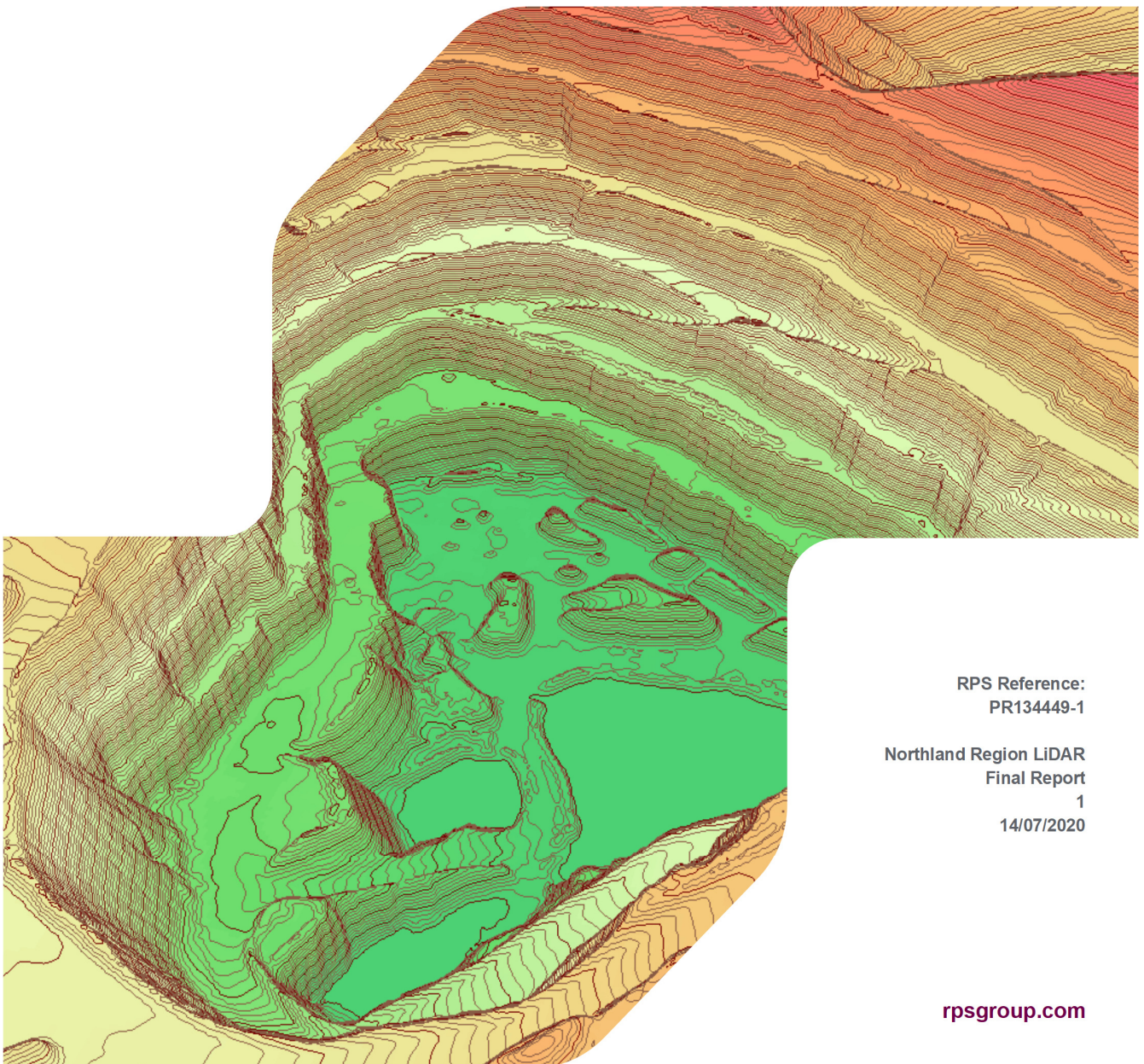


FINAL REPORT

Northland Region LiDAR Project

For Northland Regional Council



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Northland Region LiDAR
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1 SUMMARY

The following report presents the methodology and results for the Northland Region LiDAR project carried out on behalf of Northland Regional Council (NRC).

In summary, full waveform LiDAR was collected between December 2018 and July 2019 at low altitude to obtain a density of 3 points per square metre (4 points per square metre in nominated forestry areas) and to a high level of accuracy. Subsequent flights were conducted in February 2020, after initial data review had been completed on the dataset.

The accuracy of the LiDAR data was validated against ground control points collected by Opus surveyors (now WSP). Comparing the LiDAR to the ground control points presented a calculated vertical accuracy as seen in Section 4.4.

In addition to the accuracy assessment, a density check was carried out and this concluded that the points per square metre (ppsm) met the requirements of 3ppsm or greater. The survey was coordinated on NZVD and OTP datums.

The set of seamless products consists of a

- Digital Elevation Model,
- Digital Surface Model,
- Canopy Height Model,
- Contours,
- Classified point cloud (LAS),
- and 12.5cm imagery.

Within this final project report we have outlined a technical discussion addressing how each of the contract specifications has been met including a brief description of the project area of interest (AOI), a description of the data collection phase, a statement of consistency with specified standards, results of independent accuracy and validation tests, metadata statements and extra-ordinary issues that may have affected the nature or delivery of the project.

File	Content
Northland Flight Trajectories.kml	Flight Trajectories mapped from the airborne GPS logs
Vertical control report Northland.txt	Accuracy assessment

2 PROJECT SPECIFICATIONS

2.1 Project area

The area of interest for this project was the entire of the Northland Regional Council area, and included the Three Kings Islands to the North West of Cape Reinga.

day



2.2 Accuracy Requirements

Accuracy requirements taken from Request for documentation supplied by NRC;

The vertical positional accuracy achieved is at least:

- $\pm 20\text{cm}$ (2σ or 95% confidence int.) in Flat, Open Ground

The horizontal positional accuracy is at least:

- $\pm 100\text{cm}$ (2σ or 95% confidence int.)

2.3 Point Density

2pts/m² (emitted point density)

The sensor must be capable of:

- Detecting multiple discrete returns, with a minimum of 4 potential returns for each outbound laser pulse.
- Recording the intensity of each return.

RPS committed to capturing the project at an average point density of 3pm² in a single pass, with 4ppm² in nominated forestry areas.

2.4 Datum and Projection

Deliverables for the project have been provided in both:

- NZGD2000, NZVD2016, NZTM2000 , and
- NZGD2000, ONTPHT1964, NZTM2000.

Where:

- *NZGD2000 – New Zealand Geodetic Datum (2000)*
- *NZVD2016 – New Zealand Vertical Datum (2016)*
- *NZTM2000 – New Zealand Transverse Mercator (2000)*
- *ONTPHT1964 – One Tree Point Vertical Datum (1964)*

2.5 Equipment and software

The following describes the equipment and software RPS used to capture and process the LiDAR data for this project:

- Piper PA-34 Seneca
- Trimble AX60i LiDAR scanning instrument;
- Trimble AP50 GNSS-Inertial OEM System.

2.5.1 Aircraft

The Piper PA-34 Seneca twin engine aeroplane has been modified specifically for LiDAR survey operations and was utilised for the capture of this project.

- Aircraft: Piper PA-34 Seneca
- Crew: Pilot & Operator
- Cruise Speed: 160kts
- Survey Speed: 120kts
- Endurance: approx 6 hours

2.5.2 Trimble AX60i LiDAR Scanner

RPS used the Trimble AX60i scanner in order to carry out the LiDAR survey. The Trimble AX60i is a high performance, versatile, and fully integrated airborne LiDAR solution. It integrates a powerful long-range laser operating at 400 kHz pulse return rate with a maximum scan frequency of 200 Hz. Beam deflection is achieved through a rotating mirror instead of the common oscillating mirror, resulting in parallel scan lines on the ground with uniform point-spacing and high accuracy within a maximum of 60 degree field-of-view. With the capability of detecting theoretically unlimited returns for each outbound laser pulse, the AX60i is ideal for surveying dense vegetation areas and complex terrain. The scanner specifications are as follows:

- Laser instrument: Trimble AX60i
- Laser classification: Class 3B
- Laser wavelength: Near infrared
- Laser Pulse Repetition Rate: 100kHz – 400kHz
- Scanning mechanism: Rotating polygon mirror
- Scanning pattern: Parallel scan lines
- Scan frequency (max): 200Hz
- Scan width (FOV): 0 - 60 degrees
- Operating flight altitude: 50m – 4700m AGL
- Range measurement accuracy: 2cm
- Vertical accuracy: <15cm (absolute)
- Horizontal accuracy: <20cm (absolute)
- Beam divergence: <= 0.25mrad

- Range capture: Full waveform
- Intensity capture: 16 bit dynamic range for each echo
- Vertical discrimination distance 0.4m – 0.7m

2.5.3 Trimble AP50 Positioning System

The Trimble AP50 GNSS-Inertial OEM System is an embedded GNSS-Inertial OEM board set plus Inertial Measurement Unit (IMU) that is incorporated in the Trimble AX60 LiDAR system.

- IMU sampling rate: 200 Hz
- IMU accuracy: 0.008/0.008 (roll/pitch)
- IMU accuracy: 0.005 (velocity)
- GPS: Very low noise GNSS carrier phase measurements with <1 mm precision in a 1 Hz bandwidth

2.5.4 System Calibration

As part of our established quality assurance process the LiDAR sensors are regularly calibrated as per the manufacturer's recommendations. A copy of the LiDAR calibration certificate is available upon request.

2.6 Software

The LiDAR and imagery was processed using the following software packages:

- Riegl RiAnalyze software for full waveform data processing.
- Applanix PostPac for navigation processing and GNSS solution.
- Inpho LPMaster software is used to produce highly accurate point cloud data from the post processed GNSS and IMU data and the processed waveform data from RiAnalyze.
- Terrascan and Terramodeler: LiDAR processing and analysis tools used for importing the processed LiDAR data from TopIT to produce the final LiDAR products for delivery.
- Microimages TNTmips: a GIS tool that directly reads LiDAR data. RPS has developed a suite of tools for producing and verifying data to standard national specifications.
- ESRI ArcDesktop suite: foundation GIS software for deriving products. RPS has developed a suite of tools for producing and verifying data to standard national specifications.
- Inpho Orthovista and Orthomaster: a highly efficient digital orthophotography production tool used for Orthorectification, mosaicing, colour balancing, contrast adjustment and tiling of the photography ready for delivery.

3 AERIAL DATA CAPTURE

3.1 Capture Timing

The aerial survey program was completed over a period between December 2018 and July 2019, with some post QA flights undertaken in February 2020 to fill in voids in data.

Original schedules were severely delayed due to weather patterns. The convection layers moving in from both west and east of Northland, and colliding over the land mass, formed erratic and unpredictable cloud patterns that limited availability of capture. While originally planned to operate below cloud height, the variability in the weather meant that this was not always an option.

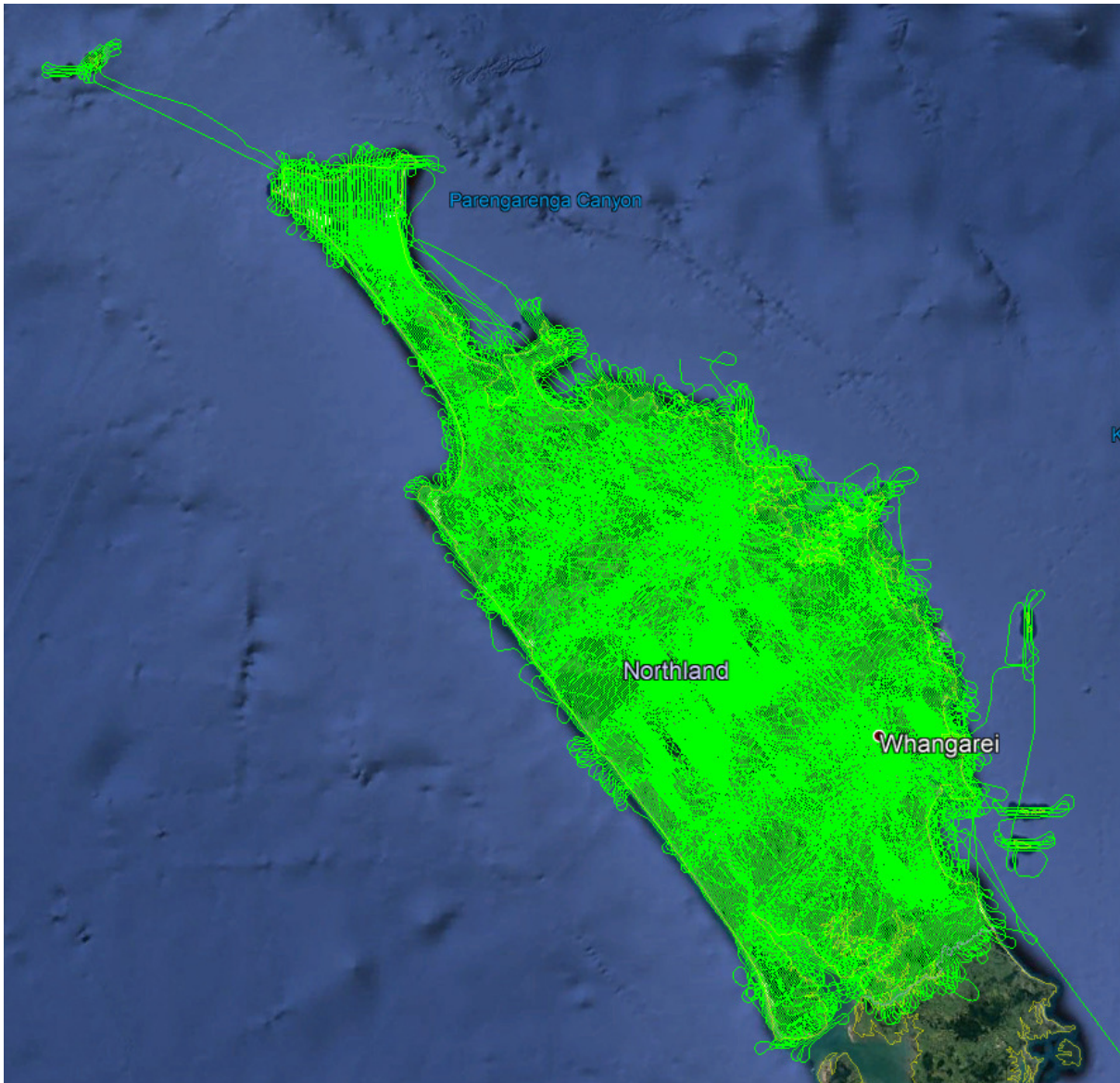
3.2 Flight Planning and Trajectories

TrackAir software was used to develop an optimised Flight Plan to meet the specified requirements, the flying height, flying speed, overlap, scan rate and pulse frequency were specified to achieve the nominated point density at ground level. Outgoing pulse density is equivalent to first return density except where there are no returns e.g. from water surfaces and possibly features with very low infra-red reflectivity (composite roofing materials, powerlines etc).

The flight plan was designed with the following settings:

Parameter	Value
Flight Altitude	820 m
Swath Overlap	30%
Swath Width	947 m
Scan FOV	60°
Pulse Frequency	300 kHz
Non-Cumulative Pulse Density	3.41 ppm ²
Pulse Footprint	0.21m

The flight trajectories mapped from the airborne GPS logs are shown in Figure 1 and are presented in: *Northland Flight Trajectories.kml*



Flight Trajectories

3.3 LiDAR Processing

For each LiDAR swath the point cloud was generated from the full wave form instrument data and post processed GPS/IMU logs. Each sortie was validated against check points to quantify residual errors.

The cross strips and LiDAR swaths form a network of overlapping data that was analysed and levelled to establish the internal integrity of the dataset using TopoSys software. The survey swaths were adjusted to the cross strips in increments of 1cm, while viewed in profile. Several profiles were measured in each intersecting block and adjustments were averaged along the swath. No automatic adjustments were applied as this can introduce errors (by polynomial warping) and obscure systematic errors.

The vertical accuracy of the LiDAR was tested against control survey. If necessary a vertical adjustment of the LiDAR can be applied at this point, however, the vertical accuracy assessment result was within the specifications of 0.05m therefore no adjustment to control was applied.

The tiles were automatically classified to ground and non-ground (classes 2 and 1, respectively) using TerraScan software. Low and high noise points were automatically classified and allocated to class 7 prior to review, where low noise was identified below the ground level, high noise identified as points greater than 100m above ground.

The classified LiDAR ground points were improved to ICSM Level 2 specification by manual editing in TerraScan software. This involved reclassifying points from or to the Ground class, so that confirmed ground points were in the Ground class. This was done with the point cloud displayed in profile view and the terrain surface (TIN) in plan view. The 'above ground' points were then automatically classified as per the ICSM specification Level 1 using classes specified by Northland Regional Council.

Once classification was complete, the data was regenerated to 1km x 1km tiles in LAS v1.2.

3.3.1 Strip Levelling, Classified Data and Filtering Data

The LiDAR point cloud for each survey strip was generated from the full waveform LiDAR signal and translated from the temporal/angular units to geographic coordinates by reference to the calculated flight trajectories.

Residual errors were measured using the "boot control" points at the start and end of each sortie. This process provided an initial quality check and an opportunity to enhance the accuracy of the LiDAR data.

The LiDAR strips were levelled and combined, and then adjusted to ground control to produce a set of LAS files with the required spatial accuracy. The process provided a high level of confidence in the internal integrity of LiDAR heights, and a sound assessment of the quality of GPS/IMU data.

All data was processed without any major issues.

4 DATA VALIDATION AND ASSESSMENT

Raw LiDAR strips are checked visually to ensure there is complete coverage of the areas surveyed and there are no obvious discrepancies. More thorough visual assessments are undertaken during processes such as levelling, classification and quality assurance of classified tiles. During processing any voids that are not due to water or non-reflect surfaces is investigated. In our experience the only situation in which such voids occur is where there is no overlap between adjacent strips, in which case the missing data will be re-flown.

Once the LiDAR for an AOI has been internally levelled, TerraScan software is used to calculate residual error reports for the complete set of ground control points. The vertical accuracy of the point cloud dataset is tested using a TIN surface constructed from bare-earth LiDAR points, which is compared against ground survey locations.

RPS obtained ground survey from Opus surveyors to evaluate the vertical accuracy of the LiDAR data. The comparison of these heights to the ellipsoidal heights will be used to give a measure of the quality of the LiDAR ellipsoidal heights.

The residual error reports list the location of each check point and the differences between the measure z values and the interpolated LiDAR ground surface.

Data for the entire project area was processed as a whole to ensure vertical consistency.

4.1 LiDAR Point Density Assessment

In order to verify the point density, all raw swaths were analysed using an RPS developed, purpose built software tool that calculates a raster with 5m x 5m pixels, where each pixel represents the number of first returns falling on that 25 square metres.

Edge pixels are removed to eliminate pixels that are only partially covered by the swath. The software not only produces the pulse density rasters, but also a report on the mean density within each swath.

In summary, the point density meets the specified requirements as illustrated below. This includes overlap, as it is difficult to ascertain single swath returns given the modification to the flight plan for the regions captured at ppsm. Other than very minor localised variations in areas of high relief, the only significant departures from this specification were over waterbodies.

There are no gaps between strips or other voids apart from water surfaces or features of low infra-red reflectivity. The individual swath density rasters were mosaicked, assigning values from the overlapping swath with the lowest point density.



Density Mosaic for Northland Region

4.2 Classification Accuracy

The data supplied meets the minimum of Level 2 Automated and Semi-Automated Classification as per project brief. Classification accuracy is not programmatically tested by the automated processes developed by RPS, given the inherent variability of this metric, so manual review of the dataset is the only testing methodology.

It is important to note that while this data was classified to Level 2 as a part of this project, the option remains for further classification of the dataset to allow for additional uses at a later date by NRC.

4.3 Aerial Imagery Accuracy Statement

Imagery accuracy is verified as a subset of LiDAR accuracy. As photographic control is not explicitly established as a part of LiDAR capture, any analysis of the accuracy of aerial photography is a function of the level of inaccuracy present within the LiDAR data. As the imagery cannot be categorically determined as being either more or less accurate than the LiDAR capture, accuracies can only be given in broad terms. For

a project at this density of LiDAR capture, the stated accuracy of the aerial photography is +/- 100cm horizontally. This is verified by a comparison to identifiable features within both the LiDAR and aerial photography, including road edges and building eaves.

4.4 Ground Survey Data

Ground survey data was collected by Opus (now WSP) surveyors to collect information for measuring the fundamental accuracy of the LiDAR.

Ground Survey Locations (GSLs) were measured across the project areas to allow assessment of the fundamental accuracy.

4.4.1 Accuracy Assessment

Residual errors (dz) were calculated as the difference between the height of fundamental check points (Known Z) and the interpolated LiDAR ground surfaces using Terrascan software. Ellipsoidal Heights were used for all the comparisons. The LiDAR point cloud and derived products were not adjusted to the control.

The Fundamental Vertical and Horizontal Accuracy Reports were generated from the Terrascan residual error report for the entire AOI and is supplied as a Microsoft Excel spreadsheet and a text file.

A complete listing of check points and errors are given in the files: Northland Vertical Accuracy Report.txt.

4.4.2 Accuracy Summary Table

The below tables contain a summary of the accuracy assessment for the entire region

Northland Region LiDAR capture	
Average dz	+0.025
Minimum dz	-0.249
Maximum dz	+0.361
Average magnitude	0.049
Root mean square	0.062
Std deviation	0.056

5 CONDITIONS OF SUPPLY

RPS Australia East Pty Ltd has captured and supplied LiDAR data at the request of NRC.

The data is offered free from defect and in conformance to the client specifications applied and agreed at the time of offer. Data accuracy is as stated and is not to be used beyond its intended scope of capability and as limited by the specifications and reported accuracy findings stipulated within this document.

RPS imposes no restrictions to Intellectual Property rights over the supplied deliverables. NRC is free to use the data as required.