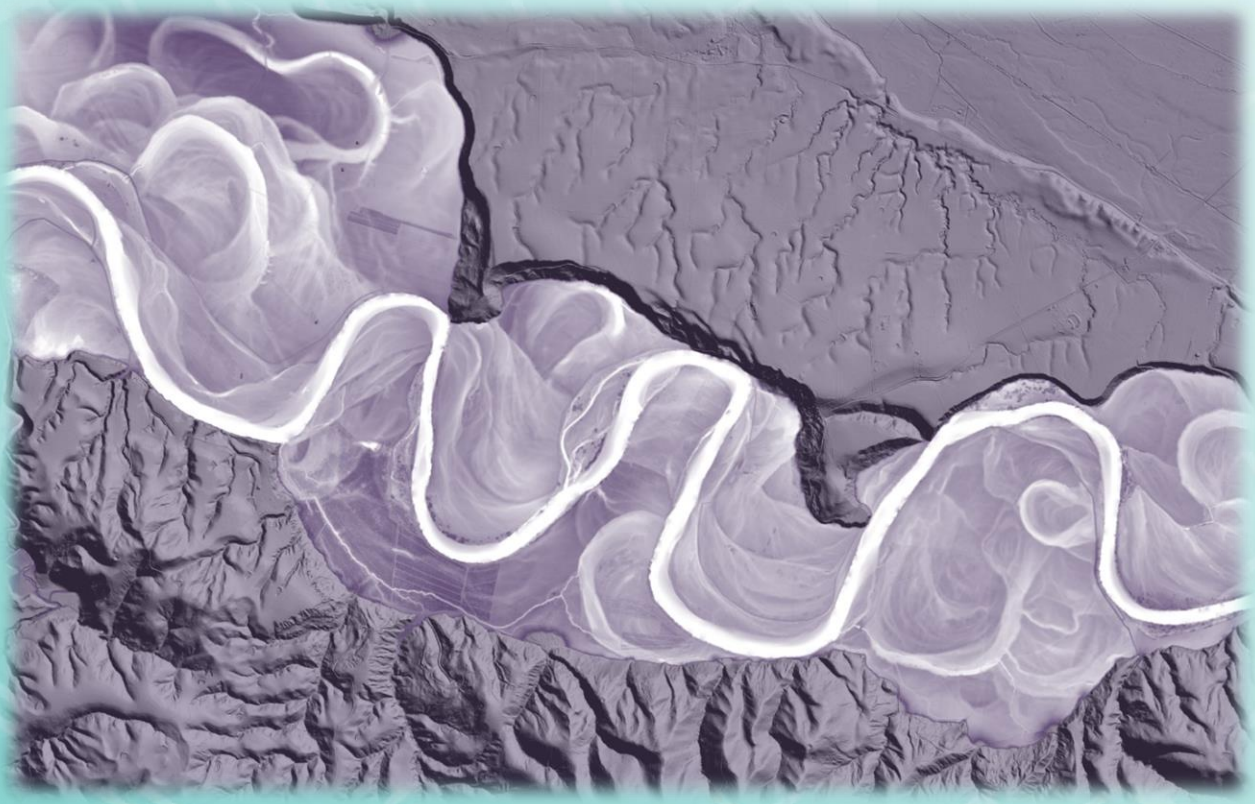
Toitū Te Whenua
Land Information
New Zealand

New Zealand National Aerial LiDAR Base Specification

Toitū Te Whenua Land Information New Zealand

Objective ID: A5038563



Version 1.2

10 October 2022

Table of Contents

Version History **4**

Abbreviations **5**

Foreword **6**

Purpose and Summary 6

Background 6

Acknowledgements 6

References **7**

1 Scope **8**

1.1 Mandatory Deliverables 8

1.2 Accuracy and Pulse Density 9

2 Intended Use of Specification **9**

3 Copyright and Creative Commons **10**

4 Exceptions to Requirements **10**

5 Collection **10**

5.1 Collection Area 10

5.2 Quality Level 10

5.3 Multiple Discrete Returns 11

5.4 Intensity Values 11

5.5 Data Voids 12

5.6 Collection Conditions 12

6 Data Processing and Handling **13**

6.1 The ASPRS LAS File Format 13

6.2 Time Stamp of Navigational Data 13

6.3 Datums and Coordinate Reference System 13

6.4 Positional Accuracy Validation 13

6.4.1 Relative Vertical Accuracy 13

6.4.2 Check Sites 14

6.4.3 Local Accuracy 15

6.5 Use of the LAS Withheld Flag 16

6.6 Use of the Overlap Flag 16

6.7 Point Classification 16

6.8 Classification Accuracy 18

6.9 Classification Consistency 18

7 Hydro-Flattening 19

8 Deliverables 22

8.1 Reporting and metadata 22

8.1.1 Project Reports 22

8.1.2 Extents 23

8.1.3 Flight Lines 23

8.2 Classified Point Cloud Tiles 23

8.3 Elevation Models 24

8.3.1 Bare-Earth Digital Elevation Model (DEM) 25

8.3.2 Digital Surface Model (DSM) 25

8.4 Breaklines 26

8.5 Backed up Project Source Data 26

9 Tiles 26

9.1 Tiling and Delivery 26

9.2 File Naming 27

Version History

Version	Changes applied
1.0 December 2016	Original specification produced by technical working group
1.1 June 2018	Reference to version 3.0 removed from Copyright and Creative Commons section
1.1a June 2021	Fixed minor errors and added clarifications.
1.2 September 2022	Increased minimum pulse density to 4 Made LAS v1.4 mandatory (v1.2/1.3 are no longer acceptable) Added requirements that obvious artefacts are removed from DEM/DSM Added requirement for bridge classification in the point cloud Clarified expectation for bridge removal in the DEM Clarified the use of Overlap flag and removed reference to Overage Added GeoPackage as an acceptable format for vector deliverables Added 1:500 tiling option for point cloud of high-density datasets Removed section/requirement on GNSS data delivery Reworded accuracy description in terms of RMSE Fixed minor errors and added minor clarifications

Abbreviations

For the purposes of this specification, the following abbreviations are used.

Abbreviation	Meaning
3D	three-dimensional
ANPD	aggregate nominal pulse density
ASPRS	American Society for Photogrammetry and Remote Sensing
DEM	digital elevation model
DSM	digital surface model
DTM	digital terrain model
GIS	geographic information system
GNSS	global navigation satellite system
GPS	global positioning system
HA	horizontal accuracy
LAS	LAS file format (.las)
LAZ	compressed LAS format (.laz)
LINZ	Toitū Te Whenua Land Information New Zealand
LiDAR	light detection and ranging
NVA	non-vegetated vertical accuracy
PDRF	point data record format
RMSDz	root mean square difference in the z direction (elevation)
RMSE	root mean square error

Foreword

Purpose and Summary

This specification provides a foundation for New Zealand public sector airborne linear mode light detection and ranging (LiDAR) data procurement. It defines a consistent set of minimum products to ensure compatibility across projects and regions. Using this specification and robust QC checks in procurement will ensure that consistent and high quality LiDAR point cloud data and digital elevation models (DEMs) are delivered. Data captured under this specification will contribute to the National Elevation Model consisting of a bare earth DEM, a digital surface model (DSM), and the corresponding classified point cloud.

Background

The 1.0 version of this specification was based on the US Geological Survey *LiDAR Base Specification* (Reference 1) and the Intergovernmental Committee on Surveying and Mapping (ICSM) *LiDAR Acquisition Specifications and Tender Template* (Reference 2). It was developed for use primarily by the New Zealand public sector in support of the National Elevation Programme by a Technical Working Group representing local government, central government, Crown Research Institutes, LiDAR data providers and industry.

This aim of developing this specification was to ensure that when public sector organisations commission LiDAR, the data gathered will meet minimum requirements which will allow Toitū Te Whenua Land Information New Zealand (LINZ) to host consistent data and provide on-line access.

Revisions to this specification are managed by LINZ. Feedback and suggestion for changes to future versions may be provided at any time to elevation@linz.govt.nz. Material changes are subject to external stakeholder consultation and review.

Acknowledgements

LINZ would like to thank all the councils, suppliers, and other stakeholders that provided consultation feedback that has contributed to this version 1.2 update as well as to the previous versions. Their time and effort ensure this national specification remains fit for purpose.

References

1. LiDAR Base Specification version 1.2, United States Geological Survey, November 2014
2. LiDAR Acquisition Specifications and Tender Template New Zealand Version 1.0, Intergovernmental Committee on Surveying and Mapping, September 2011
3. Standard for the Geospatial Accuracy Framework – LINZS25005, Toitū Te Whenua Land Information New Zealand, September 2009
4. LAS Specification 1.4 – R15, American Society for Photogrammetry and Remote Sensing, July 2019
5. Standard for New Zealand Geodetic Datum 2000 - LINZS25000, Toitū Te Whenua Land Information New Zealand, November 2007
6. LINZS25009: Standard for New Zealand Vertical Datum 2016 - LINZS25009, Toitū Te Whenua Land Information New Zealand, June 2016
7. Standard for New Zealand Geodetic Datum 2000 Projections: Version 2 - LINZS25002, Toitū Te Whenua Land Information New Zealand, July 2008
8. Positional Accuracy Standards for Digital Geospatial Data, American Society for Photogrammetry and Remote Sensing, 2014

1 Scope

1.1 Mandatory Deliverables

The following deliverables are required for the National Elevation Programme in standard specified formats as detailed in Section 8 - Deliverables:

(a) 1m gridded bare earth digital elevation model (DEM) and digital surface model (DSM) elevation models (in New Zealand Transverse Mercator 2000 (NZTM2000) projection and New Zealand Vertical Datum 2016 (NZVD2016)).

(b) Classified point cloud (.las file format (LAS v1.4), in NZTM2000 and NZVD2016).

(c) Breaklines for hydro-flattened features (GeoPackage or Esri shapefile format, in NZTM2000).

(d) Flightlines (GeoPackage or Esri shapefile format, in NZTM2000).

(e) Project reports.

(f) Project extent (GeoPackage or Esri shapefile format, in NZTM2000).

(g) Project tile index (GeoPackage or Esri shapefile format, in NZTM2000).

Buyers may wish to include additional requirements and deliverables in their contracts, such as:

- Increased pulsed density
- Additional classifications such as vegetation, buildings, and roads
- Concurrent imagery
- RGB colourised point clouds
- Contours
- Higher resolution DEM/DSM
- River flow collection restriction
- Tidal collection restrictions
- Bathymetric lidar
- Treatment of DEM generation in specific situations such as when dense low crop prevents reliable ground points

1.2 Accuracy and Pulse Density

The minimum accuracy and pulse density required for the National Elevation Programme are:

(a) Vertical Accuracy (95%) ≤20 cm.

(b) Horizontal Accuracy (95%) ≤100 cm.

(c) Pulse density ≥ 4 pls/m^2.

A buyer may specify more stringent criteria than the minimum identified in this specification.

Accuracy

Accuracy, as used in this specification, refers to local accuracy and is the uncertainty of the bare-earth point cloud and DEM relative to 4th order or better control. See Standard for the Geospatial Accuracy Framework (Reference 3) for accuracy related definitions.

95% confidence and Root Mean Squared Error

The 95% confidence requirements used in this specification are 1.96 times the root mean square error (RMSE). RMSE is the square root of the average of the set of squared differences between dataset coordinate values and coordinate values from an independent source of higher accuracy for identical points. 1.96 times the RMSE is used to estimate the local accuracy where accepted values are known (e.g. check sites).

2 Intended Use of Specification

This specification is applicable to LiDAR data and deliverables to be used by the National Elevation Programme. It is a requirement for data collection supported with financial or in-kind contributions for the National Elevation Programme. In the case of a phased supply of survey blocks that make up a larger overall survey, this specification applies to each survey block delivery.

The National Elevation Programme is a New Zealand partnership programme managed by LINZ which seeks to maximise the amount of LiDAR data available for re-use. LiDAR may be commissioned by LINZ or other buyers including other central government agencies, local councils, and private sector businesses.

This specification applies to traditional linear mode airborne LiDAR data capture and may not be fully applicable to other technologies.

3 Copyright and Creative Commons

The buyer requires unrestricted copyright to all delivered data and reports, allowing it to release data for widespread re-use with a Creative Commons license (CC BY) with attribution to the buyer in line with the New Zealand Government Open Access Licensing framework (NZGOAL). This specification places no restrictions on the rights of the data provider to resell data or derivative products.

4 Exceptions to Requirements

Any exceptions to these requirements are understood to be by the buyer with agreement of those contributing funding or in-kind support to the applicable dataset. This includes LINZ if it is hosting the data.

Vendors and buyers are encouraged to contact LINZ to discuss any proposed exceptions to this specification. This includes technical alternatives that may enhance the value of the proposed services. In the event of conflict, the relevant procurement contract takes precedence over this specification.

This specification sets the minimum requirements for the National Elevation Programme. Additional deliverables and more stringent criteria may be added by the buyer in their contracts.

5 Collection

5.1 Collection Area

The project extent specified by the buyer must be adequately buffered to avoid edge effects and safeguard against missing data.

5.2 Quality Level

The minimum acceptable point cloud quality level is per Table 1. Individual procurements may require better accuracy and greater pulse density. The buyer may also specify additional requirements such as scan angles, swath overlap, and laser footprint depending on end user applications.

Table 1 – Minimum Point Cloud Quality Level

Criterium	Requirement
Non-vegetated Vertical Accuracy (95%)	≤20 cm
Horizontal Accuracy (95%)	≤100 cm
Aggregate Nominal Pulse Density (ANPD)	≥ 4pls/m^2

Pulse

A pulse of laser light emitted from the LiDAR instrument.

Point/return

A discrete point measured from the returning pulse to the LiDAR instrument. In vegetated areas there are often multiple points/returns per pulse.

Aggregate nominal pulse density (ANPD)

The total density of pulses (not points) recorded by the LiDAR instrument per specified unit area resulting from the aggregate of all collections such as overlap or multiple passes. ANPD refers to the typical pulse density delivered based on the project mission planning.

5.3 Multiple Discrete Returns

Collecting and delivering discrete returns (points) from the ground and surface features such as shrubs, buildings, and trees is required. The LiDAR system must be capable of recording at least three returns per pulse.

5.4 Intensity Values

Intensity or reflectance values are required for each discrete return, normalised to 16-bit by multiplying the value by 65,536 divided by the intensity dynamic range of the sensor per LAS v1.4 (Reference 4).

5.5 Data Voids

Data voids are gaps in the point cloud first return coverage, caused by problems including terrain/surface feature obstruction, instrumentation failure, processing anomalies, surface non-reflectance and improper survey planning.

Data voids greater than or equal to 16/ANPD measured using first returns only are not acceptable (example: if ANPD is 4pls/m^2, then the maximum allowable data void is 4 m^2), except in the following circumstances:

(a) Where the data void is caused by water bodies.

(b) Where the data void is caused by areas of low near infrared (NIR) reflectivity, such as asphalt or composition roofing.

(c) Where the line of sight from the sensor to the surface is in the shadow of buildings, structures, vegetation, and terrain features (as expected after accounting for the buyer's requirements and the survey planning that formed the basis for flying altitudes, scan angles, overlap and other factors).

The buyer may allow lower passing thresholds for this requirement in areas where larger data voids are deemed acceptable and do not compromise the quality of the dataset.

5.6 Collection Conditions

LiDAR data must be collected when the following conditions are met:

(a) Atmospheric conditions must be free of cloud, fog, heavy smoke and haze between the aircraft and ground during all collection operations.

(b) Ground conditions must be free of snow (except for permanent snowfield/glaciers).

(c) Ground conditions must be free of extensive flooding or any other type of inundation. Floodplain/wetland data must be captured during times of base flow.

(d) Surveys of the Coastal Marine Area must be flown within three hours either side of low tide to minimise the effect of standing water or wave action unless other bounds are provided by the buyer.

The buyer may waive these requirements on a case-by-case basis.

6 Data Processing and Handling

6.1 The ASPRS LAS File Format

Point deliverables are required to be fully compliant with the LAS Specification Version 1.4, American Society for Photogrammetry and Remote Sensing (ASPRS) (Reference 4) using Point Data Record Format 6, 7, or 8 (referred to as LAS v1.4). If waveform data is required by the buyer, the buyer will advise on the delivery format.

6.2 Time Stamp of Navigational Data

Each GNSS aircraft positional measurement must be time stamped using Adjusted GPS Time (Standard [satellite] GPS time minus $1*10^9$), at a precision sufficient to allow a unique timestamp for each LiDAR pulse.

6.3 Datums and Coordinate Reference System

The required datum for latitude, longitude, and ellipsoid heights is the New Zealand Geodetic Datum 2000 (NZGD2000) (Reference 5).

The required vertical datum for normal-orthometric heights is NZVD2016 (Reference 6). If a local vertical datum is requested by the buyer, then the relevant deliverables in this specification shall be supplied in both the local datum and NZVD2016.

Projected data products are to be delivered in NZTM2000 projection (Reference 7) with NZVD2016 normal-orthometric heights.

6.4 Positional Accuracy Validation

The vendor is expected to apply best practice in assessing the project accuracy and achieving compliance with this specification.

Before classifying and developing derivative products from the point cloud, the relative vertical, local vertical and horizontal accuracies of the point cloud must be verified.

The vendor must deliver a detailed report of the validation processes used.

6.4.1 Relative Vertical Accuracy

The relative vertical accuracy refers to the internal geometric quality of a LiDAR dataset, without regard to surveyed ground control. The minimum acceptable relative vertical accuracy needed to support the national minimum point cloud requirements (in Table 1 above) is included in Table 2.

Individual procurement contracts may require greater local vertical accuracy. In these cases, the vendor is expected to ensure the relative vertical accuracy is sufficient.

Table 2 – Swath relative vertical accuracy requirements

Criterium	Requirement
Smooth surface repeatability (intraswath, maximum)	≤6 cm
Swath overlap consistency (interswath, root mean square difference in the z direction (RMSDz))	≤8 cm
Swath overlap consistency (interswath, maximum)	≤16 cm

Smooth surface repeatability

A measure of variations documented on a surface that would be expected to be flat and without variation.

Overlap consistency

A measure of geometric alignment of two overlapping swaths. The principles used with swaths can be applied to overlapping flights and projects. Overlap consistency is the fundamental measure of the quality of the calibration or boresight adjustment of the data from each flight. This is of particular importance as the match between the swaths of a single flight is a strong indicator of the overall geometric quality of the data and establishes the quality and accuracy limits of all downstream data and products.

6.4.2 Check Sites

A check site is a surveyed array of points used to estimate the positional accuracy of a LiDAR dataset against an independent source of greater accuracy. Control points used in the calibration process for data acquisition must not be used as check sites.

Check sites must be an independent set of points used for the sole purpose of assessing the vertical and horizontal accuracy of the project. Check sites may not be used for the calibration of data without approval from LINZ and the buyer.

Check sites must be:

(a) uniformly distributed across the project area; and

(b) surveyed to better than +/-5cm (95%) vertical and horizontal local accuracy relative to 4th Order or better control.

Where feasible, approximately half of the check sites should include features that can be used for horizontal accuracy assessment.

Table 3 provides the required number of check sites for vertical accuracy assessment as a function of the areal extent of the project, based on the recommendation in the ASPRS *Positional Accuracy Standards for Digital Geospatial Data* (Reference 8).

Table 3 – Required number of check sites based on area

Project area	Number of static 3D check sites in non-vegetated vertical accuracy (NVA) assessment
<100 km^2	As agreed by buyer and vendor
100 to 750 km^2	4 + 1 per additional 40 km^2 over 100 km^2
750 to 2500 km^2	20+5 per additional 250 km^2 over 750 km^2
> 2500 km^2	55+3 per additional 500 km^2 over 2500 km^2

The vendor is expected to apply best practice selecting and surveying check sites.

The vendor must agree check site details including locations, array sizes and surface type with the buyer.

6.4.3 Local Accuracy

The vendor is expected to apply best practice in assessing the project accuracy. Two local accuracy (Reference 3) values must be assessed and reported:

(a) Non-vegetated Vertical Accuracy (NVA); and

(b) Horizontal Accuracy (HA) for the point cloud.

The minimum NVA and HA for the point cloud is the Vertical and Horizontal Accuracies in Table 1 unless a higher level of accuracy is specified by the buyer.

The NVA for the point cloud is assessed by comparing NZVD2016 elevations for check sites surveyed in clear, open, non-vegetated areas (which produce only single LiDAR returns) to the corresponding single return LiDAR point cloud.

The method for assessing HA must be documented in the project reporting.

If the unclassified point cloud does not comply with the required NVA or HA at any check site, it must be investigated, reported, and discussed with the buyer before further classification and processing is carried out.

Options to consider include a re-survey of the check site if it is suspect, verification of the control points used for the check site and LiDAR survey, or a repeat LIDAR survey for the local area if this is determined to be the cause of significant non-compliance.

6.5 Use of the LAS Withheld Flag

Outliers, noise points, geometrically unreliable points near the extreme edge of the swath, aerosol backscatter, laser multipath, airborne objects, sensor anomalies, and other points that cannot be reasonably interpreted as valid surface returns or the vendor deems unusable must be identified using the Withheld flag (as defined per Reference 4) and not deleted.

All data collected must be delivered in the classified point cloud. The use of the Withheld flag ensures that the buyer receives all data collected (rather than the vendor deleting the points they consider "unusable"), while allowing the vendor to apply their best judgement in what to use for further classification. Withheld points are to be included in the classified point cloud delivery. Any deletion of data prior to delivery requires buyer approval.

6.6 Use of the Overlap Flag

Identifying overlap points is not required. However, if overlap points are explicitly identified, they must be identified using the Overlap flag as defined per Reference 4, not a classification number. Points flagged as overlap must still be delivered in the classified point cloud, and they must be classified per the project classification requirements unless also flagged as Withheld. This ensures classification of all points that are not flagged as Withheld.

6.7 Point Classification

The minimum classification scheme required for LiDAR point clouds is listed in Table 4. Additional classes may be required for specific projects.

A point classification scheme must meet the following requirements:

(a) All points not identified as Withheld must be processed for classification.

(b) No points in the classified LAS point cloud deliverable can remain assigned to Class 0 (created but not processed for classification) unless these points are flagged as Withheld.

(c) Overlap points must be identified using the Overlap flag, as defined in Reference 4.

Table 4 – LAS point cloud classification scheme

Code	Description
1	**Processed, but unclassified (required)**
2	**Ground (required)**
3	Low vegetation (<2m suggested)
4	Medium vegetation
5	High vegetation (>8m suggested)
6	Building
7	**Low noise (required)**
9	**Water (required)**
11	Road surface
17	**Bridge deck (required)***
18	**High noise (required)**

Items in bold are minimum requirements. If other classifications are required by the buyer as part of their contract, or assigned by the vendor during processing, they must conform with the Reference 4 classification scheme. The most common additional classifications are included in Table 4 for clarity.

* At a minimum, bridges identified in the LINZ Topo50 Bridge Centrelines layer (LINZ Data Service layer 106965) must be classified. The buyer may require addition bridges to be included as part of their contract.

6.8 Classification Accuracy

It is expected that as a minimum automated classification will be used with further manual ground surface improvement to incorporate hydro-flattening and clean up poor automated classification results such as vegetation incorrectly classified as ground or ground points classified as vegetation. Classification of returns shall be as complete as is feasible and without avoidable return misclassification.

Following classification processing:

(a) no non-withheld points can remain in Class '0'; and

(b) within any 1km x 1km area, no more than two percent of non-withheld ground points can have demonstrable errors in the classification value.

In most circumstances, detailed visual inspections of the DEM, hillshade, individual classified scan line profiles, and use of high-quality reference imagery will be sufficient to independently demonstrate if classification standards have been achieved for the specified classes. The vendor must report on classification methods used and on how classification accuracy is checked and assured.

The buyer may relax these requirements to accommodate collections in areas where classification is particularly difficult.

6.9 Classification Consistency

Point classification must be consistent across the entire project. Noticeable variations in the character, texture, or quality of the classification between tiles, swaths, flights, or other unnatural divisions are grounds for rejection.

7 Hydro-Flattening

Hydro-flattening

The process of creating a LiDAR-derived DEM in which water surfaces appear as they would in traditional topographic DEMs created from photogrammetric digital terrain models (DTMs).

The use of breaklines is the predominant method used for hydro-flattening. The National Elevation Programme does not require that breaklines be used for flattening but does require the delivery of breaklines for all flattened water bodies and any other breaklines developed for each project.

Hydro-flattening will be performed in the local vertical datum specified by the buyer. If no datum is identified, hydro-flattening must be performed in NZVD2016.

Converting data between local vertical datums and NZVD2016 is not simply achieved by applying a fixed offset value. As a result, 'tilting' of hydro-flattened features may be present in data represented in a vertical datum that has not been used for the hydro-flattening. This is acceptable.

Vendors are expected to use professional judgement in how to best display the hydro-flattened features in other datums. The aim is to provide good cartographic appearance and not introduce errors that are propagated into derivative products such as contours.

Specific requirements that must be met for hydro-flattening are (including the minimum features for which breaklines must be collected and delivered):

(a) Permanent islands 5,000 m^2 or larger must be delineated.

(b) Inland ponds and lakes - water bodies of 10,000 m^2 (1 hectare) or greater surface area at the time of collection must be flattened.

  (i) Flattened water bodies must present a flat and level water surface (a single elevation for every bank vertex defining the water body's perimeter, in the vertical datum used for hydro-flattening).

  (ii) The entire water-surface edge must be at or below the immediately surrounding terrain (bottom of bank level or just above water strike).

  (iii) Long impoundments such as reservoirs, inlets, and fjords, whose water-surface elevations decrease with downstream travel must be treated as streams or rivers.

(c) Inland streams and rivers of ≥30m nominal width (width of water flow in a single channel at time of capture) must be flattened. In most cases braided rivers will not be flattened and shingle beds treated as ground:

(i) Streams or rivers whose width varies above and below 30 m must not be broken into multiple segments; data producers will use their professional cartographic judgment to determine when a stream or river has attained a nominal 30m width.

(ii) Flattened streams and rivers must present a flat and level water surface bank-to-bank (perpendicular to the apparent flow centerline).

(iii) Flattened streams and rivers must present a gradient downhill water surface, following the immediately surrounding terrain.

(iv) In cases of sharp turns of rapidly moving water, where the natural water surface is notably not level bank-to-bank, the water surface must be represented as it exists while maintaining an aesthetic cartographic appearance.

(v) The entire water-surface edge must be at or below the immediately surrounding terrain.

(vi) Stream channels must break at culvert locations leaving the roadway over the culvert intact.

(vii) Streams must be continuous at bridge locations.

(viii) When the identification of a structure as a bridge or culvert cannot be made definitively, the feature must be regarded as a culvert.

(d) Non-tidal boundary waters:

(i) Boundary waters, regardless of size, must be represented only as an edge or edges within the project; collection does not include the opposite shore.

(ii) The entire water-surface edge must be at or below the immediately surrounding terrain.

(iii) The water-surface elevation must be consistent throughout the project.

(iv) The water surface must be flat and level, as appropriate for the type of water body (level for lakes, a gradient for streams and rivers).

(v) Any unusual changes in the water-surface elevation during the course of the collection (such as changes in upstream dam discharge) must be documented in the project metadata.

(vi) In the event of an unusual change in water-surface elevation, the water body shall be handled as described in 'Tidal Waters' below.

(e) Tidal waters:

Tidal water bodies are defined as any water body that is affected by tidal or other variations in water level, including oceans, seas, gulfs, bays, inlets, estuaries, creeks, salt marshes, lower reaches of rivers/streams, and large lakes.

Water level variations during data collection or between different data collections can result in lateral and vertical discontinuities along shorelines.

LiDAR ground points must not be removed for the sake of adjusting a shoreline inland to match another shoreline. Likewise, adjusting a shoreline outland can create an equally unacceptable area of unmeasured land in the DEM.

In addition to meeting the requirements for inland water bodies listed in (b) Inland ponds and lakes, and (c) Inland streams and rivers above, the treatment of tidal water bodies must also meet the following requirements:

(i) Within each water body, the water surface must be flat and level for each different water-surface elevation.

(ii) Vertical discontinuities within a water body resulting from tidal or other variations in water level during the collection are considered normal and must be retained in the final DEM.

(iii) Horizontal discontinuities along the shoreline of a water body resulting from tidal variations during the collection are considered normal and must be retained in the final DEM.

(iv) Long tidal water bodies that also exhibit down-gradient flow (such as a sound or fjord) can present unusual challenges. Data producers must exercise professional judgment in determining the appropriate approach solution to meet the overall goal of hydro-flattening as described in this section.

8 Deliverables

8.1 Reporting and metadata

8.1.1 Project Reports

Project report(s) must be provided in pdf format and include the following:

(a) A collection report detailing mission planning and flight logs, including dates of collection.

(b) A survey report detailing the collection of all ground control, including the following:

  (i) Control points used to calibrate and process the LiDAR and derivative data.

  (ii) Check sites used to validate the LiDAR point data or any derivative product

  (iii) A map and GIS file (GeoPackage or Esri shapefile format) showing the name and location of each control and check site.

(c) A processing report detailing calibration, classification, and product generation procedures including methodology used for breakline collection, use of breaklines (for example, crest elevation of stopbanks, seawalls, dams), hydro-flattening, manual and automated classification methods used, DEM creation including interpolation method, DSM creation including binning function, and the process for calculating NZTM coordinates.

(d) A QA/QC report, detailing analysis, accuracy assessment and validation of the following:

  (i) Vertical and horizontal local accuracy, including a table of the product data compared to each check site.

  (ii) Point cloud data, including a summary of relative (smooth surface repeatability and overlap consistency), non-vegetated vertical and horizontal local accuracy, and classification accuracy.

  (iii) DEM/DSM, including a summary of checks for artefacts and hydroflattening quality.

  (iv) Other optional deliverables as relevant.

8.1.2 Extents

A geo-referenced spatial representation of the detailed extent of each delivered dataset must be provided to the following requirements:

(a) The extents must be those of the actual LiDAR source or derived product data, exclusive of TIN artefacts or raster void areas.

(b) A union of tile boundaries or minimum bounding rectangles is not acceptable unless these are identical to the dataset extents.

(c) For the point clouds, the boundary line segment can be within four metres of the nearest LiDAR point.

(d) GeoPackage or Esri shapefile format is required.

8.1.3 Flight Lines

Flightlines, as GeoPackage or Esri shapefile format, are required. Each flightline must be assigned a unique File Source ID that is equal to the Point Source ID assigned to each point collected during that flightline.

8.2 Classified Point Cloud Tiles

Delivery of a single classified point cloud is required. Classified point cloud deliverables must include or conform to the following:

(a) Data from all project swaths, returns, and collected points, fully calibrated, adjusted to ground, and classified. Project swaths exclude calibration swaths, crossties, and other swaths not used in product generation.

(b) Provided in the NZTM2000 coordinate system and the NZVD2016 vertical datum. Additional vertical datums may be specified by the buyer.

(c) Fully compliant LAS v1.4, Point Data Record Format 6-8 (all files must have the same PDRF).

(d) Each point includes a Point Source ID linking it to the flightline File Source ID.

(e) Correct and properly formatted geo-reference information (EPSG: 2193 + 7839) as Open Geospatial Consortium (OGC) Well Known Text (WKT) included in all LAS file headers.

(f) File Source ID set to 0 for tiled LAS files.

(g) GPS times recorded as Adjusted GPS Time (Standard [satellite] GPS time minus $1*10^9$), at a precision sufficient to allow a unique timestamp for each LiDAR pulse.

(h) Points are provided in the order in which they were collected.

(i) Height values reported to three decimal places (nearest mm). (While not significant for accuracy, this supports numerical processing and reduces the number of identical values caused by rounding.)

(j) Intensity values normalised to 16-bit by multiplying the value by 65,536 divided by the intensity dynamic range of the sensor per LAS v1.4 (Reference 4).

(k) Classification as required by the buyer (Table 4 at a minimum).

(l) Tiled delivery, without overlap, per the project tiling scheme in Section 9 – Tiles.

(m) Files named per Section 9 – Tiles.

8.3 Elevation Models

Digital Elevation Model (DEM)

A uniformly spaced bare-earth elevation model, devoid of vegetation and man-made structures.

Digital Surface Model (DSM)

A uniformly spaced elevation model that depicts the highest surface, including buildings, vegetation, towers, and other non-noise features.

Delivery of a DEM (bare earth) and DSM (surface) is required. Deliverables must include or conform to the following:

(a) Grid spacing: 1m cell size.

(b) Generated to the limits of the project area.

(c) Raster format: Geotiff (.tif).

(d) Geo-reference information (EPSG 2193) in each raster file.

(e) Tiled delivery without gaps or overlap.

(f) NOT clipped using polylines for land-water boundaries from national databases (for example coastlines, river, or lake boundaries) as these can be inaccurate and subject to continual geomorphic change.

(g) Tiles with no edge artefacts or mismatch, including across blocks if the overall project area is split into multiple delivery blocks. A quilted appearance in the overall surface can be grounds for rejection of the entire deliverable - whether the rejection is caused

by differences in processing quality or character among tiles, swaths, flights, or other unnatural divisions.

(h) Tiles with no visually obvious artefacts (e.g. large spikes and dips) resulting from noise or other errors.

(i) Void areas (for example, areas outside the project area but within the project tiling scheme) coded using "NODATA" value equal to -9999. This value must be identified in the appropriate location within the raster file header.

(j) Constrained with any additional breaklines required by the buyer, such as stopbanks, streams, and narrower rivers.

(k) Provided in the NZTM2000 coordinate system and the NZVD2016 vertical datum. Additional vertical datums may be specified by the buyer.

8.3.1 Bare-Earth Digital Elevation Model (DEM)

The Bare-Earth DEM is the bare earth devoid of vegetation and man-made structures. It must also include or conform to the following:

(a) Based on ground return points in the point cloud. All ground points should be used in areas of low ground strike density such as under dense vegetation.

(b) Visually obvious artefacts (e.g. large spikes and dips, processing block edge offsets) removed.

(c) Hydro-flattening as outlined in Section 7 - Hydro-Flattening.

(d) Bridges removed from the surface, while culverts are treated as ground. At a minimum, bridges identified in the LINZ Topo50 Bridge Centrelines layer (LINZ Data Service layer 106965) must be removed. The bare-earth surface below the bridge shall be a continuous, logical interpolation of the apparent terrain lateral to the bridge deck.

(e) Method for removal of buildings, structures or other ground cover/vegetation and interpolation techniques documented.

8.3.2 Digital Surface Model (DSM)

The DSM is the heights of the top of the highest feature at each grid raster square cell (bin), including ground, vegetation, and man-made structures. The DSM is based on first return points after removal of noise.

8.4 Breaklines

Delivery of breaklines representing all hydro-flattened features in a project is required. Additional breaklines may also be required by the buyer. These are to be delivered as GeoPackage or Esri shapefiles using the NZTM2000 projection.

8.5 Backed up Project Source Data

Raw project source data, such as native format LiDAR files and point cloud swaths, are NOT required for delivery. However, the vendor must hold a copy of all relevant raw project data, for a minimum of five years beyond the final delivery of the project deliverables. The vendor must provide this data, with unrestricted copyright, to the buyer on request. The vendor may charge a reasonable access and distribution charge in such instances.

9 Tiles

9.1 Tiling and Delivery

(a) NZTopo50 subtiles based on NZTM2000 coordinates. The 1-m gridded raster products and point clouds must be delivered at 1:1000 nominal scale (refer to LINZ Data Service layer 104692 - 2,500 720m high x 480m wide subtiles per full NZTopo50 sheet). To avoid very large (>1GB) files, the point cloud (only) may be tiled to a 1:500 nominal scale (refer to LINZ Data Service layer 106965).

(b) The origin of the raster tiles must be placed on a whole metre coordinate value of the southwest corner of each tile (for example, 5429500 mN_17490300mE).

(c) The tiled deliverables must edge-match seamlessly and without gaps.

(d) The tiled deliverables must conform to the project tiling scheme without overlap.

(e) File naming must conform with the naming convention described in section 9.2.

A Tile Index must be provided in GeoPackage or Esri shapefile format. The file name must be included as an attribute in the Tile Index.

9.2 File Naming

The naming convention for point clouds, DEMs, and other tiled products must be in the format *[product]_[sheet]_[year]_[scale]_[tile].[ext]* per the fields detailed in Table 5:

For example: *DEM_BK34_2016_1000_4118.tif*

Table 5 – Tile naming convention

Field	Example	Detail
Product	*DEM*	CL2-Point Cloud Classification Level 2 DEM-Bare Earth Digital Elevation Model DSM-Digital Surface Model DTM-Digital Terrain Model UNC-Unclassified Point Cloud INT-Intensity image CHM – Canopy Height Model IMG-Aerial photography etc
Sheet	*BK34*	LINZ Topo50 identifier (4 characters)
Year	*2016*	Year of survey commencement
Scale	*1000*	Nominal scale of NZTopo50 subtiles
Tile	*4118*	Row number (41), Column number (18) of tile with respect to an upper left origin
ext	*tif*	File extension according to format conventions las laz tif shp etc