Technical Report RT-120

Post-processing, validation and integration of LIDAR data into the St. Lawrence River Digital Terrain Model

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ABSTRACT

Three new improvements have been brought to the St. Lawrence River digital terrain model (DTM) that will contribute to improve the prediction of the impacts of water level changes on the ecosystem of the St. Lawrence River. These improvements had been identified as deliverables by the Common Data Needs Group meeting that was held in Burlington at the end of august 2002.

Firstly, the DTM now includes a large amount of georeferenced points that cover the area of the St. Lawrence River's floodplain from the low water mark all the way to the 100 year flood line. Thorough validation procedures have been applied to the data such that they can be considered a reliable data source for future projects on the St. Lawrence River.

Given the large volume of information, a new tool had to be developed in order to simplify the data set. Thus, the field model was further improved by the development of a grid made of virtual points with a 5 meter spacing. Each point of the grid represents the mean field elevation for a 25 m^2 square and on a larger scale, the grid is representative of the entire LIDAR data set. This grid can also express, for each grid point, the variation in elevation for neighboring grid points. This was used as a selection tool to extract points from the grid according to set criteria for the variation in field elevation. This methodology reduces the number of points to handle and consequently all the processes necessary to manage this large quantity of information.

Finally, the model is now provided with contour lines that describe both the centennial recurrence and the bathymetry of the St. Lawrence River. Spacing between contour lines is 4 meters. These lines were produced with a commercial software but tools were also programmed by MSC-Québec to build contour lines either for the entire region or for a user-defined area.

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Introduction

The present report was done within the context of a project involving the Meteorological Service of Canada – Québec region (MSC-Québec), hydrology section and the International Joint Commission (IJC) that aims to assess the impacts of changes in water levels on the ecosystem of the St. Lawrence River. It describes a further step in the construction of a high resolution Digital Terrain Model (DTM) of the St. Lawrence River drainage basin located between Cornwall and Trois-Rivières. This DTM is an important component of the system designed to predict the impacts of different water level scenarios.

In november and december 2001, topographic data was collected by airborne laser survey (LIDAR) within the floodplain of the St. Lawrence River defined by the low water mark and the 100-year flood line for the section of river betweeen the Hochelaga archipelago and Trois-Rivières. The acquired data are in the form of georeferenced points (x, y and z values) and provide a three-dimensional representation of the region described above. The data have been inserted into an Oracle 9i database managed by MSC-Québec, hydrology section.

As the amount of data is large (approximately 200 million points), and despite the fact that the consultant met previously stated precision standards, additional data quality controls were applied to the data. A comparison was done between topographic points acquired in the present project and reference points (benchmarks) that where gathered from a number of organizations. These are documented in the technical note NT-100 produced by MSC-Québec, hydrology section (Pomares, 2001).

As stated above, the quantity of data to be managed is huge and requires a considerable amount of technological resources to process. Consequently, lengthy tasks were carried out on dedicated computers. A need was identified for creating a regular grid over the entire region of the St. Lawrence River watershed containing points that would approximate raw LIDAR data while being much easier to manage. Furthermore, an algorithm was developed by MSC-Québec to reduce point density from the regular grid according to slope changes. This greatly reduces the amount of information to manipulate in projects that rely on LIDAR data without a significant loss in precision.

Contour lines of the entire region covered by the LIDAR data were then created from the grid described above that was coupled to the bathymetric data available in the present St. Lawrence River DTM. The large surface to manage forced the use of relatively large intervals between contour lines and the division of the whole region into 3 zones.

This document is designed to explain the means used by MSC-Québec, hydrology section to fulfill the objectives stated both by the IJC and MSC-Québec concerning LIDAR data validation, construction of a regular grid made of points representing raw LIDAR data and production of contour lines of the entire region covered by the airborne laser survey. Difficulties encountered during the project and solutions to these difficulties will also be discussed.

Methodological approach

Data validation

During the fall of 2001, the consultants retained for the work, GROUPE LASER AEROPORTÉ (G.L.A.) Inc., carried out 378 flights with a plane equipped with a laser to cover the St. Lawrence River floodplain. Flights were done at 750 meters of altitude at a speed of 70 m/s using a 402 meter scanning width, a +/- 15 degree angle and a 25% overlap between flight lines. Scanning frequency was 15 Hz and repeat frequency was 5000 Hz. The longitudinal and lateral spacing between points is 2.3 and 1.9 meters respectively. For validation purposes, the consultants visited 86 geodetic points and 41 terrestrial sites were used as control profiles. Differences between LIDAR values and data derived from the latest profiles allowed them to estimate the error associated with altimetric data, which was 10 cm in completely open environments and 15 cm in forested areas.

Even though the consultant carried out their own LIDAR data validation, a second validation was initiated by MSC-Québec. Consequently, georeferenced points (validation points) obtained from several governmental services and having an error of at most 15 cm (except for the Québec Cartographic Service where the precision can reach 50 cm in some rare cases) were used in this respect. These points were documented in Pomares (2001), which identified a total of 30292 points in the St. Lawrence River watershed among which 13972 are located in the region covered by the LIDAR data.

Three methods were used to compare LIDAR data with the reference points discussed above. The first was to calculate, for each validation point, the mean altitude of LIDAR points located in a 5 meter square with the validation point located in the center. An altitude difference was calculated between the LIDAR mean and the validation point height. The distribution of the validation points according to the differences in comparison to the LIDAR mean will be showed in order to visualize points with large differences.

The second method consisted in looking for the LIDAR point nearest to each validation point and compare their respective heights. Again, a distribution showing point numbers as a function of the difference in height with their nearest LIDAR neighbor will be shown.

Finally, some research was done to obtain the physical position context for some validation points. This was done to gain a better understanding of some unexplained height differences between validation points and LIDAR points. The Department of National Defense already provided these contexts for 18 of their points and the Québec Cartographic Service provided 8 such contexts for their points. A more detailed research was initiated by MSC-Québec at the Québec Cartographic Service to support the present validation. Thus, 44 validation points were chosen where the difference with their associated LIDAR mean height was greater than or equal to 0.5 meters and where the combined error associated to LIDAR measurements and validation points could not explain the observed differences. Each of these were located on aerial photography in order to describe the physical context in which they are located.

Difficulties encountered

It is important to discuss some of the difficulties that were encountered in the data processing for further interpretation of the results. First, several points within the LIDAR data set are located on water; the signal received by the LIDAR acquisition system cannot differentiate points coming from the water or from the ground. Points on the water surface do not represent the topographic reality of the ground and must consequently be eliminated from the database.

As well, the consultant proceeded in a systematic sort of all raw data with the objective of removing points that would be located on vegetation (trees, shrubs, emerging plants), buildings, or other structures with a surface of at most 30 m^2. Following this, extracted points were transferred into a folder named “vegetation“. The selection process applied by the consultants (systematic sort) had to face a lot of different situations so that the possibility still exists that ground surfaces like small wharves or slopes have been removed from the raw data and placed into the vegetation folders. Given this situation, the consultant brought some corrections to the data set for cases where it was proven by field observations that the sorting method was incorrect. Some slopes have thus been reinserted into the ground data as requested by MSC-Québec. Therefore, in some cases, individuals using the data will have to superimpose vegetation data to ground data in order to verify if some wharves or slopes were classified as vegetation or a small structure.

Finally, the high density of raw information dramatically decreases the effectiveness of the analysis processes that become cumbersome. The need to create an equidistant regular grid that sums up raw ground data and possesses the capacity to indicate the amount of slope variation becomes relevant. This becomes useful to allow the execution of queries to eliminate points from projects where the slope is small or inexistant. The method used to construct this grid is explained in the GRID section of the document.

Grid

Grid size

Before building an equidistant point grid to summarize LIDAR ground data, the distance between grid points had to be fixed. The fact that data density was approximately one point for each 2.5 m^2 gave us a starting point for the definition of the mesh size. A first grid was built on a portion of the LIDAR ground data using a 2 meter distance between points. It was then decided to assign an altimetric value (z) for each grid point by calculating the mean height between LIDAR points located in a 4 m^2 square with the grid point at the center. This way, each grid point represents the mean height of a square-shaped part of the region covered by the LIDAR. However, the square size was recognized as being too small since the majority of the grid points had no LIDAR data within the 4 m^2 square and consequently no height values were assigned for these points.

To solve this problem, it was chosen to raise the mesh size up to 5 meters resulting in 25 m^2 squares within the grid. This solution significantly decreased the number of points having no altitude data as well as decreasing the total number of points in the grid so that all processes related to grid data handling became easier to manage.

Finally, a 5 meter grid was completed to cover the entire region where LIDAR data were present and for each grid point, the height is represented by the mean height of LIDAR points present in a 25 m^2 square around the grid point.

Slope change representation

Assigning a value representing the slope (or height) variation around each grid point can be useful to state if one grid point is selected or not for a given analysis. For example, points located in a field where the height variation is small may not be useful in a large scale study (excessive redundancy). These points can further be identified by their weak height (slope) variation. At the database level, this can be done by the presence of given values upon which queries can be made.

The method used to characterize all grid points according to their slope change first looks for the maximum height difference between one grid point and its nearest neighbors, that is the 8 points located on a square having 10 meter sides around each grid point or having a lateral distance of 5 meters from the grid point (Figure 1). If there are more than two points among the nearest neighbors with no assigned mean height value (no LIDAR data around the grid point), the analysis was stopped for this point and a value of “-1” was assigned as the height assessment value for the center point. Otherwise, the maximum difference was calculated between the point under analysis and each of its neighbors.

The same exercise is done next with the 16 points located on the square having 20 meter sides around the point under analysis. Here, the maximum allowable number of neighboring points with no mean height value was 4 and the maximum height difference is determined among the 16 neighbor points.

Finally, the slope variation value assigned to a given grid point is the maximum height difference value between this point’s mean height value and the mean height values of all 24 neighbor points, that is points located within the 5 and 10 meter square around this given point. It is then possible for a database user to prepare queries according to the height variation. For example, if one needs grid points where the maximum height variation is greater than or equal to 0.75 meter, a query could be prepared so that only these points are extracted from the database.

Difficulties encountered

As mentioned previously in the validation section, raw data contains points located on water and these are useless in the present context such that they must be removed from the database. However, another solution was used for the purpose of the present work. All grid points having a height variation value greater than or equal to 0.5 meters were first extracted from the database (i.e. grid points having among its 24 neighbors one grid point with a height difference of 0.5 meter or more). This sorting among grid points aims to decrease point density while still preserving the majority of the information for further analysis. In this case, all extracted points have been transferred to the MapInfo (V6.5) software to identify points located on water by superimposition with a water level simulation of the St. Lawrence River (Morin, J. personal communications, Morin and Bouchard 2001). The hydrodynamic simulation used to represent flooded areas was calculated with similar discharges to those observed during LIDAR data acquisition. This simulation was then converted into a MapInfo layer to make it easier to differentiate valid points (ground points) from points in “flooded” areas. Points located on water were eliminated and the corrected table was loaded into the database as an independent entity.

Thus, all grid points having a height variation greater or equal to 0.5 meters were inserted into a file which was copied on the CD-ROM furnished with this report (see Annex 1).

Contours for the entire region

Contours produced with a commercial software

Vertical Mapper v.3.0 was chosen to build contour lines on the entire region covered by LIDAR data. First, grid points with a height variation value greater than or equal to 0.5 meters were extracted from the database and points located on water were removed as explained in the previous section through the comparison of the point layer with a water level simulation (Morin, J. personal communication, Morin et Bouchard 2001). Next, bathymetric data from several sources like the Canadian Hydrographic Service (mostly), the Canadian Coast Guard, Hydro-Québec and MSC- Québec (Fortin 2002) were added to the sorted grid points. It was now possible to create a complete 3 dimensional profile

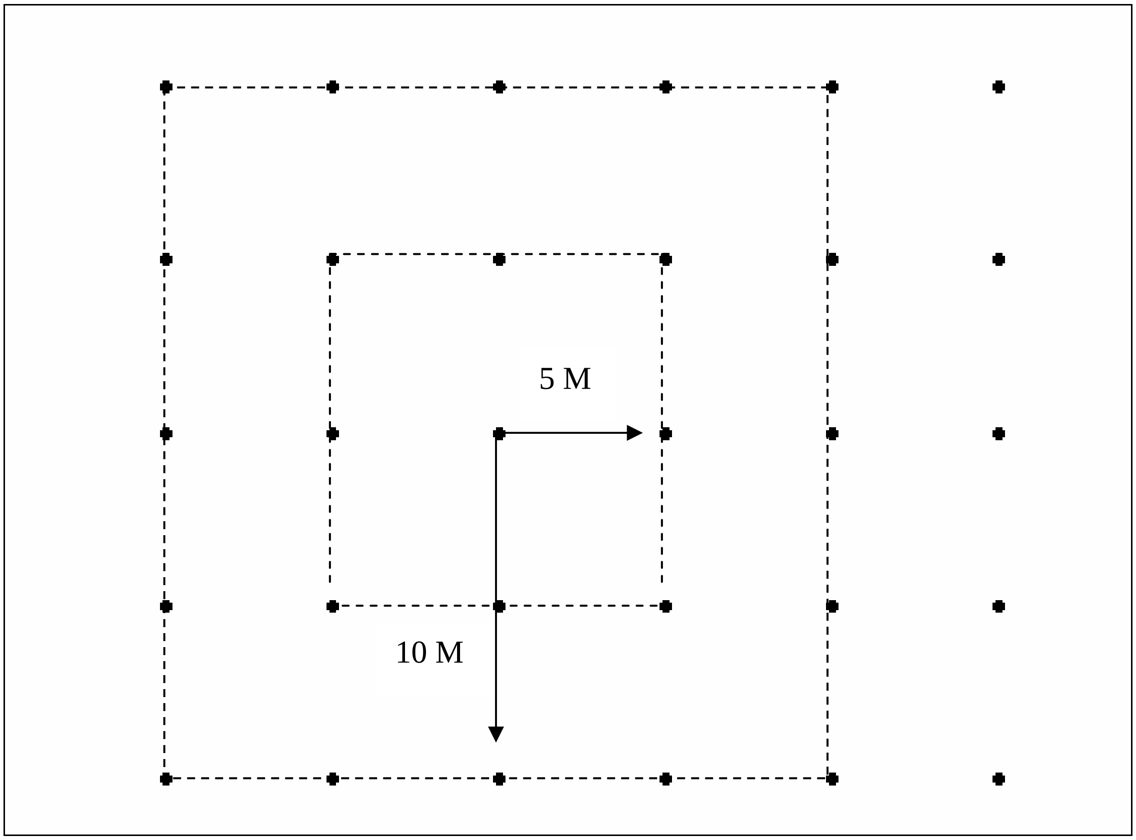

Figure 1: Method used to assess height variation for a grid pointof the study area from the middle of the river channel all the way up to the 100-year flood line.

At this point, comparisons can be made with contour lines produced from the complete grid (no sorting) and contour lines produced with the light grid where points were sorted to remove redundant information.

Finally, contour lines were produced using a 4 meter height interval.

Contours produced by programming

Keeping in mind a certain ease of use and enhanced control on the interpretation of results, it was preferable to build contour lines through programming. It was chosen to follow the strategy for contour point interpolation between grid points discussed earlier. This strategy is based on the fact that a contour line which has an interpolated point on a straight line joining two valid and consecutive grid points must have another interpolated point on one of the two other straight lines that describes a triangle with the straight line on which the first interpolated point is located. For example, the interpolated point 1 on Figure 2 is located on the straight line AB so that height values associated with A and B are higher and greater (or vice versa) than the contour line value. The straight line AB is part the ABC triangle. The contour line from which the point 1 is part of must have another interpolated point on the BC straight line or on the AC straight line according to the height value of C.

Next, the straight line where this last point is located (straight AC on Figure 2) is shared with the adjacent triangle (ACD) completed with a valid grid point (D) and the straight line AC. The next contour point must be located on one of the other straight lines of the adjacent triangle and finally, the contour line becomes the sequence of interpolated points having a common height value. Interpolation using this method is executed by following adjacent triangles until the research of the third point of a triangle is associated with a point of the same contour line (closed polygon), with an non-existent grid point (LIDAR region border) or with a point located on water.

Each interpolated point is inserted into a database table in the interpolation order with a point identifier and a line identifier.

Otherwise, in order to interpret the point sequence as a line in a commercial geographic information system (GIS) like MapInfo, this sequence has to be inserted in a data structure that is part of the database and so that the GIS can recognize it as an object.

The Oracle Spatial tool contains data structures and functions that have the capacity to store this data in vector form and manage interactions between a database and a GIS by providing the SDO_GEOMETRY data structure (object) and functions associated with it (Oracle Corporation, Spatial User Guide and Reference, Rigaux, 2002). Thus, procedures have been programmed using the PL/SQL programming language into the database environment to build a program that interpolates and inserts contour line points from the grid, transform these points into line objects of the SDO_GEOMETRY type and finally insert these lines into a database table that is accessible by a GIS.

Comparisons can later be made between contour lines for a given surface by overlapping contour lines built with the method described in this section and the ones built with a commercial software (ex. Vertical Mapper v3.0).

To reach ease of use and precision objectives for LIDAR data users, another program was constructed to build contour lines from any user-chosen rectangular selection of the region covered by the LIDAR data. Thus, starting from minimum and maximum x and y input values, the program extracts from the table containing the interpolated data the points located within the selection parameters. Next, these points are transformed into a SDO_GEOMETRY object under a line format as discussed above and stored in a table that is accessible by a GIS.

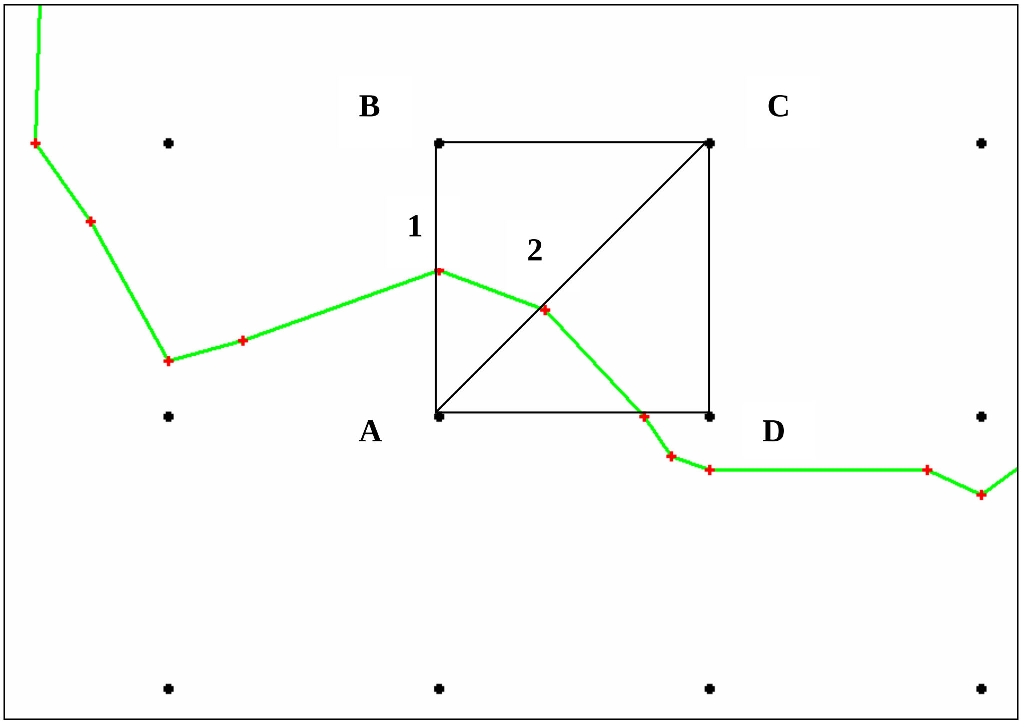

Figure 2: Contour line point interpolation strategy between grid points. Black marks represent grid points and red marks represent interpolated points that are part of the contour line (green line).

Results

Validation

As shown in Figure 3, most validation points have a height difference that is lower than 20 cm compared to the mean LIDAR height. Moreover, 77% of validation points have a height difference of less than 30 cm compared to the LIDAR points located in a 25 m^2 square with the validation point at its center.

The method comparing the nearest LIDAR point to the validation point height shows similar results than those obtained with the calculation of the mean height of LIDAR points. Figure 4 shows that most validation points have a height difference smaller than 20 cm compared to the height of the nearest LIDAR point and 75 % of validation points have a height difference smaller than 30 cm when compared to the nearest LIDAR point.

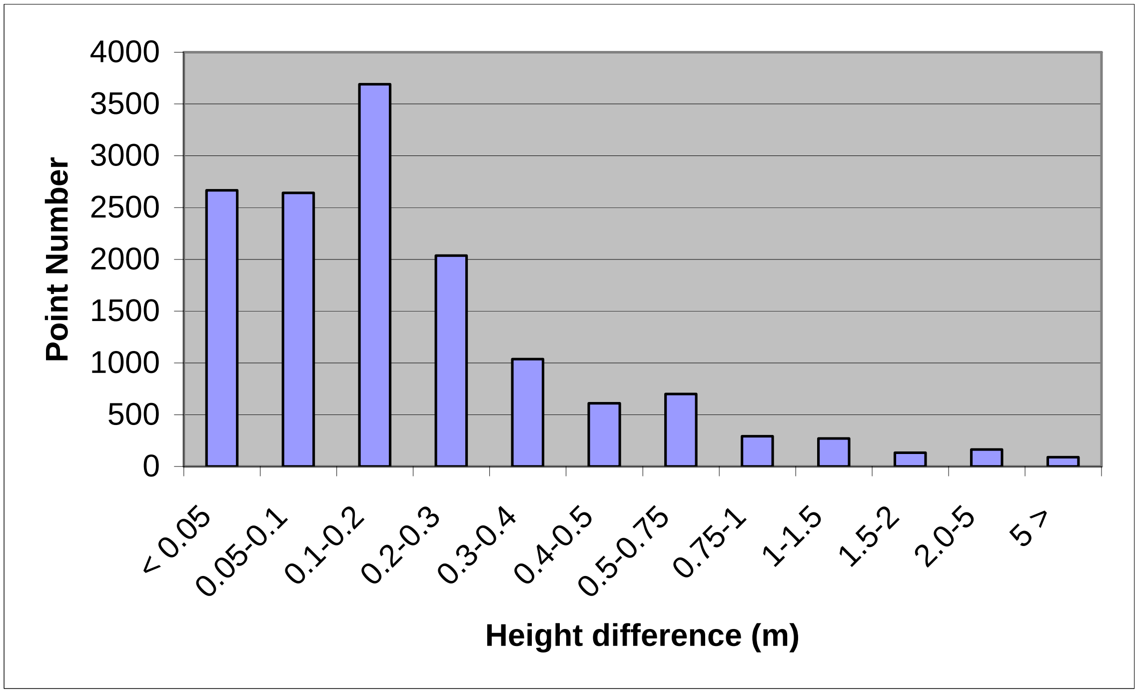

Figure 3: Distribution of the difference between validation point height values and height calculated with LIDAR values from points located in a 25 m^2 square around validation points.

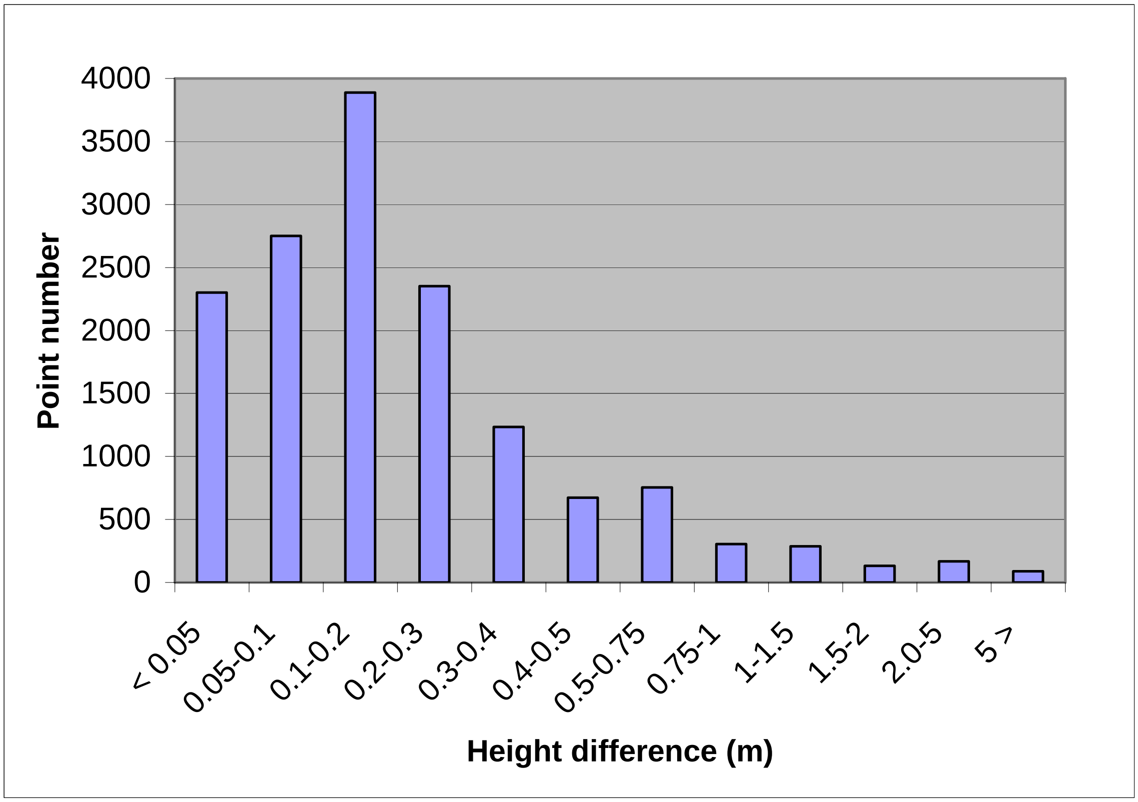

Figure 4: Distribution of the difference between validation points height value and the height of the nearest LIDAR point.

Following this analysis, a question was raised as to the ratio of points that show an acceptable height difference that is within the range of errors associated both with laser measurements and with validation points. Thus, the range of error around each validation point's height values, as provided by governmental bodies, was used and the same kind of error was calculated around the nearest LIDAR point. We used 15 cm to assess error size ranges around LIDAR points. Comparisons were then done to verify if height differences between validation points and the nearest LIDAR point were within the error ranges (overlapping ranges : points validated by data) or outside these ranges (non-overlapping ranges : points non-validated by data).

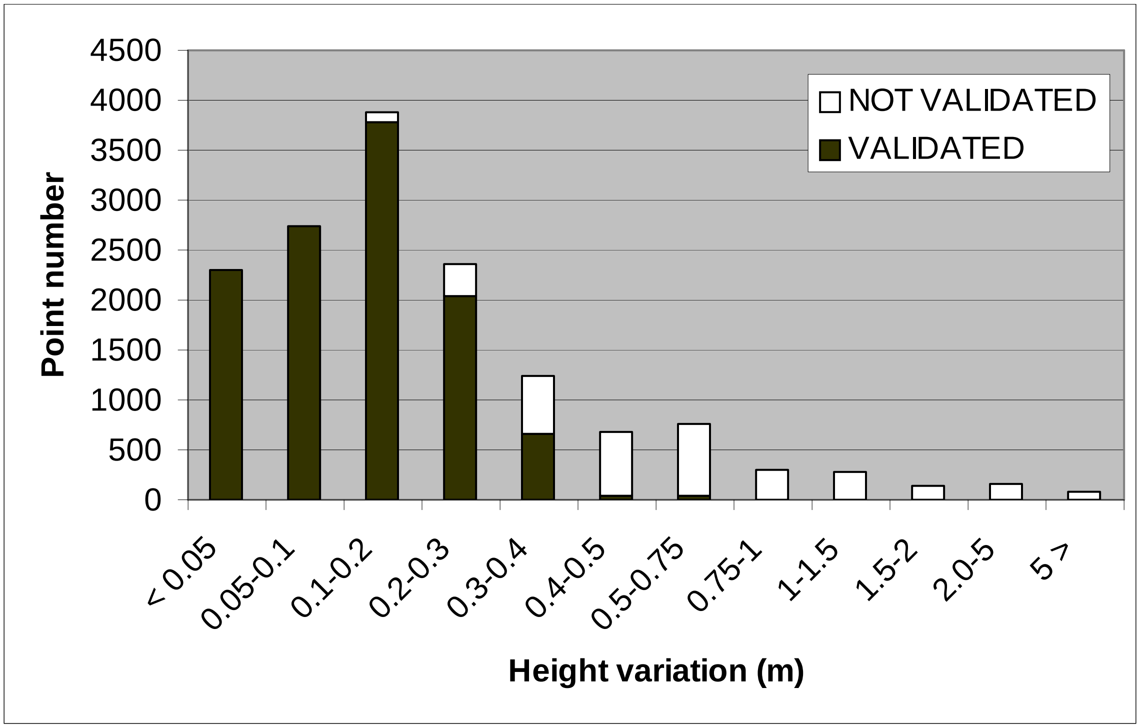

Figure 5: Distribution of the number of validated and non-validated points as a function of the height difference between each validation point and the nearest LIDAR point.

A total of 13292 validation points extracted from Pomares (2001) are located in the region covered by LIDAR data and 2989 of these were calculated as being non-validated by data when compared to the nearest LIDAR point. Of course, the nearest LIDAR point never has the same coordinate as the validation point and spatial variability on the ground is not taken into account. Consequently, height differences are expected. For this reason, more than 40 points from the Québec Cartographic Service and 18 points provided by the National Department of Defense (all qualified as non-validated by data) were subjected to a more detailed analysis in terms of their physical position context. Among points provided by the National Department of Defense, most are located on fixed structures, and 3 descriptions were not sufficient to explain observed differences. For these 3 points, the smallest height difference is 6.6 meters suggesting that they are all located on elevated structures. For points provides by the Québec Cartographic Service, several (31) are located on irregular surfaces like fields or riparian areas. The 13 other points are located on fixed structures like streets, sidewalks, buildings or structures where very few changes in height can be seen but where a spatial height variation is still possible.

For example, Figure 6 shows a region represented by isosurfaces with different colors according to height. One can see a water body in blue, LIDAR points covering the region (pink points) and a validation point (green square). The height difference between the validation point and the closest LIDAR point is 2.5 meters. The description provided from the Department of National Defense indicates that this validation point is located on a bridge. Thus, this example shows that there are no LIDAR points on the bridge since these were probably rejected by the mechanism used to remove points on surfaces having an area smaller than 30 m^2 and the nearest LIDAR point is located on water. One can thus conclude erroneously that LIDAR data points are incorrect when compared to this validation point.

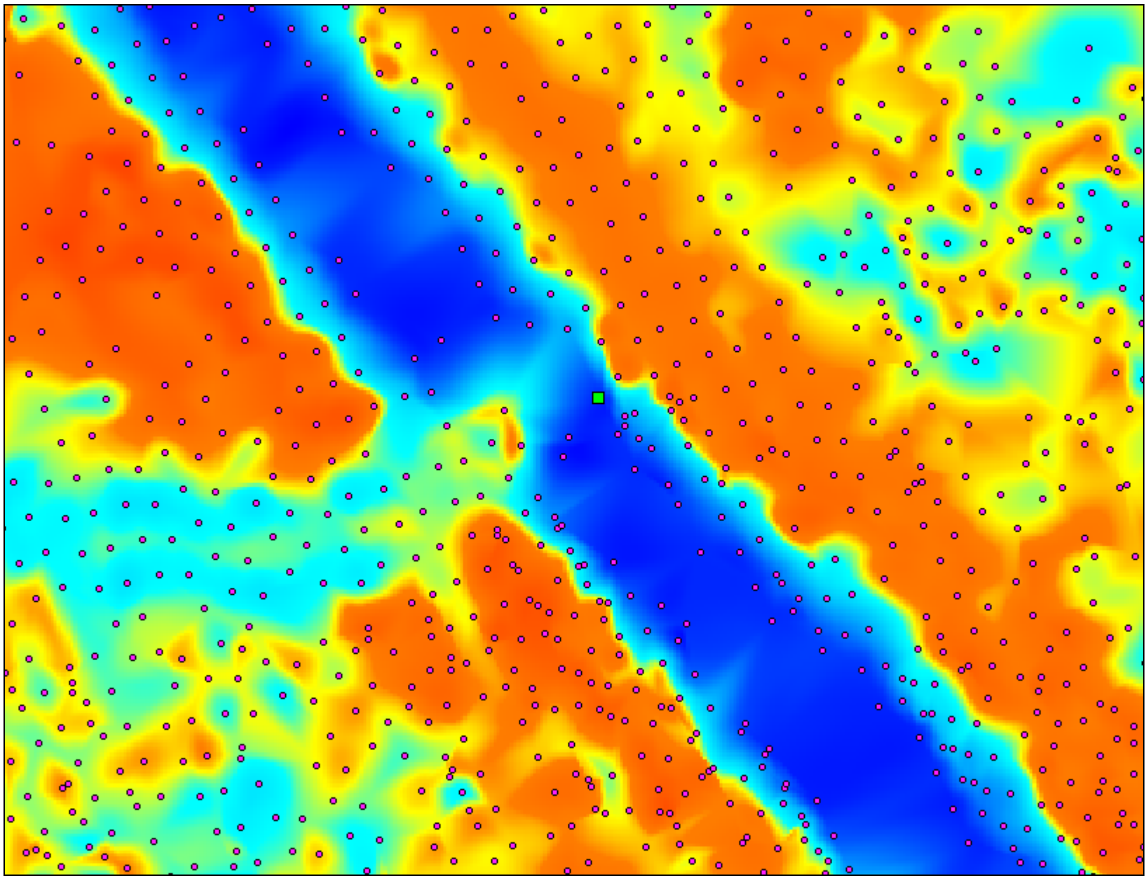

Figure 6: Example showing the case of a validation point (green square) that do not represent surrounding LIDAR data (pink points). Here the validation point provided by the Department of National Defense is located on a bridge where LIDAR values were probably removed.

Grid

Table 1 shows the distribution of the point numbers according to the height variation as assessed by the method described earlier for the whole region covered by LIDAR data (or by grid points). One can observe that the large majority of points having enough valid grid points in their neighborhood have a height variation value smaller than 1 meter. Consequently, a query based on the height variation value will greatly decrease the quantity of points necessary in some projects without significant impacts in the digital terrain model's precision. For example, Figure 7 illustrates a region described with a total of 35122 grid points (yellow points covering all the surface). A layer containing grid points having a height variation value higher or equal to 0.2 meters (blue points) superimposes the complete grid and was used to reject points where the slope is smaller than 1 % (20 cm on 20m). This request conserved 20341 grid points or 57.9 % of the

Table 1: Distribution of the number of points for each existing height variation value for the entire surface covered by grid points.

Height variation value	Number of points	Significance
0	3057344	Between 0 and 0.1*
0.1	16103425	Between 0.1 and 0.2*
0.2	15338543	Between 0.2 and 0.3*
0.3	9652332	Between 0.3 and 0.4*
0.4	6051650	Between 0.4 and 0.5*
0.5	7932878	Between 0.5 and 0.75*
0.75	3739736	Between 0.75 and 1*
1	5806815	Between 1 and 2.5*
2.5	1246701	Between 2.5 and 5*
5	218167	Between 5 and 10*
10	10487	Greater than 10 m
99	30483721	Out of the LIDAR covered region
1000	5203649	Height value calculated on a 10 meters square
Total	111735085**	

*: The superior limit is not included.

**: The total number of points does not equal the listed point numbers for all height variation values since there are existing points where no height variation value was assigned (no LIDAR values near the grid point) or not enough nearby LIDAR data to calculate this value.

complete grid. With this methodology, projects that do not need a height variation value smaller than 0.2 meter (1% slope) on this surface could work with only 57.9 % of the total number of grid points. This reduces the number of points to handle and the subsequent processing time. Along the same lines, Figure 8 shows a layer of points having a height variation value higher or equal to 0.5 meters (red points) that superimposes the two layers described above. This layer contains 5553 grid points or 15.8 % of the complete grid. Finally, Figure 9 superimposes a layer of points having a height variation value greater or equal to 1 meter (black points) over all the layers previously described. This layer represents 5.6% of the complete grid and is composed of 1849 points.

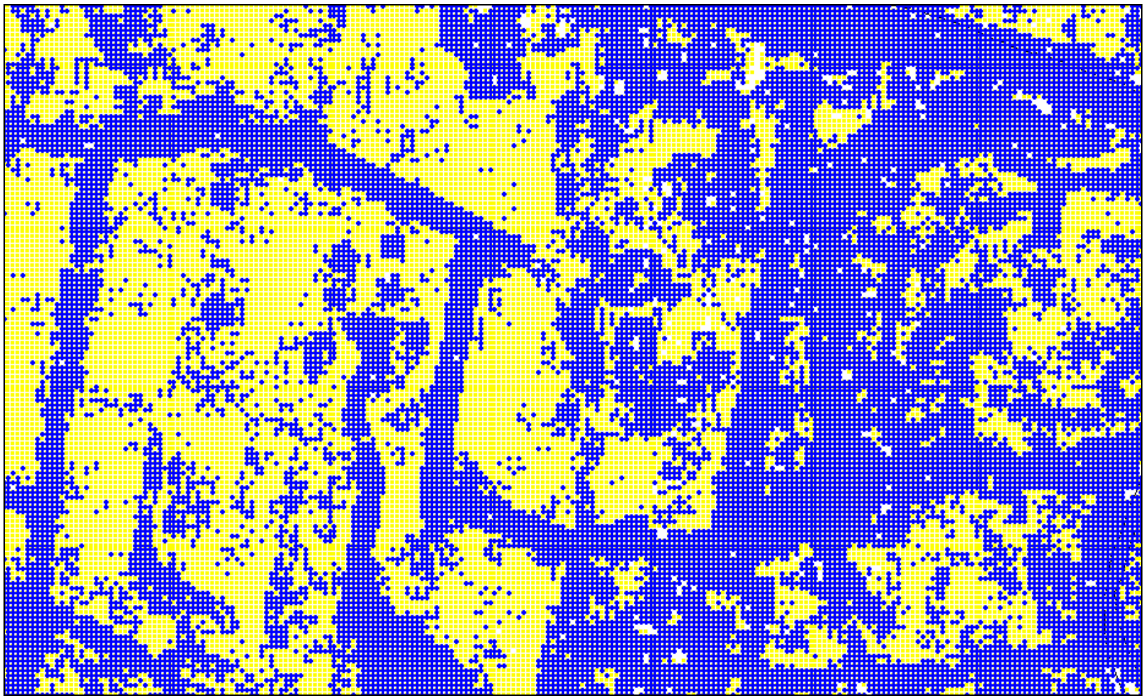

Figure 7: Spatial distribution of the 5 meter mesh size grid according to the height variation value for a surface located near the St. François River delta. Yellow points represent the complete grid (all points) and they are superimposed by a layer of points of the same grid having a minimal height variation value of 0.2 meters.

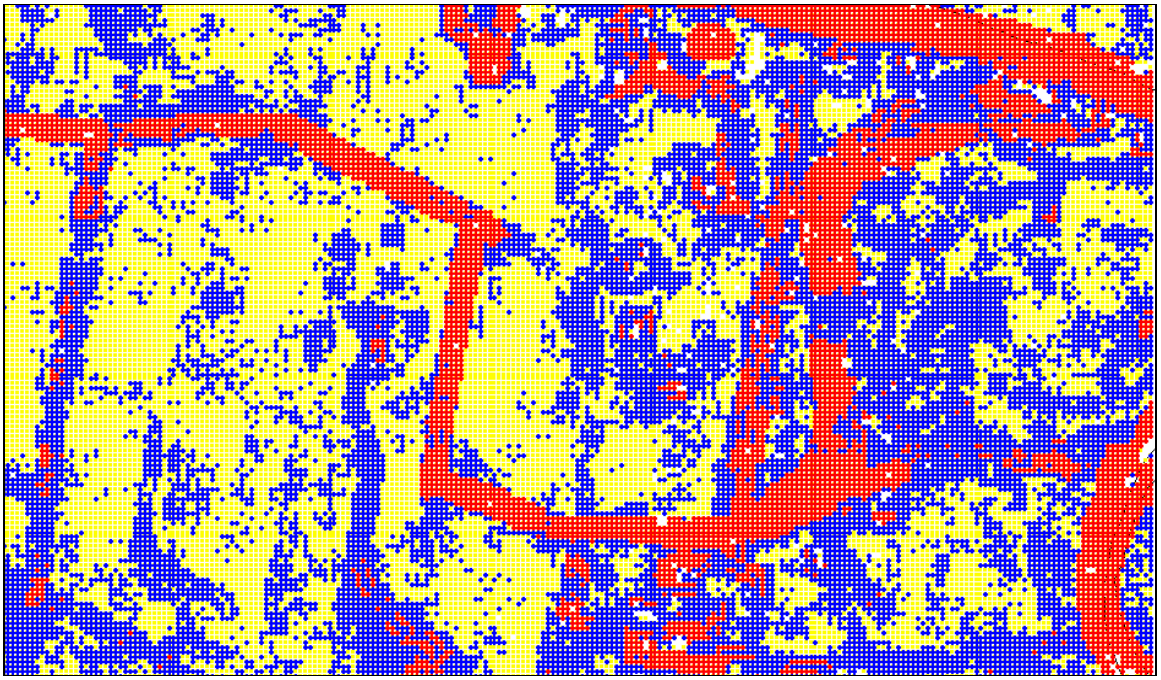

Figure 8: Spatial distribution of the 5 meter mesh size grid according to their height variation value for a surface located near the St. François River delta. A layer of grid points having a minimal height variation value of 0.5 meters (red points) superimposes the layers shown in Figure 7.

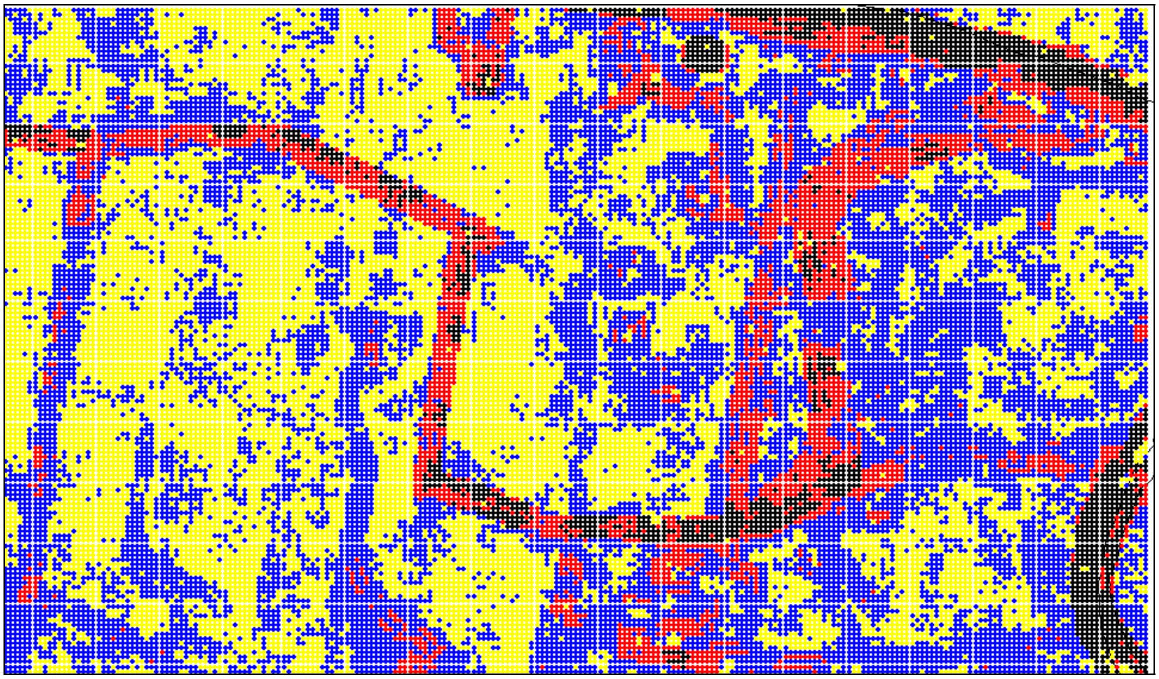

Figure 9: Spatial distribution of the 5 meter mesh size grid according to their height variation value for a surface located near the St. François river delta. A layer of grid points having a minimal height variation value of 1 meter (black points) superimposes the layers shown in Figure 8.

Contour lines

Contour lines have been traced for the entire region covered with LIDAR data from the grid points where height variation values smaller than 0.5 meters have been removed and to which we have joined bathymetric data. The resulting data set is a complete topographic profile of the St. Lawrence River between the Hochelaga archipelago and Trois-Rivières. Contour lines were traced using Vertical Mapper v.3.0. Figures 10 through 15 illustrate this profile divided into 4 sectors. These images were produced with a 10 meter pixel height surface. Sector 4 does not have associated bathymetric data.

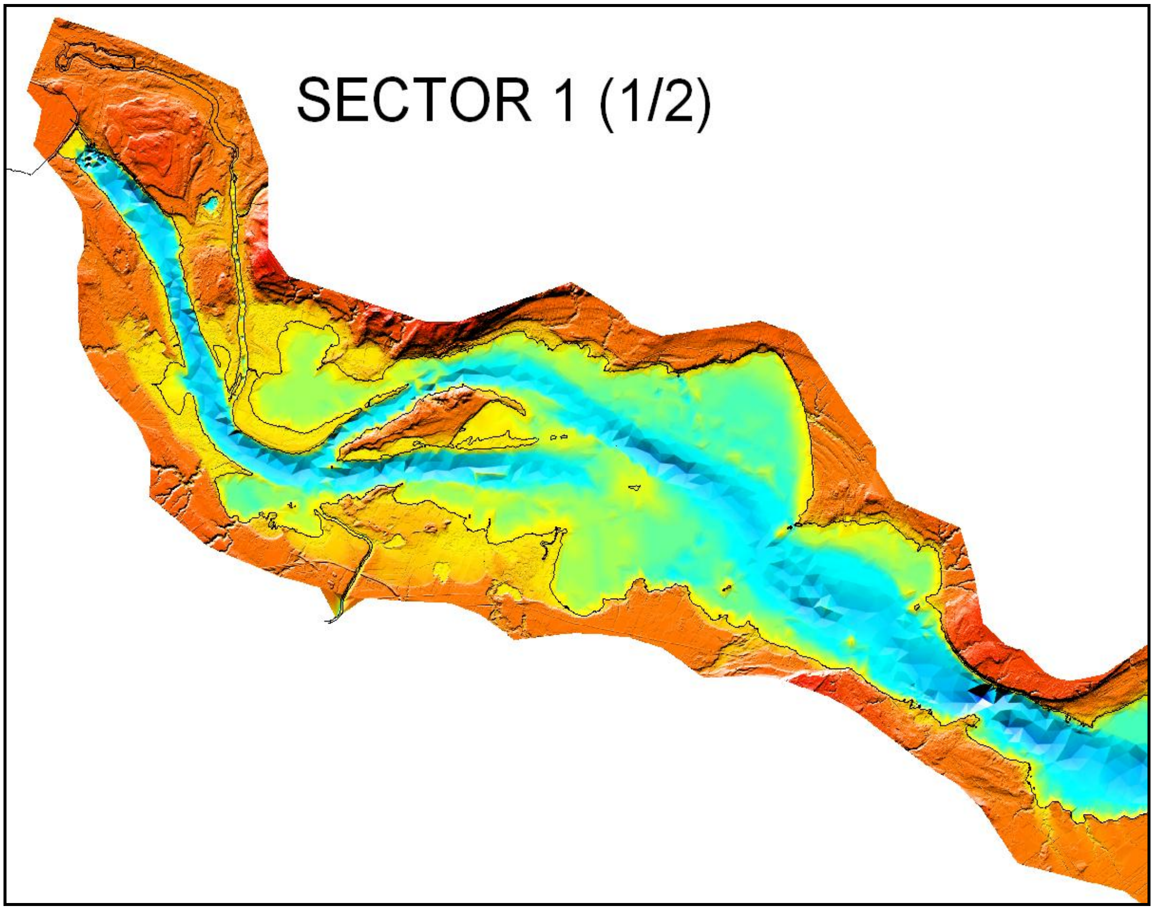

Figure 10: Western part of Sector 1 illustrating Lake des Deux-Montagnes. The black line represents the shoreline.

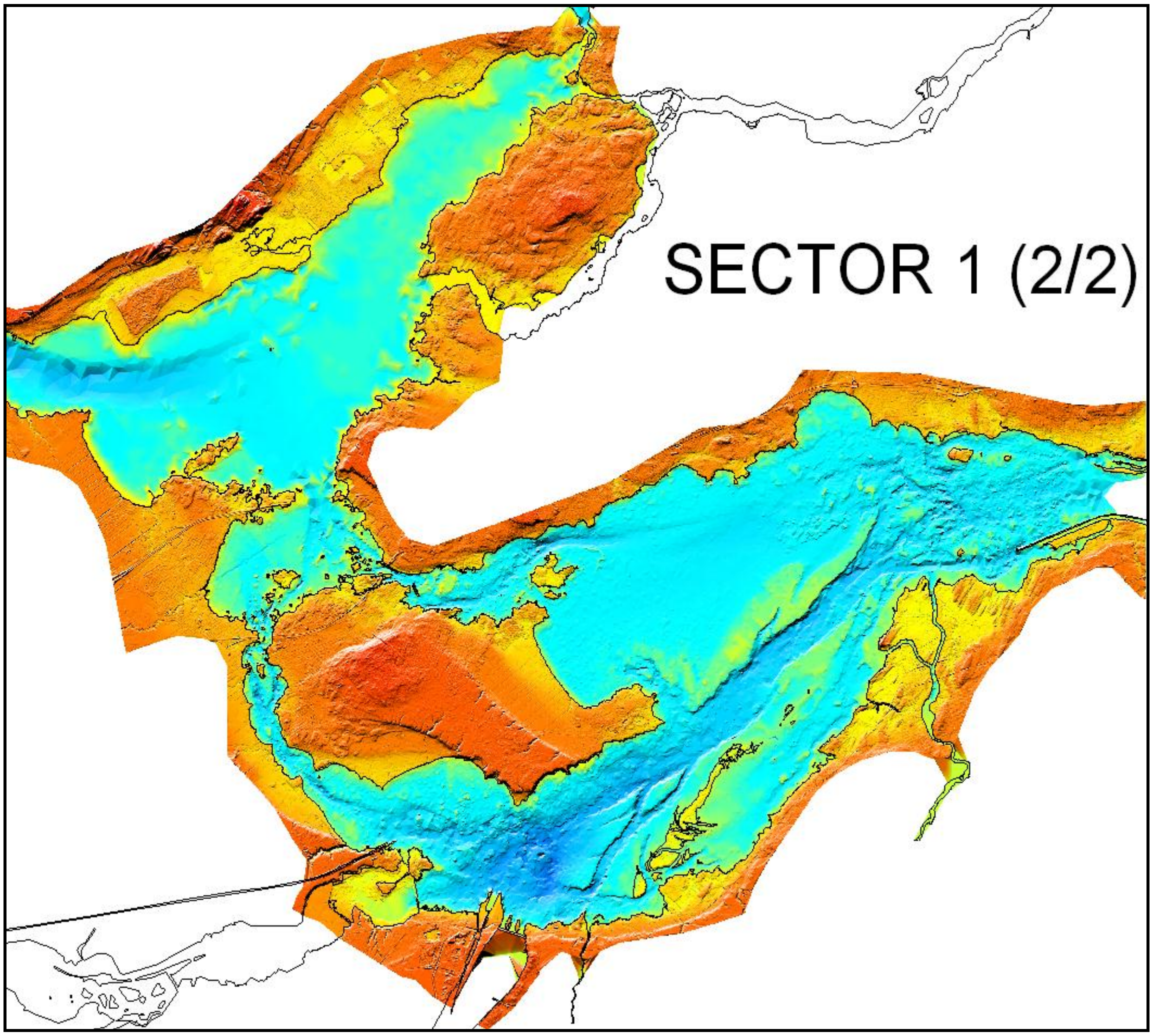

Figure 11: Eastern part of sector 1 illustrating Lake St. Louis. The black line represents the shoreline.

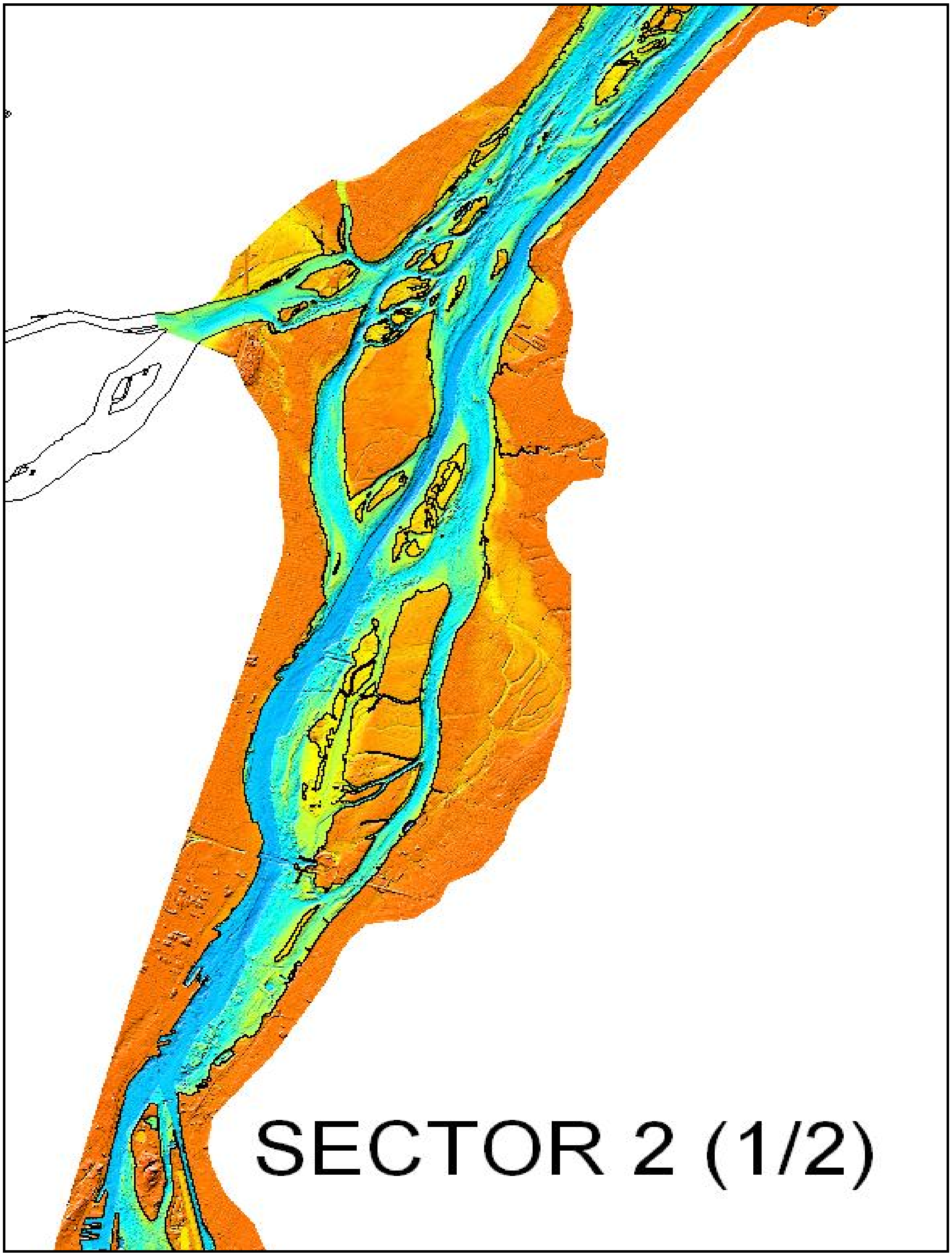

Figure 12: Southern part of sector 2. Port of Montréal to Varennes. The black line represents the shoreline.

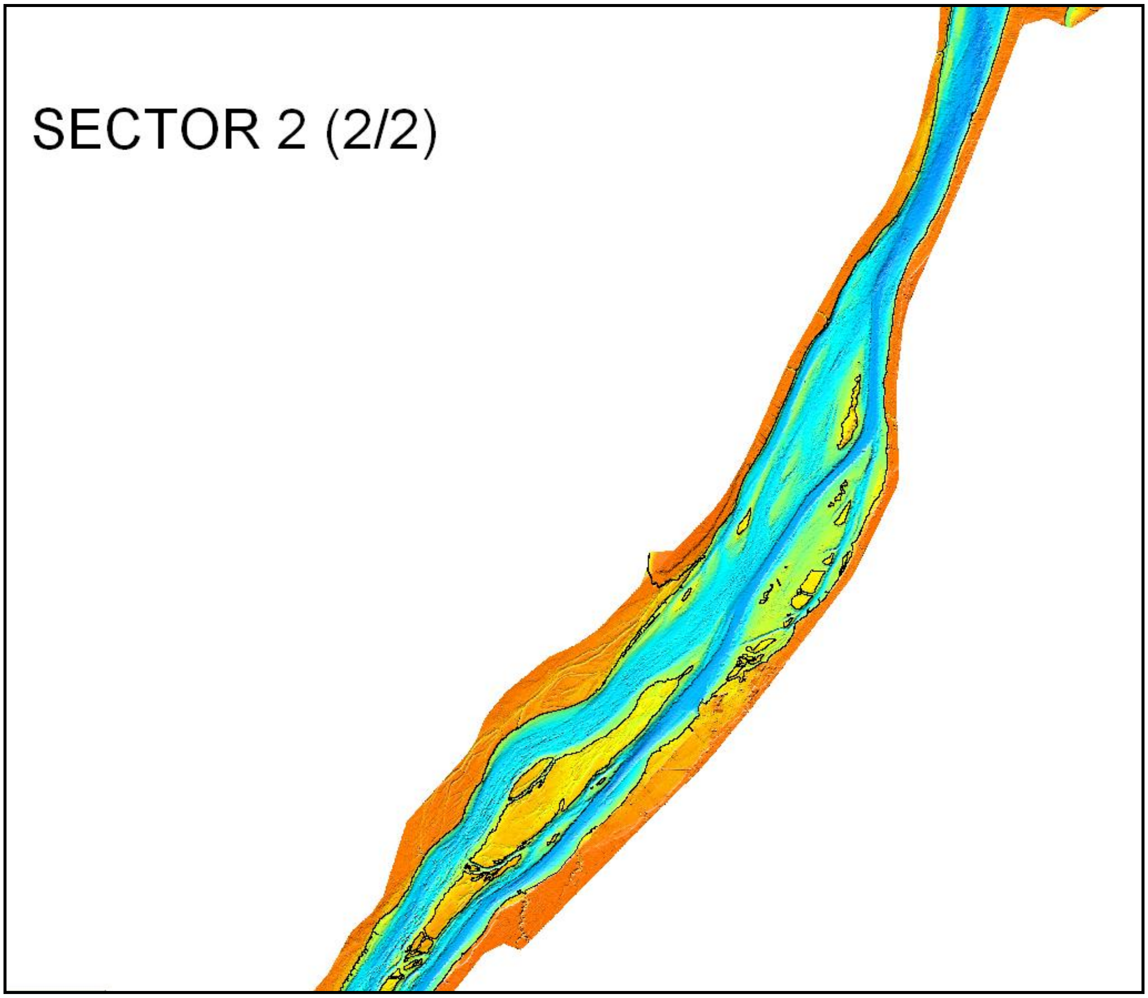

Figure 13: Northern part of sector 2. Varennes to Lanoraie. The black line represents the shoreline.

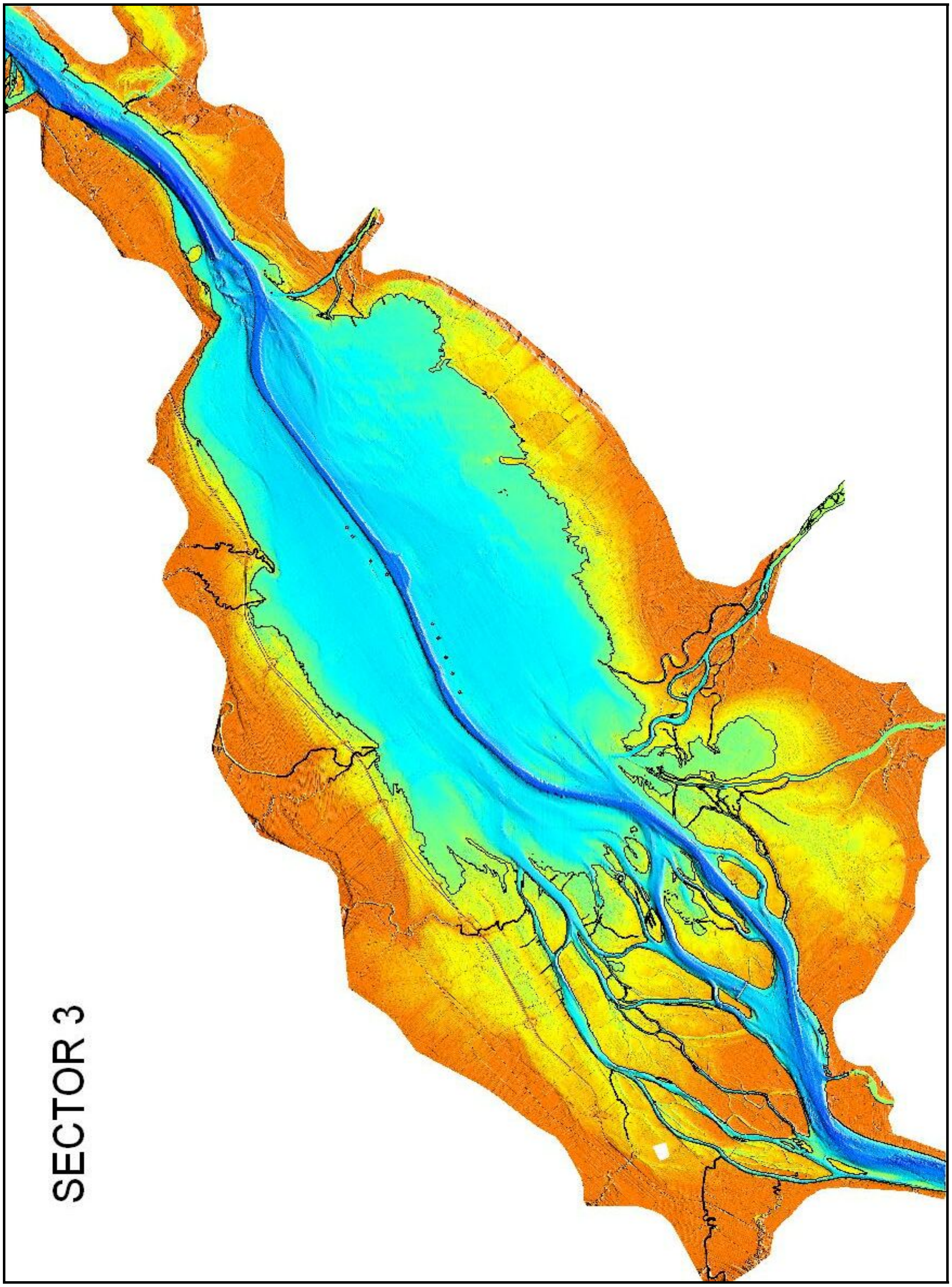

Figure 14: Sector 3 illustrating Lake St. Pierre. The black line represents the shoreline.

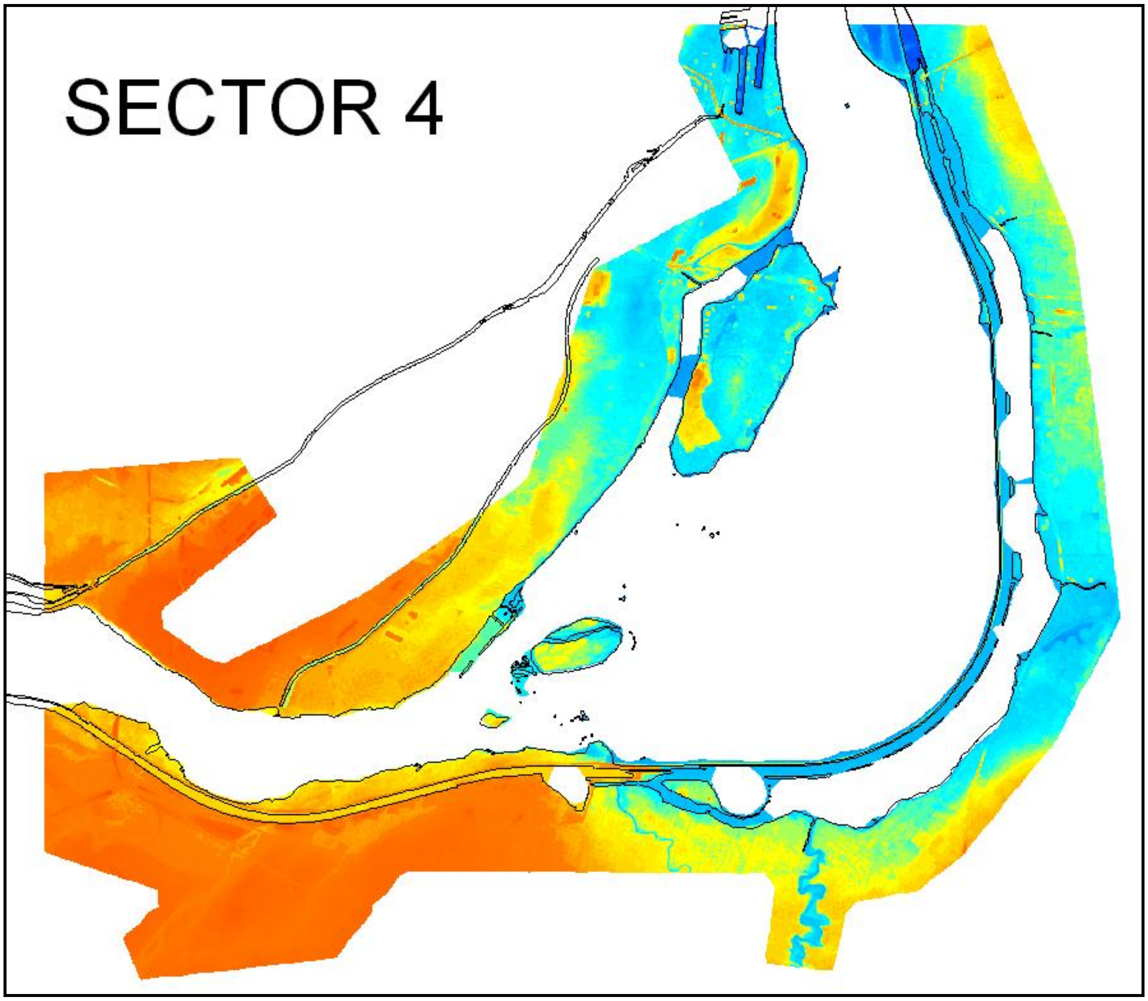

Figure 15: Sector 4 representing the Lachine Rapids and Bassin Laprairie. For this area, the bathymetric data are incomplete. The black line represents the shoreline.

Contour lines made with a commercial software

Figure 16 compares contour lines that were both made with a commercial software package (Vertical Mapper v3.0). The red lines represent contour lines built from a part of the grid upon which no sorting was done and the black lines are contour lines built from a grid where points with a height variation value smaller than 0.2 meter have been removed. In the case where data were extracted from an incomplete grid, the quantity of points is reduced by 42.1 % thus decreasing point density. On the other hand, the Digital Terrain Model’s resolution is slightly reduced.

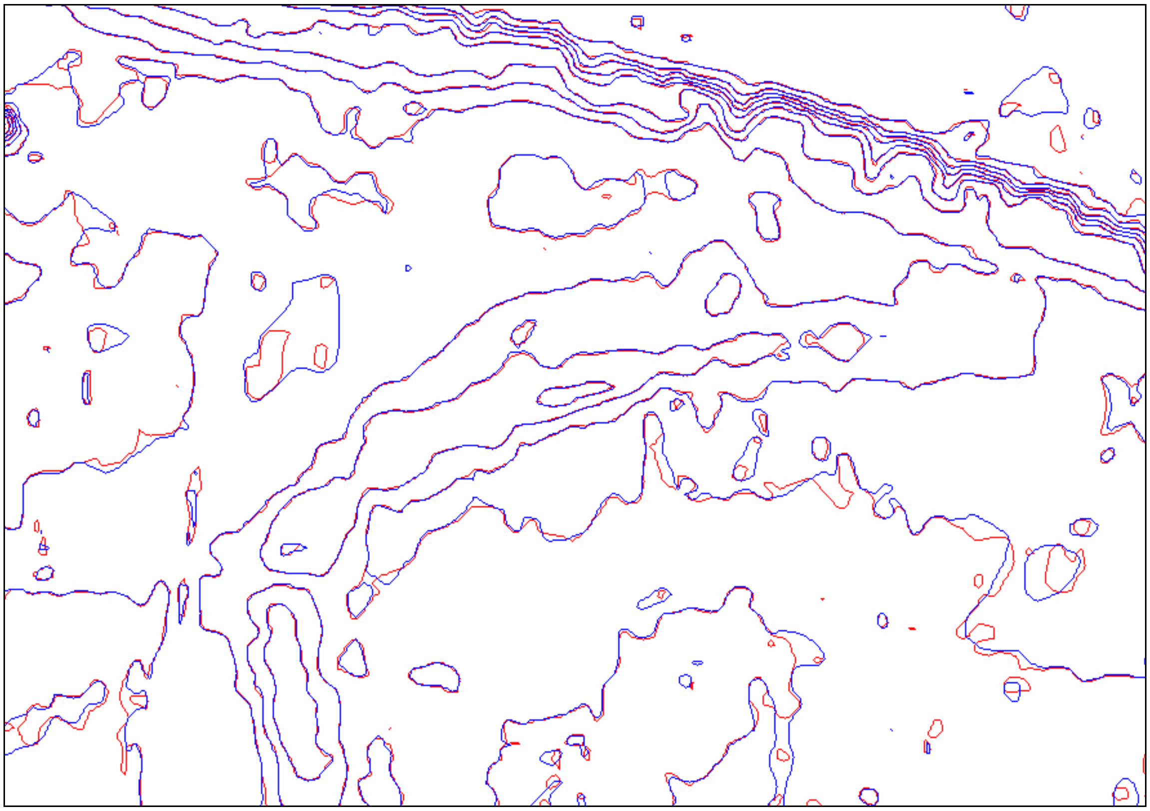

Figure 16: Comparison between contour lines produced from a complete grid (red lines) and the ones built from a grid where height variation values are greater or equal to 0.2 meter. Both contour lines were produced with Vertical Mapper v3.0.

Contour lines produced with MSC-Québec tool

Figures 17 and 18 compare contour lines produced by a commercial software using a complete grid (black lines) and contour lines produced with a tool programmed by the MSC-Québec also from a complete grid (colored lines). No significant differences are visible between these two contour line sequences suggesting that the tool programmed by MSC-Québec has the capacity to produce contour lines with a comparable precision to those produced by commercial software. Moreover, MSC-Québec also programmed a tool to produce contour lines with a user-defined selection (Figure 18). Since these tools can be used by LIDAR and Grid data users, ease of use and control over data interpretation are enhanced.

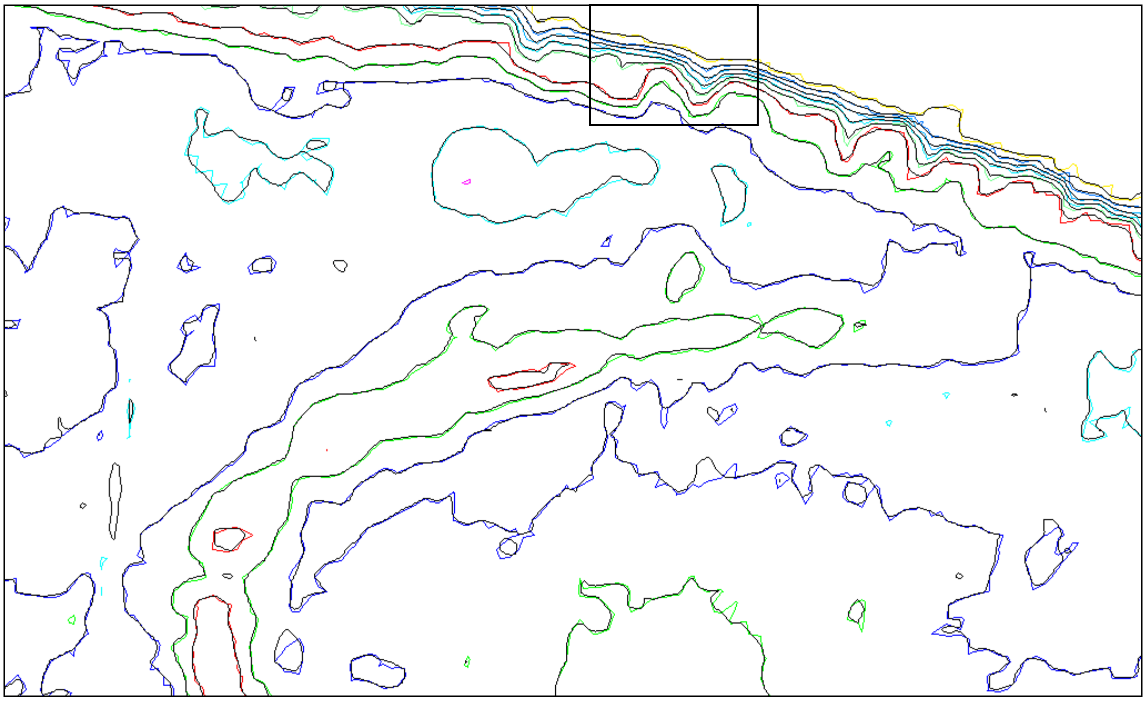

Figure 17: Comparison between contour lines made with Vertical Mapper v3.0 using a complete grid as a data source (black lines) and those produced by MSC-Québec's program which also used a complete grid as a data source (colored lines). Details from the region described in the small square are shown in Figure 18.

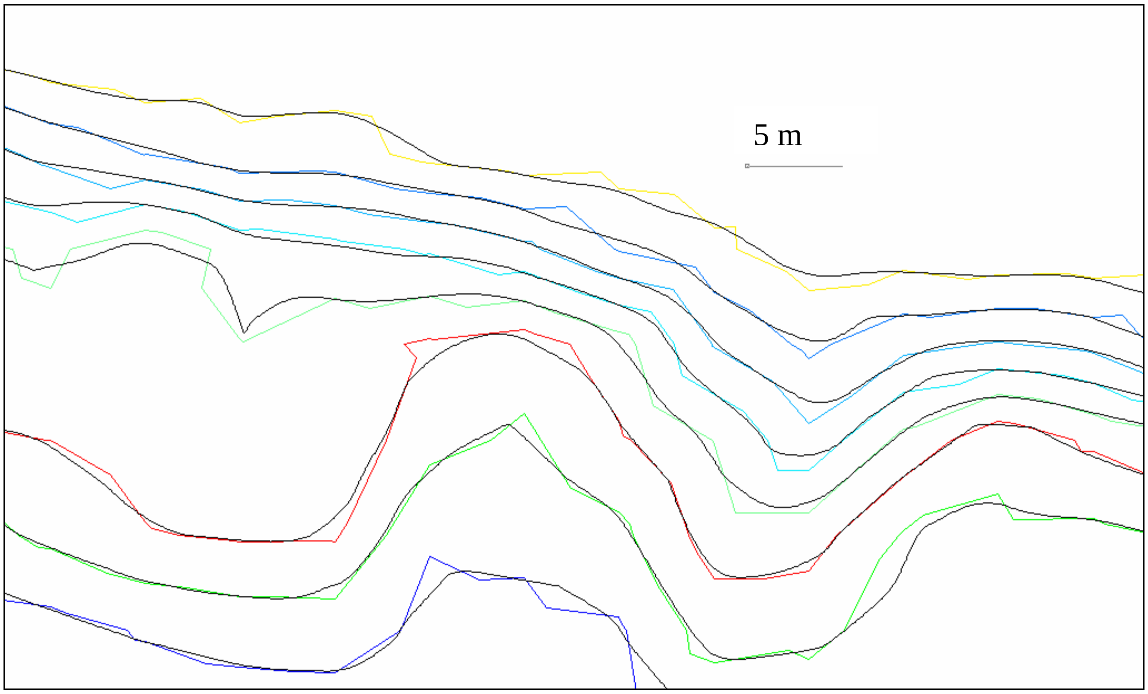

Figure 18: Detailed comparison between contour lines produced with Vertical Mapper v3.0 using a complete grid (black lines) and those produced by MSC-Québec's program (colored lines).

Conclusion

This work allowed us to pursue the development of a numerical field model on the St. Lawrence River watershed by incorporating a large amount of georeferenced points that are valid and reliable enough to be considered as a reference data source for any future study or project in the area of interest.

The field model is also now enriched with a regular point grid respecting a 5 meter distance between points. This grid has the capacity to represent LIDAR data and to express the height variation characteristics among neighboring LIDAR points. This can reduce the number of points to manage and decrease the computer resources required to process the data.

Finally, the digital terrain model was also improved with contour lines that cover the St. Lawrence River's 100 year flood zone including the river bed (bathymetry) from the Hochelaga archipelago to Trois-Rivières using a 4 meter interval. These contour lines were produced with a commercial software but virtual tools have been programmed by MSC-Québec, Hydrology section to build such contour lines both for the entire region and for a user defined area.

As well, it is important to note that all the data discussed in this report are stored/secured in a database managed by MSC-Québec.

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Annexes

Annex 1: Deliverables

Data delivered from this project are divided into four large zones:
All the files are on CD included (Annex 2).

Zone 1: South-west of the Hochelaga archipelago. More accurately, Lake des Deux-Montagnes and Lake St.François. Figure 10 and 11.
Zone 2: From Montréal harbour to Lanoraie. Figure 12 and 13.
Zone 3: Sorel archipelago to Trois-Rivières. Figure 14.
Zone 4: Laprairie basin. It is important to note that bathymetric data for this zone were not used because of low reliability and insufficient density. Figure 15.

Regular grid points

For each of the zones described above, a MapInfo folder containing grid points where height variation values are greater than or equal to 0.5 meters was created. Given the large amount of raw data present, this sorting was necessary for the visualization and handling of the delivered folders. The height values for each point correspond to height above Mean Sea Level (MSL). The projection used is MTM Zone 8 and the datum is NAD83. As described in this report, points located on water when sampling with laser were manually removed.

Zone 1: Gridbox1F.mif/mid (5,179,869 points)
Zone 2: Gridbox2F.mif/mid (2,653,189 points)
Zone 3: Gridbox3F.mif/mid (7,012,977 points)
Zone 4: Gridbox4F.mif/mid (999,617 points)

Contour lines

Contour lines or isosurfaces were produced for each zone. They were created from the grid using points where height variation values are greater than or equal to 0.5 meters (see the above folders) coupled with bathymetric data from several sources as described in the **Contour lines** section of this report. Vertical spacing used is 4 meters. The following folders are in MapInfo format and use the MTM zone 8 projection with a NAD83 datum. Contour line height was set according to Mean See Level (MSL).

Zone 1: iso_box1F_4m.MIF/MID
Zone 2: iso_box2F_4m.MIF/MID
Zone 3: iso_box3F_4m.MIF/MID
Zone 4: iso_box4F_4m.MIF/MID

Annex 2: CD-ROM

CD-ROM containing the deliverable.