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TECHNICAL REPORT:

LIDAR and Photogrammetric Survey

Project: FMT-192-21
Site: Quepos, Puntarenas, Costa Rica

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Technical Report: LIDAR and Photogrammetric Survey

Project: FMT-192-21

Quepos Urban Area

Puntarenas, Quepos, Costa Rica

Professional Responsible:

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Resume

This report includes the methodology, equipment used and results obtained from the LIDAR / photogrammetric flight carried out in the area of Quepos, Puntarenas, Costa Rica, on 10/04/2021, to obtain geospatial information on the urban area and its surroundings of the study site.

For this project, a DJI Matrice 300 RTK multi-rotor aerial vehicle was used, with a 40 Mega-pixel photographic sensor and a Zenmuse L1 LIDAR sensor with a capacity of 24 thousand points per second. The flight was adjusted using known coordinates and elevations, from bathymetric data from the Ministry of Public Works and Transportation of Costa Rica (MOPT), and a geodetic quality GNSS system.

The LIDAR point cloud information and aerial photographs were processed to obtain the products requested by the client, specifically the dense point cloud, the rectified Orthomosaic and the digital surface model of the study area.

The modeling accuracies are within defined tolerances. The model error is 2.20 cm. The precision of the Orthomosaic is 2.20 cm, while its resolution is 5 cm / pixel. On the other hand, the resolution of the digital surface model is 15.6 cm / pixel.

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1. Introduction

This report includes the results, methodology and technical aspects of the topographic survey carried out using a photogrammetric and LIDAR flight done in the urban area of the city of Quepos, Puntarenas, Costa Rica.

The technical equipment used, its description and capabilities, the topographic survey methodology and the obtaining of results for the final deliverable are included in this report.

The photogrammetric and LIDAR flight carried out corresponds to the urban area of Quepos, which is shown in the following image:

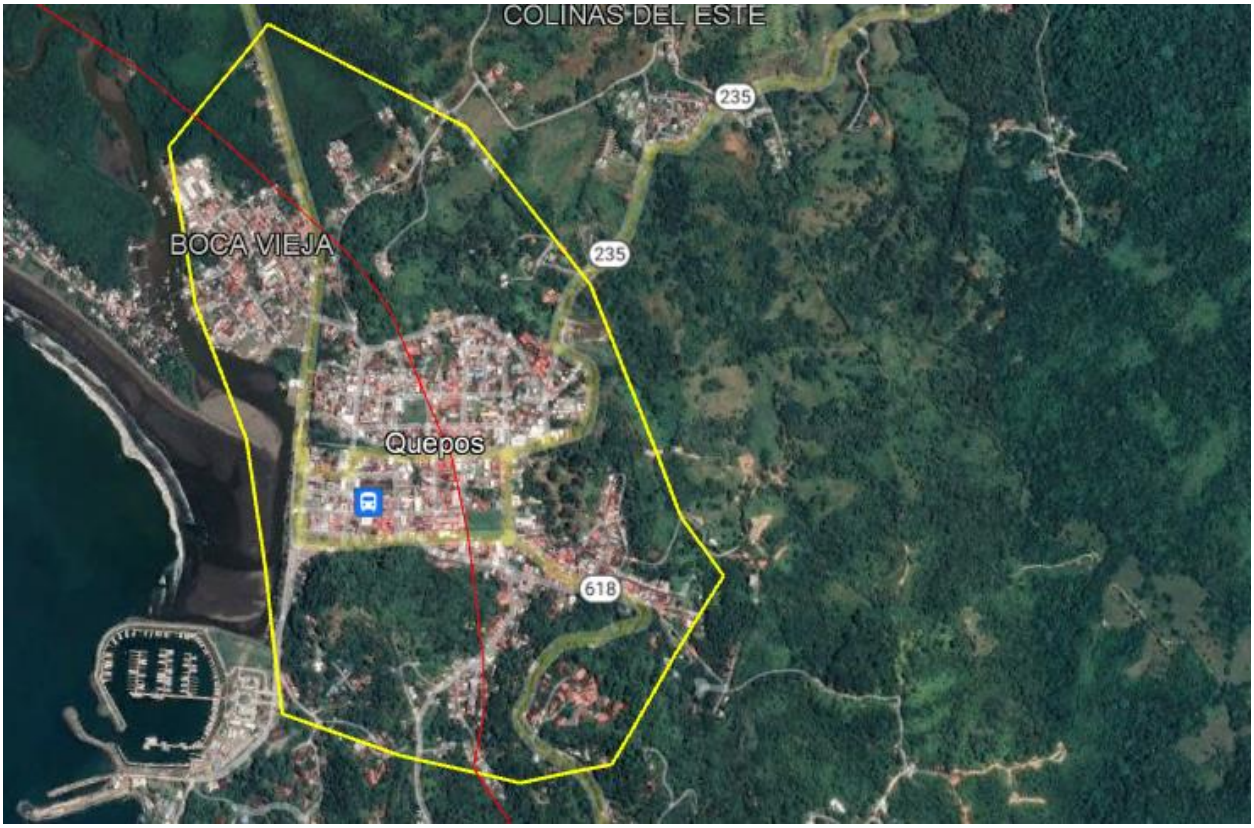

Illustration 1: Topographic survey area

The flight was made on October 4, 2021.

Among the deliverables that accompany this report include:

1- Digital Surface Elevation Model, excluding any element that is not part of the natural surface of the terrain, roads and pedestrian structure, in .TIFF format.
2- Dense point clouds obtained from the LIDAR flight, in .LAS format:
to. Point cloud classified according to elements such as natural terrain, road surface, buildings and vegetation.
3- Rectified orthomosaic of the survey area, in .JPG and .TIFF formats.
4- XYZ data (horizontal and vertical position) in a grid spaced every 5 and 10 meters, in .TXT format.

2. Methodology and Aquipment Used

Survey Method: Photogrammetry and LIDAR data recording from unmanned aerial vehicle flight.

Adjustment method: RTK real-time correction, from points with known coordinates.

Aircraft: DJI Matrice 300 RTK.

LIDAR sensor: Zenmuse L1

GNSS system: Emlid Reach RS2 / L1 / L2 / L5

Horizontal Reference System: CR05 / CRTM05 (EPSG: 5367)

Vertical Reference Datum: Orthometric Heights referred to the EGM2008 Geoid

A survey was carried out with an aerial vehicle in the study area, which includes an area of approximately 1.85 km^2. To have a correct horizontal and vertical position, a survey was completed with GNSS technology (Global positioning) and thus be able to generate reference points in the study area, which were used to adjust the survey and the products obtained.

Once these reference points were defined, the photogrammetric and LIDAR flight was carried out in the study area, using a DJI Matrice 300 RTK multirotor drone, with real-time correction by means of a reference base placed at a point with coordinates and elevation previously known.

Once the drone products were obtained, such as photographs and point cloud, the flight was processed, the corresponding information was generated, and the data was refined to modify or eliminate any element that damages the precision and quality of the results.

The following sections detail the methodology for each stage of the project.

2.1 Verification and Definition of Known Reference Points

To guarantee that the topographic survey has a correct reference in horizontal and vertical position, it was necessary to carry out a GNSS survey from known points granted by the Ministry of Public Works and Transport (MOPT), which also serve as a reference for the bathymetry carried out in the area (not carried out by Fermat Topography). The known points are as follows:

TABLE 1. Reference Coordinates for Survey

PUNTO	ESTE (m)	NORTE (m)	ELEVACIÓN (m)
UNA-MOPT	481264.991	1042131.869	6.276
1Q	481321.142	1042135.911	6.283

Source: Points obtained from MOPT bathymetric plans. Elevations referred to the mean level of low tides in SICIGIAS.

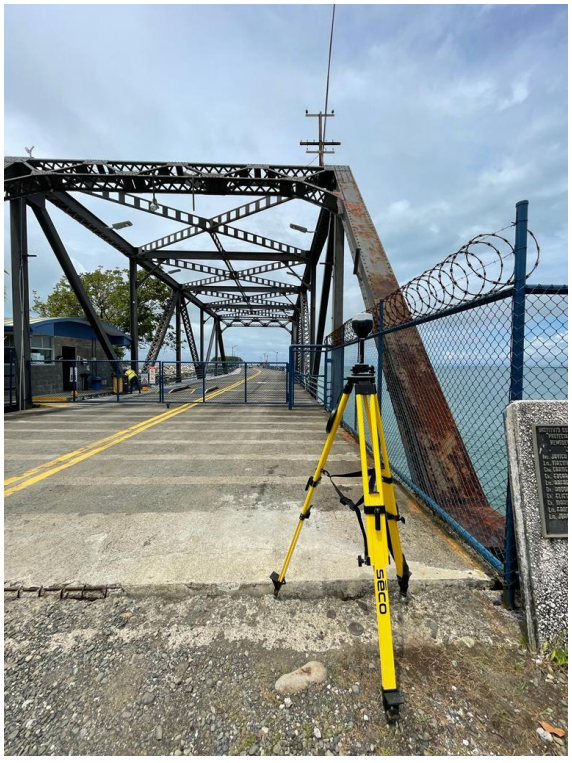

Illustration 2: Verification of reference points using GNSS system.

These points were used as reference points to generate new ones to be used during the photogrammetric flight as base points. The defined points are as follows:

TABLE 2. Reference coordinates generated for LIDAR flight.

PUNTO	ESTE (m)	NORTE (m)	ELEVACIÓN ORTOMÉTRICA (m)
AUX 2	481867.258	1042680.826	5.778
AUX 3	481855.896	1042673.768	5.773
AUX 4	481832.084	1042688.877	6.480

Source: Self made.

Illustration 3: Location of reference points for flight, generated from the MOPT reference points.

2.2 Planning of Photogrammetric Flight and LIDAR

As mentioned in previous sections, the aircraft used was a DJI Matrice 300 RTK multirotor drone, with a Zenmuse L1 LIDAR sensor. The planning consisted of defining the flight area, using the polygon of the required area, provided by the client. The details aircraft characteristics below:

- DJI Matrice 300 RTK drone.
- Horizontal accuracy: 5 cm (with RTK)
- Horizontal Accuracy: 5 cm (with RTK)
- Photographic Camera: 40 Megapixels
- LIDAR sensor: Zenmuse L1, 24,000 points per second, 3 returns

The photogrammetric / LIDAR flight was corrected in real time using RTK methodology, based on the AUX 2 and AUX 3 points mentioned in the previous section. In this way, the precision of the aircraft's position at all times was kept in the range of less than 5 cm.

Illustration 4: DJI Matrice 300 RTK.

2.3 Photogrammetric and LIDAR Flight Processing

Once the LIDAR information and the aerial photographs had been obtained, the information was processed. The following information is available for processing:

- Number of LIDAR points: 143 042 417 points (after statistical reduction of points).
- Number of photos: 516
- Flight height: 160 m
- Base resolution of the model: 3.89 cm / pix
- Total flight area: 2.16 km2

The information that is obtained from the dense point cloud, are the digital elevation model and the orthorectified mosaic of photographs. This processing was done in Agisoft Metashape Version 1.5.2. Image 5 shows the unified product.

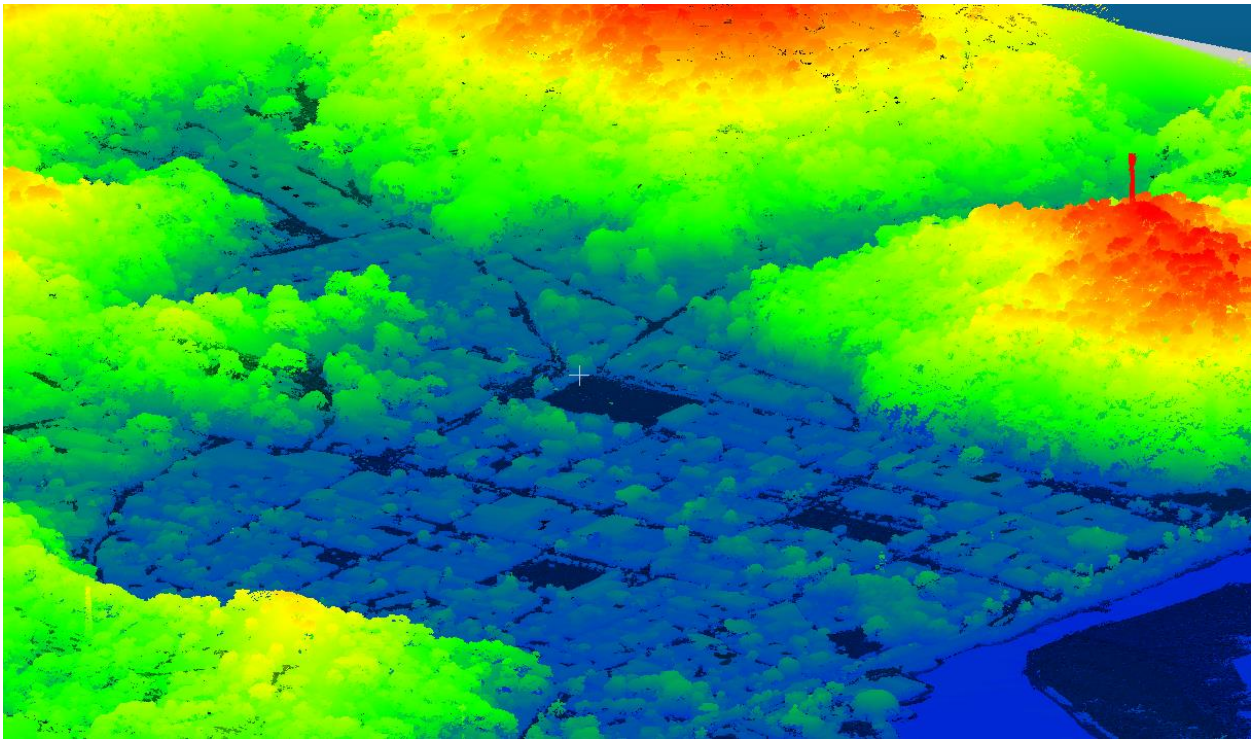

Illustration 1: Product resulting from information modeling and processing.

2.3.1 Errors of the Photogrammetric and LIDAR Model

When performing flight processing, intrinsic errors are generated from the aircraft capacity and the RTK correction methodology. To ensure the precision and accuracy of the model, the following errors are shown, extracted from the Agisoft Metashape quality report.

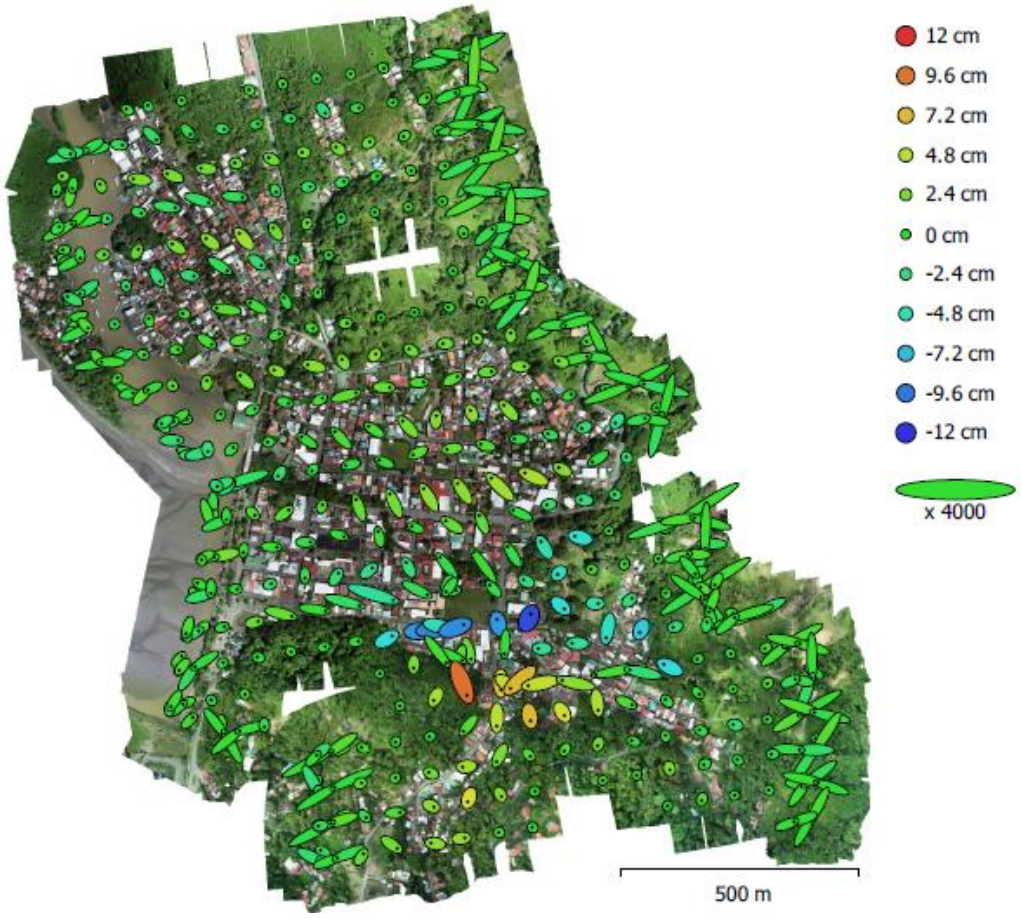

Illustration 6: Location of photographs and estimated errors. The error in Z is represented by the color of the ellipse. The XY error is represented by the shape of the ellipse. The black dot indicates the location of the photo.

TABLe 3. Estimated XYZ errors. Errors are in centimeters.

Error X (cm)	Error Y (cm)	Error Z (cm)	Total (cm)
0.771567	0.558714	1.9879	2.20437

Source: Agisoft Metashape. Quality Report.

2.4 Cleaning of the Point Cloud and Construction of the Digital Surface Model

To generate the necessary product for the end of the final study, it is required to clean the LIDAR point cloud and eliminate elements such as buildings, vehicles, vegetation, water and any other object that is not part of the natural terrain and the surface of the road. For this, the point cloud was processed in the Cloud Compare program, which allows for intelligent information filters.

Image 6 shows the dense point cloud classified according to its characteristics. The color purple and brown indicate the natural terrain and roads. Red dots indicate buildings. Light and dark green colors indicate vegetation.

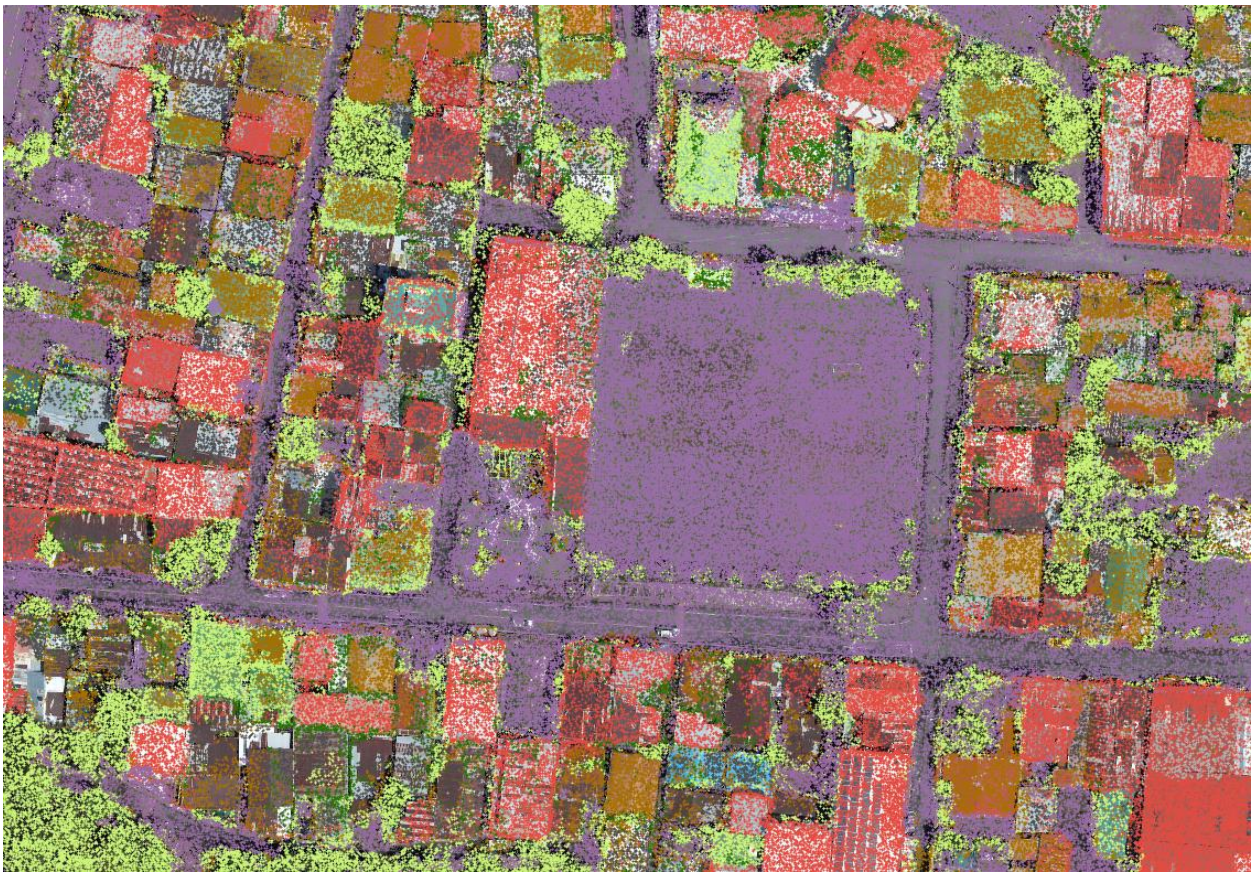

Illustration 7: Classified LIDAR point cloud. The purple and brown color indicate the natural terrain and roads. Red dots indicate buildings. Light and dark green colors indicate vegetation.

Una vez filtrados estos puntos, se obtiene la información mostrada en la imagen 7, la cual corresponde solo al terreno natura, calles, caminos y aceras.

Illustration 8: Dense point cloud classified with only natural terrain.

From the above information, the digital surface model (DSM) is built.

3. RESULTS OF THE SURVEY

3.1 Digital Surface Model

For the digital surface model, ArcGIS Pro program was used. The resulting product is as follows.

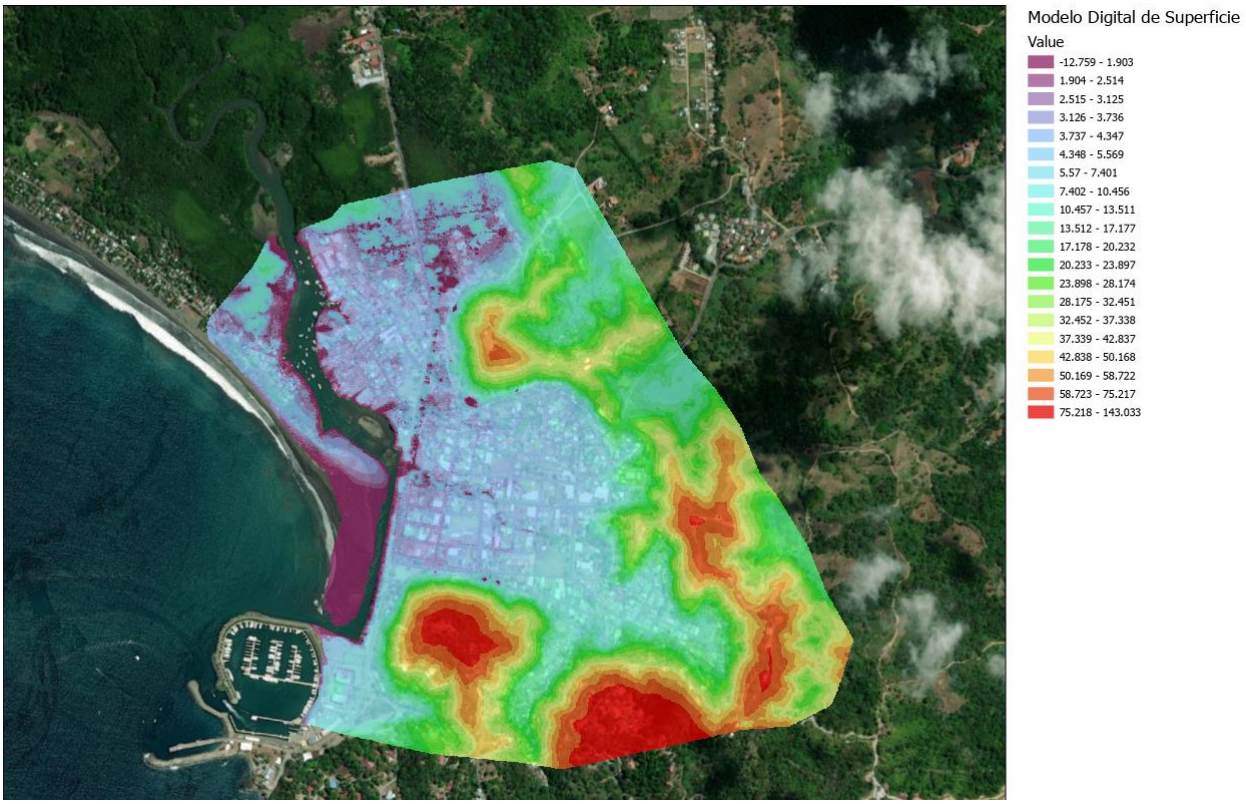

Illustration 9: Digital Surface Model

Image 9 shows the heat map of the elevations of the model made. The purple and blue colors indicate the lowest elevation sites, while the yellow and red tones indicate high areas.

- Model accuracy: ± 15.6 cm / pix

3.2 Orthomosaic

The georectified Orthomosaic generated from the flight processing is shown in image 10:

Illustration 10: Rectified orthomosaic.

La precisión del mosaico es el siguiente:

- Precisión del mosaico: ±2 cm
- Resolución del mosaico: 5 cm/pix

Illustration 11: Detail of the orthomosaic.

4. Shared Products and Final Considerations

The shared products, at the request of the client, are the following:

1- Rectified Orthomosaic .TIFF and .JPG files.

2. TIFF file of the Digital Surface Model

3. .TXT files of a grid of points with XYZ information every 5 and 10 m.

4. LIDAR point clouds in .LAS format.

- o Ground point cloud
- o Point cloud of elements that do not include the ground
- o Complete and classified point cloud.

4.1 Other products that can be obtained

From the LIDAR and photogrammetric information generated, a large number of products can be obtained such as **(these products are not within the contract):**

1. Digitization and quantification of roads, paths, sidewalks and other road elements.
2. Digitization and quantification of buildings, urban footprints, quantification of houses and other structures on the site.
3. Cadastral assemblies with cadastral plans.
4. Estimation of height, type and areas of vegetation cover.
5. 5. Identification and Inventory of elements in the city such as bus stops, lighting poles, sewers, road signs, public areas, private areas, etc.