INFLUENCE OF THE POST-SPACING DENSITY OF THE LIDAR-DERIVED DEM ON FLOOD MODELING.

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ABSTRACT: The primary objective of the research is to determine the optimal post spacing for LIDAR-derived digital elevation models (DEMs) that is required to achieve different levels of accuracy in the prediction of flood risk using hydrologic and hydraulic (H&H) models. For the study, high spatial resolution LIDAR data were collected by the University of Texas Airborne Laser Terrain Mapping System and used to generate a variety of DEMs for test and evaluation. The data were entered as input to FEMA-approved H&H models at varying resolutions to determine the sensitivity of the models to the changes in the densities of the LIDAR ground elevation points. Data collection occurred in Brownsville, Texas, in an area of the North Main Drain, a major floodwater conveyance. A flood model was developed using HEC RAS to delineate the 2-year and 5-year flood plain. For each of the floodplain, 70 simulations were run using different densities of LIDAR-derived ground elevation points. The simulations were automated using the Arc GIS Model Builder. Results from the Brownsville area reveal that below a certain density (0.055 point/m^2 which corresponds to a 4.28 m cell size), the LIDAR elevation data become problematical for use in the creation of accurate flood hazard maps. At lower points densities, flow obstructions appear on the 3D cross-sections derived from LIDAR, and the inundation polygons expand to unrealistic proportions. Below the threshold of 0.055 point/m^2, the influence of LIDAR point density is weak, and results depend upon the initial conditions. Conclusions drawn from the study may be applicable to flood hazard mapping in other regions having low surface relief.
KEY TERMS: flood; sensitivity, LIDAR; density; post spacing;

INTRODUCTION

The overall objective of this project is to determine the optimal post spacing for LIDAR-derived digital elevation models (DEMs) that is required to achieve different levels of accuracy in the prediction of flood risk using hydrologic and hydraulic models. High spatial resolution LIDAR data were used to generate a variety of DEMs for test and evaluation. These data were entered as input to FEMA-approved Flood models at varying resolutions to determine the models' sensitivity to these changes. Research for this project was conducted in Brownsville, TX on the North Main Drain.

To collect the LIDAR data an Airborne Laser Terrain Mapping (ALTM) 1225 system was used. This is a scanning LIDAR system developed by Optech, Inc. of Toronto. The ALTM 1225 has the following nominal specifications:
- Operating altitude 410-2,000 m above ground level (AGL)
- Range resolution: 1 cm
- Laser pulse repetition rate: 25 kHz
- Laser scan angle: variable from 0 to 20 from nadir
- Laser scanning frequency variable, 28Hz at the 20 scan angle
- Beam divergence variable, 0.2 or 1.0 milliradian (half angle, 1/e)
- Simultaneous recording of first return, last return, and intensity of laser reflections

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The first step of the process is to generate the DEMs required to run a simulation. Seventy sets of LIDAR points with different densities were produced: the original high spatial resolution LIDAR points corresponding to the ground were classified in chronological order and then decimated by deleting one point every two points, two points every three points etc. All these sets of points were interpolated into a grid using the inverse distance weighting method (the most commonly used to generate DEMs from LIDAR data). The cell size of the grid has been defined so that there is in average one point per cell. For these 70 sets of grids the cell size goes from 1m and increases to 25 meters as the density of points decreases due to the decimation process. An illustration of the result can be seen below on Figure 1:

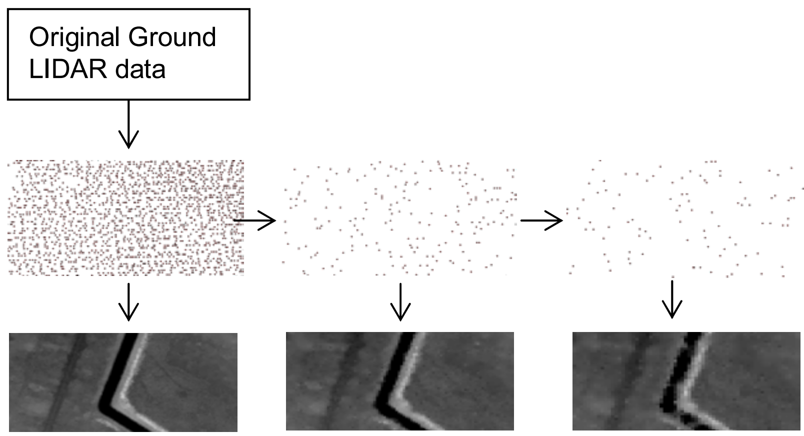

Figure 1: Decimation of the LIDAR points

The second step of the process is to extract the 3D cross sections of the North Main Drain from each DEMs and to run a flood simulation. The flood model has been developed using HEC RAS to delineate the 2-year and 5-year floodplain. For each floodplain, 70 simulations were made with the different DEMs (corresponding to the different densities of LIDAR points). The result of the simulation is a flood polygon on HEC RAS (see bellow on Figure 2):

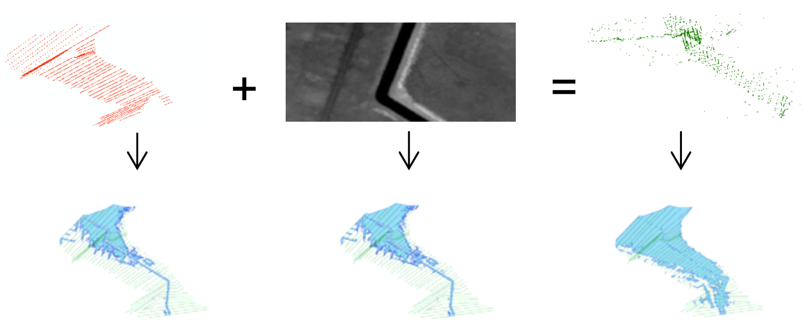

Figure 2: Flood simulations with the different DEMs

For a better analysis and understanding, the results were exported from HEC RAS into GIS. Simulations for this sensitivity analysis were automated with the Model Builder. A tool concerning the decimation process has been developed. The model takes automatically from the LIDAR points (a text file), decimate them to get the desire density, delineate the flood polygons on GIS and determine the number of buildings flooded. Then a script makes the model looping through the 70 different densities so that for each density of LIDAR points a flood polygon is corresponding.

RESULTS

Two types of results were analyzed: the influence of the density of LIDAR points on the extent and the location of the computed floodplains and the influence of the density of the LIDAR points on the number of buildings flooded.

Comparison of the flood polygons

For a given flood event, the flood polygons obtained with the different densities of the LIDAR data were compared with the flood polygon obtained with the highest density of LIDAR points. To compare these polygons and to take into account the differences in extend and location, the error has been defined as follow (Equation 1 and Figure 3):

$$Error(\%) = \frac{Area(Polygon) + Area(PolygonREF) - 2 \times Area(Polygon \cap PolygonREF)}{Area(PolygonREF)} \times 100$$

Equation 1: Error definition

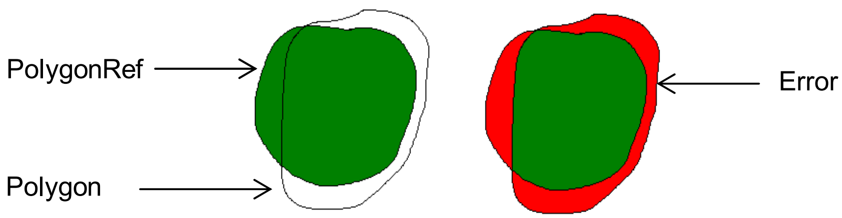

Figure 3: Illustration of the definition of the error

The following graphs (Figures 4 and 5) represent for the 2-year and 5 year-flood events, the evolution of the error when the density of LIDAR points changes.

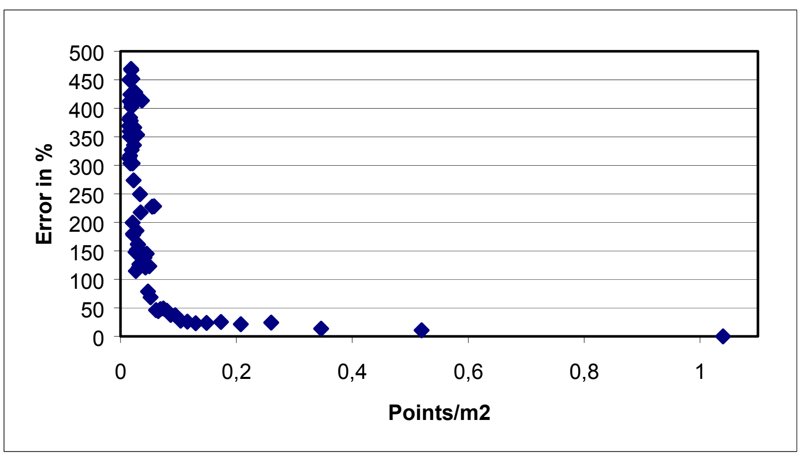

Figure 4: Evolution of the error on the delineation of the flood polygons as the density of LIDAR points changes for the 2-year flood

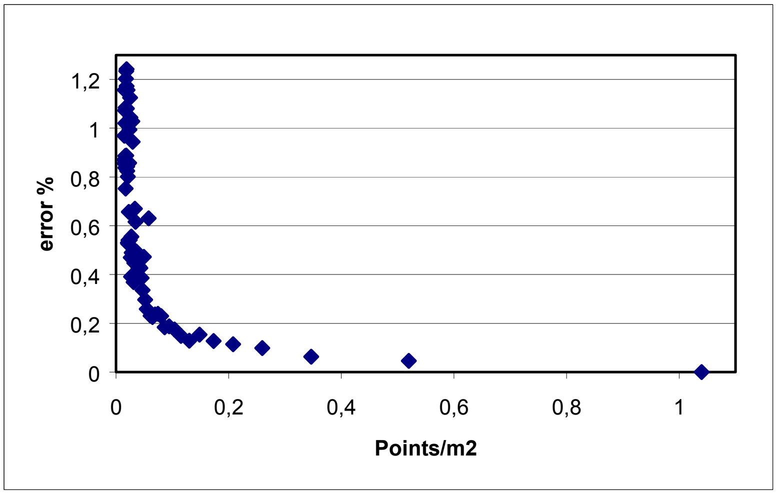

Figure 5: Evolution of the error on the delineation of the flood polygons as the density of LIDAR points changes for the 5-year flood

It is interesting to notice that the influence of the density of LIDAR points on the delineation of flood polygons is higher for the 2-year flood event than for the 5-year flood event: the error reaches 400% for the 2-year flood and only 1.2% for the 5-year food.

There is a break point around 0.055 points//m^2 which corresponds to a bit more than 5 points for 100m^2. This is due to the small width of the river. Indeed, the average distance between points corresponding to this density is 4,5 m which is very close from the width of the Drain. Therefore, for this density and lower densities of points, we cannot even see the shape of the drain on some cross sections so the flow and height computed is fare to high. For a density lower than 0.055 point/m2 the LIDAR data cannot be used to delineate the 2-year or 5-year flood event.

2- Comparison of the number of buildings flooded

The number of flooded buildings computed with the highest density of LIDAR points has been taken as a reference. The following graphs (Figures 6 and 7) represent the evolution of the number of buildings mistakenly flooded as the density of LIDAR points changes.

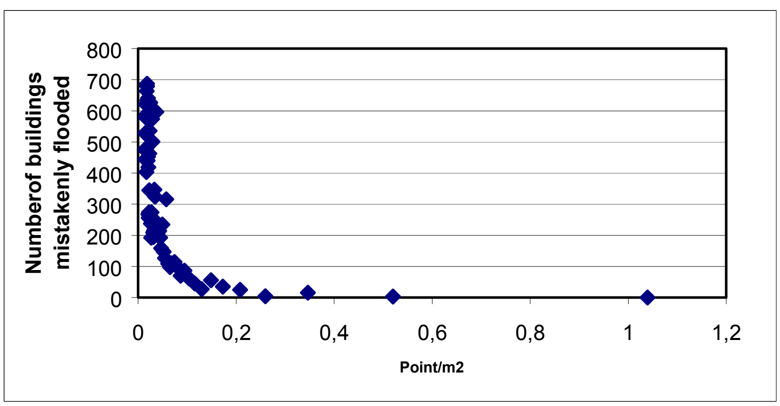

Figure 6: Evolution of the error on the delineation of the flood polygons as the density of LIDAR points changes for the 2-year flood

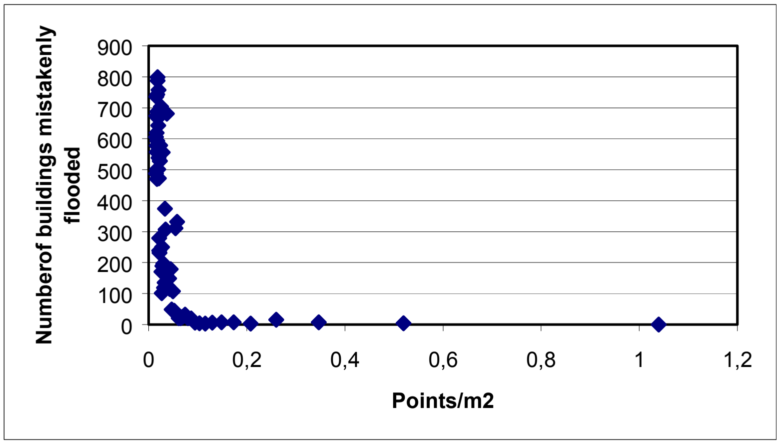

Figure 7: Evolution of the number of buildings mistakenly flooded as the density of LIDAR points changes for the 5-year flood

The shape of the curve is the same than the one of the previous graphs but it is interesting to see here that a too low density of LIDAR points can lead to a very high overestimation of the number of buildings flooded. The influence of the flood is small.

CONCLUSION

When LIDAR data are collected for flood modeling purpose, the density of points is a crucial parameter. Results from the Brownsville area reveal that below a certain density (0.055 point/m^2 which corresponds to a bit more than 5 points for 100m^2), the LIDAR elevation data become problematical for use in the creation of accurate flood hazard maps. At lower points densities, flow obstructions appear on the 3D cross-sections derived from LIDAR, and the inundation polygons expand to unrealistic proportions. Below the threshold of 0.055 point/m^2, the influence of LIDAR point density is weak, and results depend upon the initial conditions. Conclusions drawn from the study may be applicable to flood hazard mapping in other regions having low surface relief. It is interesting to see that we could reduce the density of the LIDAR data (and the cost) to 0.055 point/m^2 and almost still get the same accuracy on the flood simulation.