41.279141 | 0.070 | 0.005 |
| 1005 | -72.601304 | 41.288432 | 0.015 | 0.000 |
| 1006 | -72.625311 | 41.287785 | 0.058 | 0.003 |
| 1007 | -72.665579 | 41.290305 | 0.012 | 0.000 |
| 1008 | -72.681658 | 41.282597 | 0.116 | 0.013 |
| 1009 | -72.664072 | 41.271872 | 0.079 | 0.006 |
| 1010 | -72.731155 | 41.259881 | 0.047 | 0.002 |
| 1011 | -72.751273 | 41.268002 | 0.022 | 0.000 |
| 1012 | -72.805431 | 41.290572 | 0.031 | 0.001 |
| 1013 | -72.811718 | 41.277471 | 0.076 | 0.006 |
| 1014 | -72.867503 | 41.275298 | 0.009 | 0.000 |
| 1015 | -72.871645 | 41.246181 | 0.083 | 0.007 |
| 1016 | -72.901149 | 41.274427 | 0.091 | 0.008 |
| 1017 | -72.903147 | 41.303034 | 0.048 | 0.002 |
| 1018 | -72.878479 | 41.377815 | -0.013 | 0.000 |
| 1019 | -72.879751 | 41.320688 | -0.005 | 0.000 |
| 1020 | -72.461528 | 41.274915 | 0.047 | 0.002 |
| 1021 | -72.40384 | 41.278663 | 0.071 | 0.005 |
| 1022 | -72.385795 | 41.262512 | 0.041 | 0.002 |
| 1023 | -72.350056 | 41.281177 | 0.114 | 0.013 |
| 1024 | -72.432079 | 41.288495 | 0.036 | 0.001 |
| 1025 | -72.49393 | 41.283098 | 0.007 | 0.000 |
| 1026 | -72.465199 | 41.449063 | 0.052 | 0.003 |
| 1027 | -72.327861 | 41.319876 | 0.101 | 0.010 |
| 1028 | -72.303941 | 41.280351 | 0.058 | 0.003 |
| 1029 | -72.384594 | 41.351148 | 0.124 | 0.015 |
| 1030 | -72.431808 | 41.406927 | 0.031 | 0.001 |
| | | | | |
| | | | Mean_$d_z$ | 0.05 |
| | | | Standard dev. (m) | 0.04 |
| | | | $RMSE_{(z)}$ (m) | 0.07 |
| | | | **$Accuracy_{(z)}$ (m)** | 0.13 |