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# Beetaloo Basin LiDAR and Imagery

Beetaloo Basin LiDAR and Imagery 2025

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Issued For Use

**Beetaloo Energy**



# Document Control

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# 1. Introduction

Beetaloo Energy contracted Fugro Australia to accurately capture high-density LiDAR point clouds and high-resolution ortho imagery, sufficient to create DEM (Digital Elevation Model), DSM (Digital Surface Model), Canopy Model, Drainage Model, Contours and Imagery.

## 1.1 Document Purpose

This project closure and delivery report provides a summary of the data acquisition, processing and analysis of the data compared to the specifications for the project survey area (see section 1.2.1). This document includes the scope of work, the project specifications, the list of deliverables, and the validation of the deliverables: coverage, relative and absolute accuracy, resolution, file format, file naming convention, statistical analysis, and visual checks. The report concludes with a summary statement.

## 1.2 Report Objectives

This delivery report describes the content of the data supplied for the Beetaloo Energy – Beetaloo Basin LiDAR and Imagery 2025 project and how the specifications have been met.

### 1.2.1 Survey Area

The project extent is shown in Figure 1.1 below.

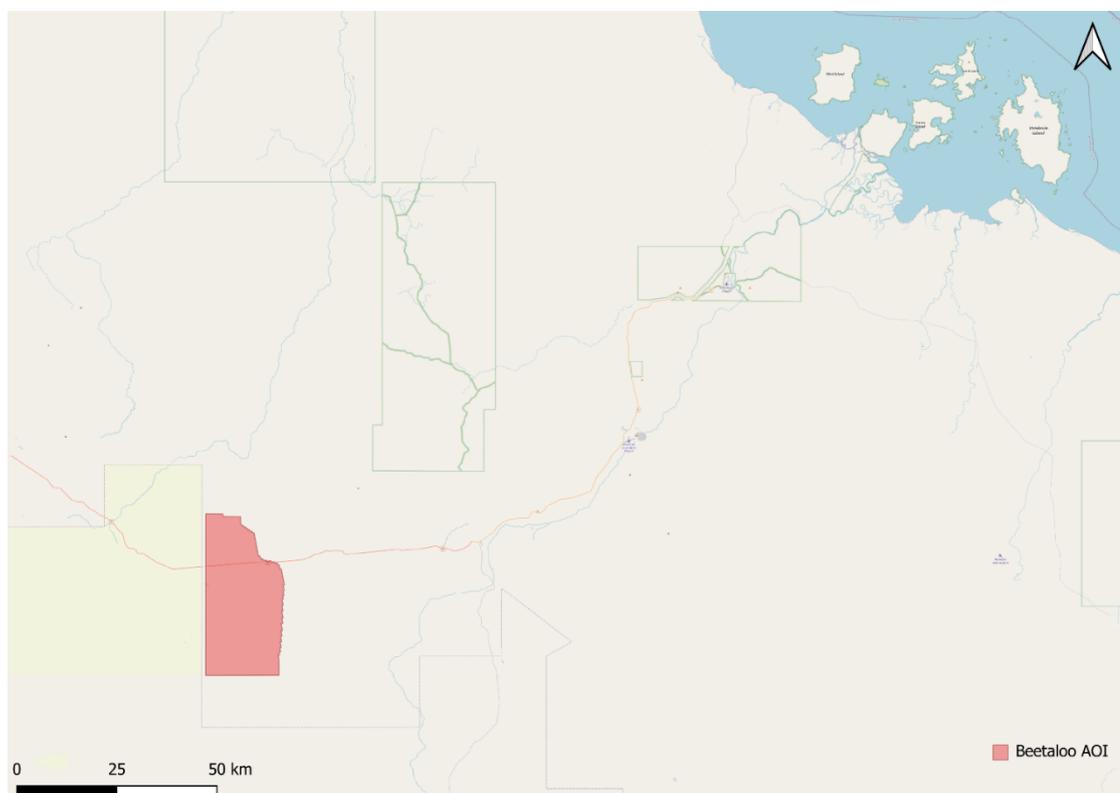


Figure 1.1: Beetaloo Basin survey area extent.

## 1.2.2 Requirements / Standards

The spatial accuracy and resolution requirements are summarised in Table 1.1 below.

Table 1.1: Requirements / Standards

Spatial Accuracy	Vt:	<= +/- 10cm at 68% using client supplied control
	Hz:	<= +/- 30cm at 68% for areas using client supplied control
Geodesy / Datum	Horizontal:	GDA2020 MGA 53
	Vertical:	AHD derived from Ausgeoid 2020
LiDAR Density	Points per m2	16 ppsm
Orthomosaic Imagery	Ground Sampling Distance (GSD)	10cm ~2 -pixel accuracy
Ground Control requirements	Client supplied	

The LiDAR classifications for Beetaloo Energy project are presented in Table 1.2.

Table 1.2: LiDAR Classifications

ID	Description	ICSM Level
1	Default	Level 1
2	Ground	Level 2
3	Low Vegetation (0m-0.3m)	Level 1
4	Medium Vegetation (0.3m-2m)	Level 1
5	High Vegetation (>2m)	Level 1
7	Noise	Level 1

The project deliverables are summarised in Table 1.3 below and conform to the client specifications.

Table 1.3: Project Deliverables

Deliverable	Requirements	Format
<b>Project Execution Plan</b>		
Deliverable 1.	Project Execution Plan	PDF
<b>Classified Point cloud</b>		
Deliverable 2.	Classified coloured point cloud (average 16 point/m2 ground-non ground, vegetation HML covering the project area (class1,2,3,4,5,7) Class 2 level 2 processing for DEM	LAZ 1.4
Deliverable 3.	1m Gridded Digital Elevation Model (DEM)	ESRI GRID ASC tiles & GeoTIFF
Deliverable 4.	0.5m Gridded DEM	ESRI GRID ASC tiles & GeoTIFF
Deliverable 5.	1m Gridded Digital Surface Model (DSM) LiDAR first returns	GeoTIFF
Deliverable 6.	1m Gridded Tree Canopy Height Model (CHM) Vegetation classified LiDAR subtract Ground	GeoTIFF
Deliverable 7.	1m LiDAR Intensity image (LiDAR reflectance value grey scale image)	GeoTIFF
Deliverable 8.	Watershed drainage model	ESRI SHP

	(Automated drainage network generated from DEM)	
Deliverable 9.	Model Key Points, smart filtered DEM (MKP)	ASCII XYZ tiles
<b>Imagery</b>		
Deliverable 10.	10cm RGB Orthomosaic in 1km tiles	GeoTIFF and ECW
Deliverable 11.	Ortho-mosaic imagery 10cm RGB Overall	ECW
<b>Mapping</b>		
Deliverable 12.	0.5m contours	ESRI SHP
Deliverable 13. Optional	Attributed Vegetation Polygons for each tree segmented from the LiDAR point cloud	ESRI SHP
<b>Metadata and Reports</b>		
Deliverable 14.	Metadata Report	PDF
Deliverable 15.	LiDAR scanning equipment calibration report	PDF
Deliverable 16.	All flight trajectories used for the capture of the delivered LiDAR data will be supplied in ESRI Shape files. The shape file tables will include the date of capture, local start time, local end time and which reference station was used for each trajectory.	Shp

### 1.2.3 Planning and Acquisition

The LiDAR and imagery data were planned and flown with the LiDAR Riegl VQ-1560ii-S to achieve a minimum of 16 ppsm with first return single swath and 10cm GSD.

The planning was designed to fit the LiDAR Riegl VQ-1560ii-S into the VH-XGL Piper Navajo, able to fly at a speed of 145kts, required to achieve the point density.

To achieve the operational requirements, the field crew was based in Borroloola, NT.



Figure 1.2: Beetaloo Basin survey area and flightlines.

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## 2. Point Cloud Regular Surfaces and Imagery Validation Report

### 2.1 LiDAR Products

As part of the Beetaloo Basin LiDAR and Imagery project, high-resolution Digital Elevation Models (DEMs), Digital Surface Models (DSMs), Canopy Height Models (CHM), Watershed drainage model and contour datasets were produced using classified LiDAR data. The following sections outline the methodologies employed and present the resulting outputs.

#### 2.1.1 Digital Elevation Model

A high-resolution Digital Elevation Model (DEM) with a 0.5 and 1-meter spatial resolution was created for the Beetaloo basin AOI using classified ground points derived from LiDAR data. Non-ground features were filtered out to ensure accurate terrain representation, and TIN interpolation techniques were applied to generate the elevation surface. The final DEM was exported in GeoTIFF format, preserving geospatial metadata for seamless integration into GIS applications. The final DEM dataset has also been delivered in ESRI ASCII for both 0.5 and 1-meter resolutions.

The DEM coverage achieved for Beetaloo Basin is shown in Figure 2.1 below.

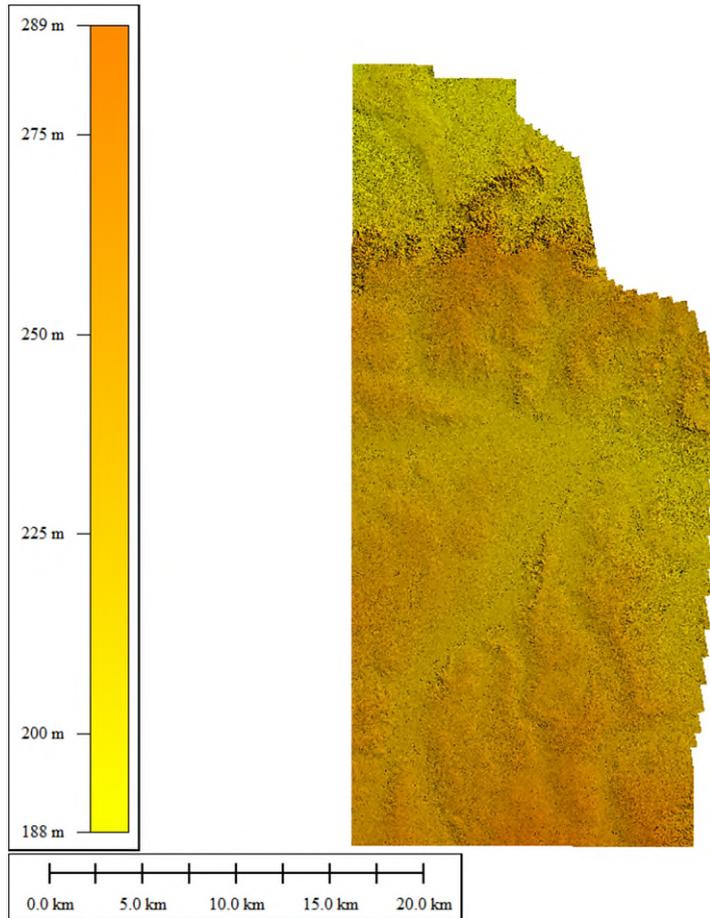


Figure 2.1: Beetaloo Basin DEM Coverage Overall.

### 2.1.2 Digital Surface Model

A high-resolution Digital Surface Model (DSM) with a 1-meter spatial resolution was generated for the Beetaloo basin AOI using LiDAR data that included classified points representing ground, vegetation, buildings, and other man-made features. This comprehensive dataset captures the true surface of the terrain, including all natural and built structures. Interpolation methods such as TIN were used to construct the surface model, and the final DSM was exported in GeoTIFF format to retain accurate geospatial referencing for use in GIS and 3D modelling applications.

The DSM coverage achieved for Beetaloo Basin is shown in Figure 2.2 below.

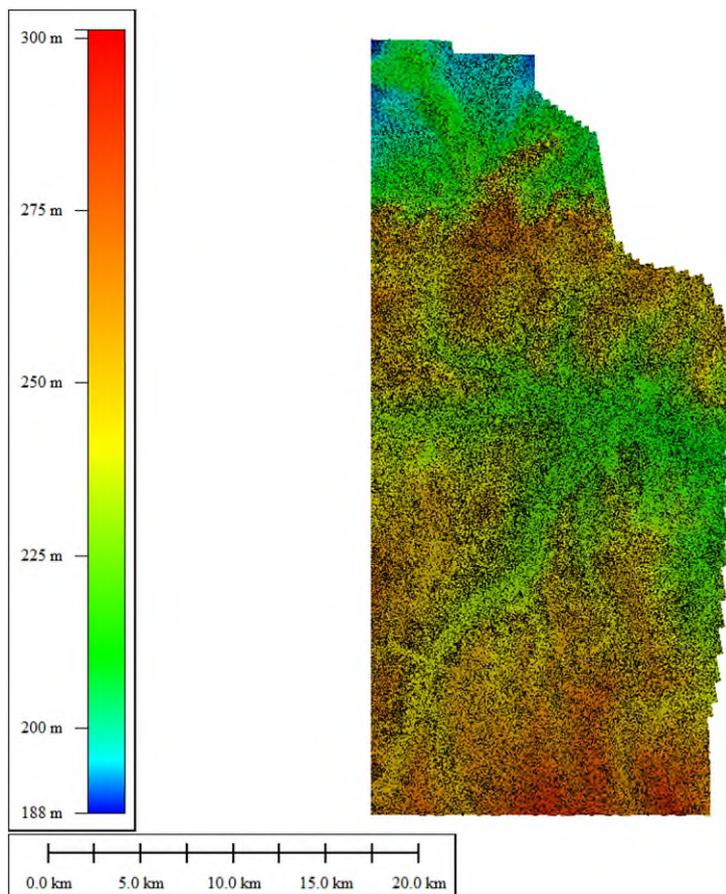


Figure 2.2: Beetaloo Basin DSM Coverage Overall.

### 2.1.3 Canopy Height Model

A high-resolution Canopy Height Model (CHM) with a 1-meter spatial resolution was generated for the Beetaloo basin AOI using LiDAR data containing classified ground and vegetation points. The CHM was derived by subtracting the Digital Elevation Model (DEM) from the Digital Surface Model (DSM), isolating the height of vegetation above ground level. This output provides valuable insights into canopy structure and vegetation distribution. The final CHM was exported in GeoTIFF format to preserve accurate geospatial referencing for integration into GIS and 3D modelling workflows.

The CHM coverage achieved for Beetaloo Basin is shown in Figure 2.3 below.

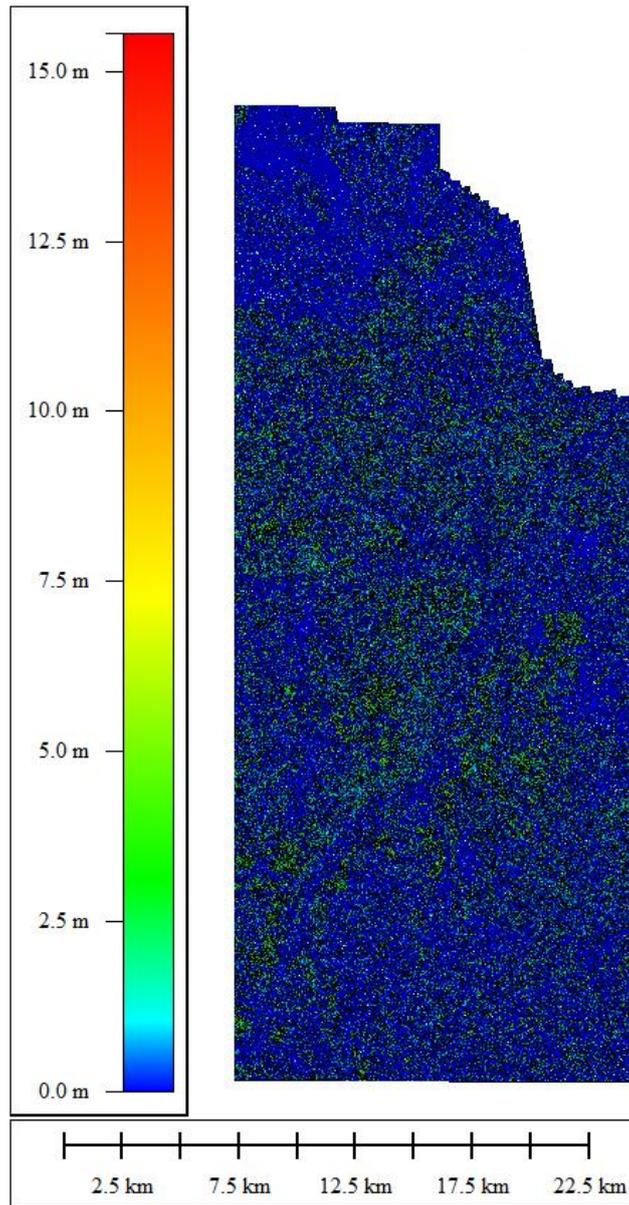


Figure 2.3: Beetaloo Basin CHM Coverage Overall.

### 2.1.4 LiDAR Intensity

A high-resolution LiDAR intensity raster with a 1-meter spatial resolution was produced for the Beetaloo basin AOI using airborne LiDAR returns. Intensity values represent the relative strength of the laser pulse reflected from surfaces, providing insight into material properties, surface reflectivity, and texture. This dataset complements elevation models by enhancing feature discrimination, particularly for vegetation, built structures, and bare ground. The final intensity raster was exported in GeoTIFF format to maintain precise geospatial referencing for integration into GIS platforms and remote sensing analyses.

The intensity coverage achieved for Beetaloo Basin is shown in Figure 2.4 below.



Figure 2.4: Beetaloo Basin Intensity Coverage Overall.

### 2.1.5 Watershed Drainage Model

A watershed drainage model was developed for the Beetaloo basin AOI to delineate hydrological flow paths and catchment boundaries based on terrain data derived from high-resolution LiDAR. Using hydrologically enforced elevation surfaces, flow direction and accumulation algorithms were applied to identify drainage networks and watershed extents. The final output was compiled into a single line shapefile. This geospatial dataset supports hydrological analysis, land management planning, and environmental assessment within GIS platforms.

The watershed drainage model coverage achieved for Beetaloo Basin is shown in Figure 2.5 and Figure 2.6 below.

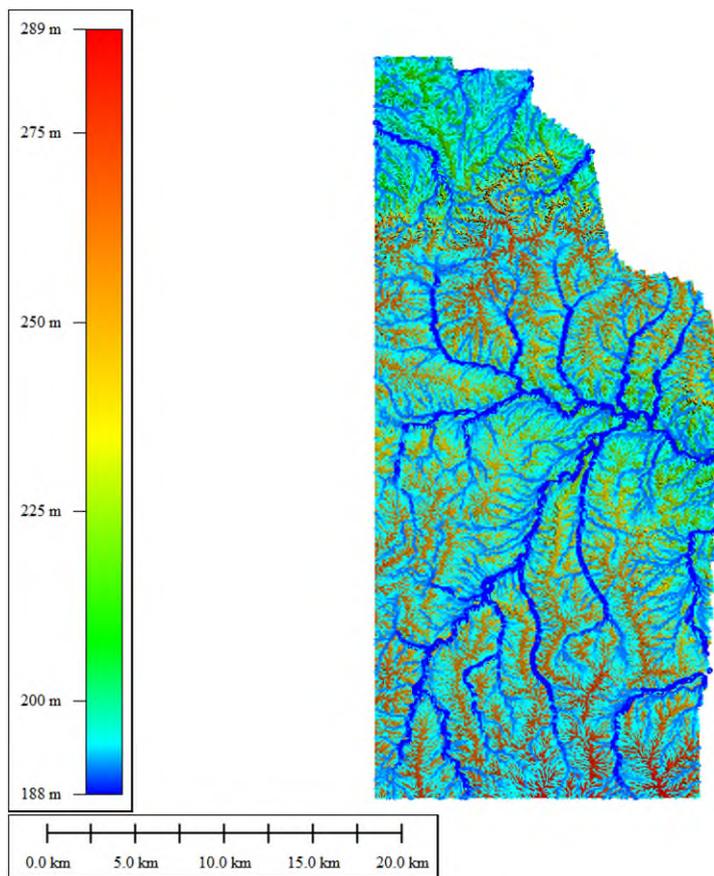


Figure 2.5: Beetaloo Basin Watershed Drainage Model Coverage Overall.

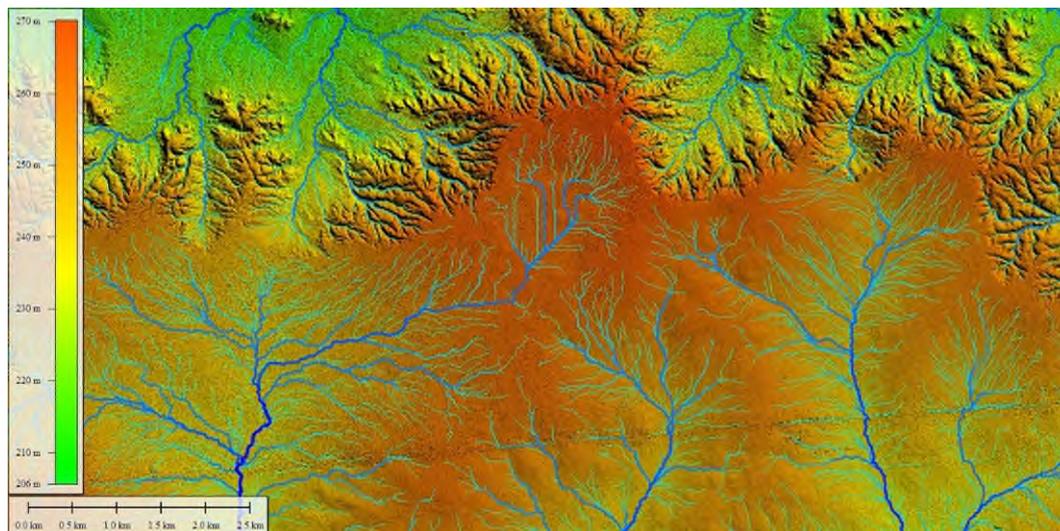


Figure 2.6: Beetaloo Basin Watershed Drainage Model Coverage Overall – Zoomed in.

## 2.1.6 Model Key Points

Model Key Points (MKP) were extracted as a refined subset of Class 2 (ground) returns from the LiDAR dataset for the Beetaloo basin AOI. These points represent critical terrain features that support efficient surface reconstruction and hydrological modelling by reducing data volume while preserving topographic integrity. The MKP dataset was compiled into a single shapefile containing spatially distributed ground control points optimised for elevation modelling and GIS-based analysis.

## 2.1.7 Contours

Contours were generated from the 0.5m resolution Digital Elevation Model (DEM) for the Beetaloo Basin AOI to represent terrain elevation in a visually interpretable format. Using cartographic styling, the contours were derived at consistent intervals to ensure clarity and aesthetic quality, suitable for mapping and analysis. The resulting contour lines accurately reflect the underlying terrain and are optimised for use in GIS applications and topographic visualisations.

The contour coverage achieved for Beetaloo Basin is shown in Figure 2.7 and Figure 2.8 below.

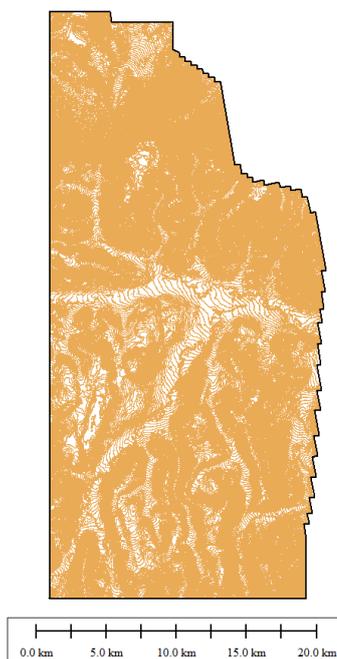


Figure 2.7: Beetaloo Basin Contour Coverage Overall.

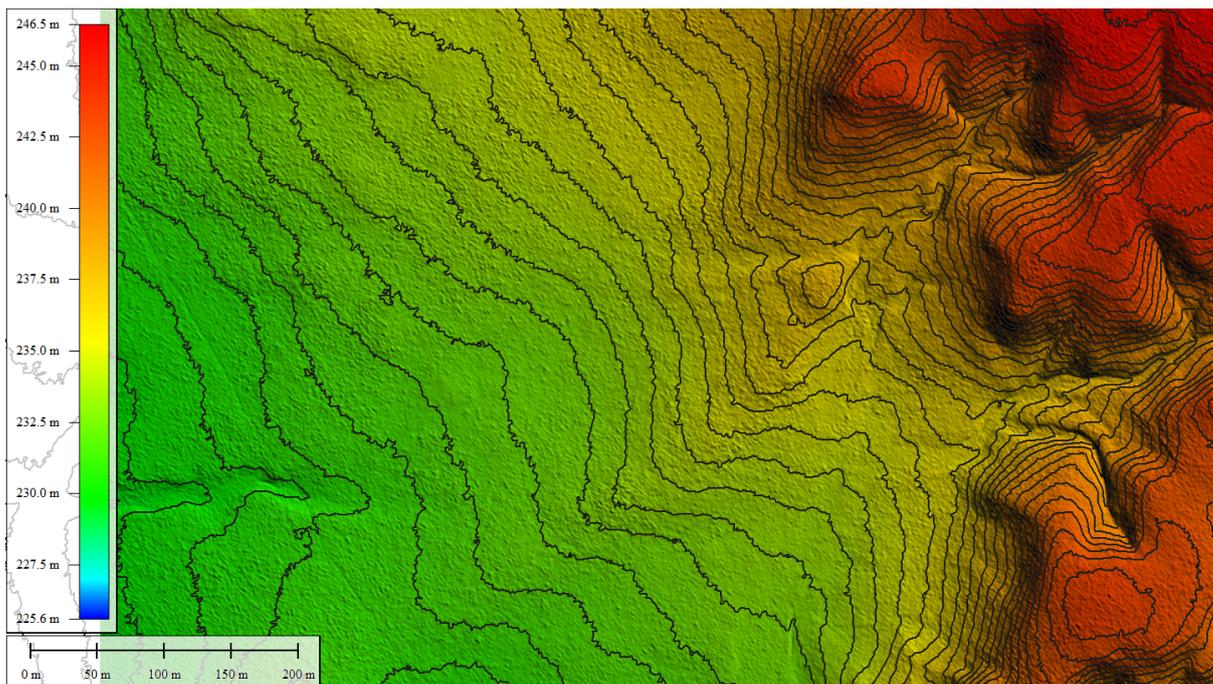


Figure 2.8: Beetaloo Basin Contour Coverage Overall – Zoomed in.

### 2.1.8 Classified LiDAR

A classified LiDAR dataset was delivered for the Beetaloo basin AOI in compressed LAZ 1.4 format, organised into 1×1 km tiles for efficient storage and processing. Each tile contains point cloud data with classification codes and specifications defined in Table 1.2, including ground, vegetation and low noise. This structured dataset supports a wide range of geospatial analyses, from terrain modelling to land cover assessment. The classification schema ensures consistency across the AOI and enables targeted extraction of features for GIS, hydrological modelling, and environmental planning.

The LiDAR coverage achieved for Beetaloo Basin is shown in Figure 2.9.

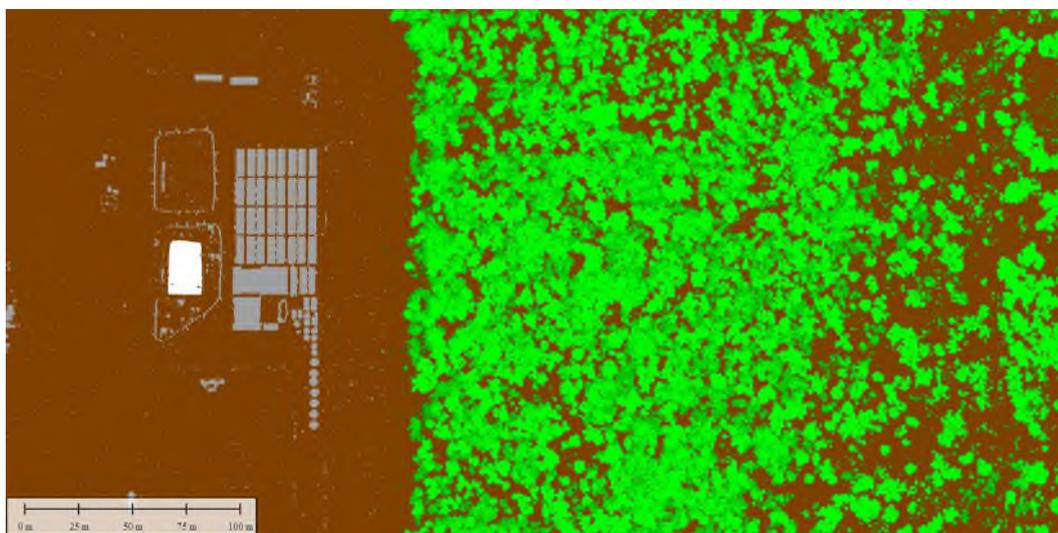


Figure 2.9: Beetaloo Basin LiDAR Coverage – Zoomed in.

## 2.2 Imagery Products

High-resolution RGB ortho imagery was acquired for the Beetaloo Basin AOI with a ground sample distance (GSD) of 10 cm, using area-triangulation and orthometric correction techniques to ensure geometric accuracy. Colour balancing and seamline optimisation processes were applied to enhance visual consistency and image quality across the dataset. The final ortho imagery was delivered in both tiled GeoTIFF format for detailed analysis and an overall ECW mosaic for efficient viewing and distribution in GIS and mapping applications.

The RGB coverage achieved for Beetaloo Basin is shown in Figure 2.10 to Figure 2.12. Infra-red imagery is available for processing as an option if required.



Figure 2.10: Beetaloo Basin RBGI Imagery Overall.



Figure 2.11: Beetaloo Basin RBGI Imagery – Zoomed in.



Figure 2.12: Beetaloo Basin RBGI Imagery – Zoomed in.

## 2.3 Supporting Products

In addition to LiDAR and Imagery products, Fugro have created supporting products and metadata to assist with visualisation and provide further context to the dataset. These include actual trajectory flight line, tile index and ground control locations.

### 2.3.1 Flightline Shapefile

Flightlines were captured for the Beetaloo basin AOI to document the aircraft's trajectory during LiDAR acquisition. Represented as line features in shapefile format, each flightline traces the precise path flown by the sensor platform, providing spatial context for data coverage and acquisition geometry. Temporal attributes within the shapefile record the start

and end times of each flight segment in local time, supporting quality assurance, temporal analysis, and alignment with other datasets.

The flightlines for Beetaloo Basin are shown in Figure 2.13.

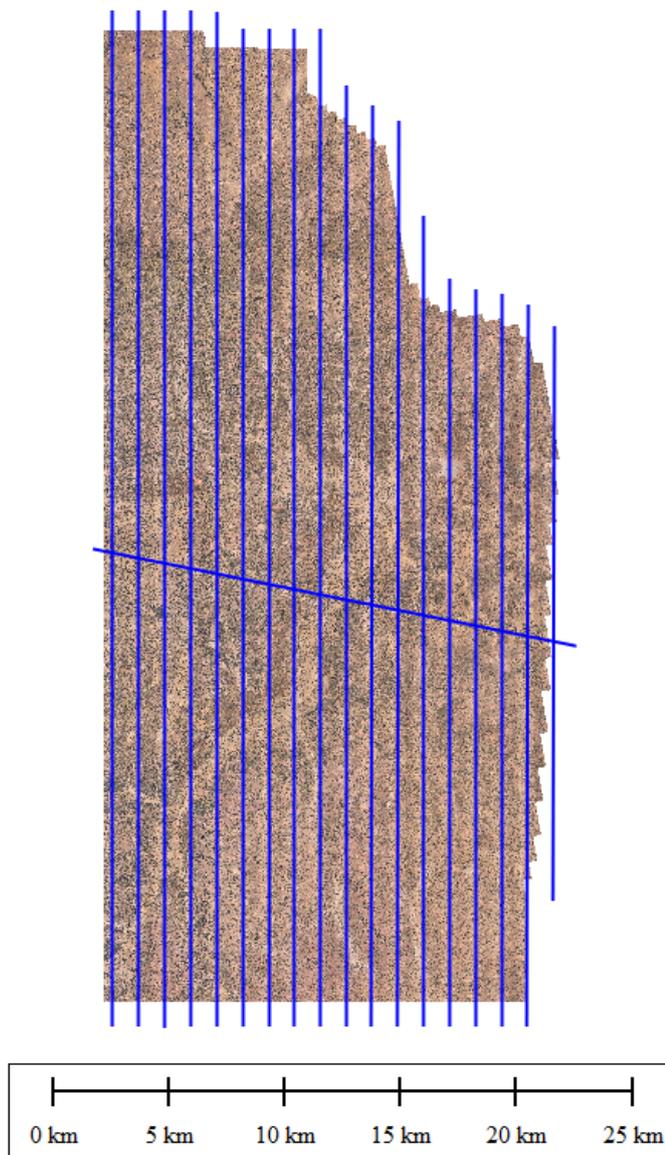


Figure 2.13: Beetaloo flightlines.

### 2.3.2 Tile Index Shapefile

Figure 2.14 presents the tile index layout, illustrating how the dataset is segmented into individual tiles. These indices enable easy correlation between each tile and its corresponding LiDAR or imagery product.

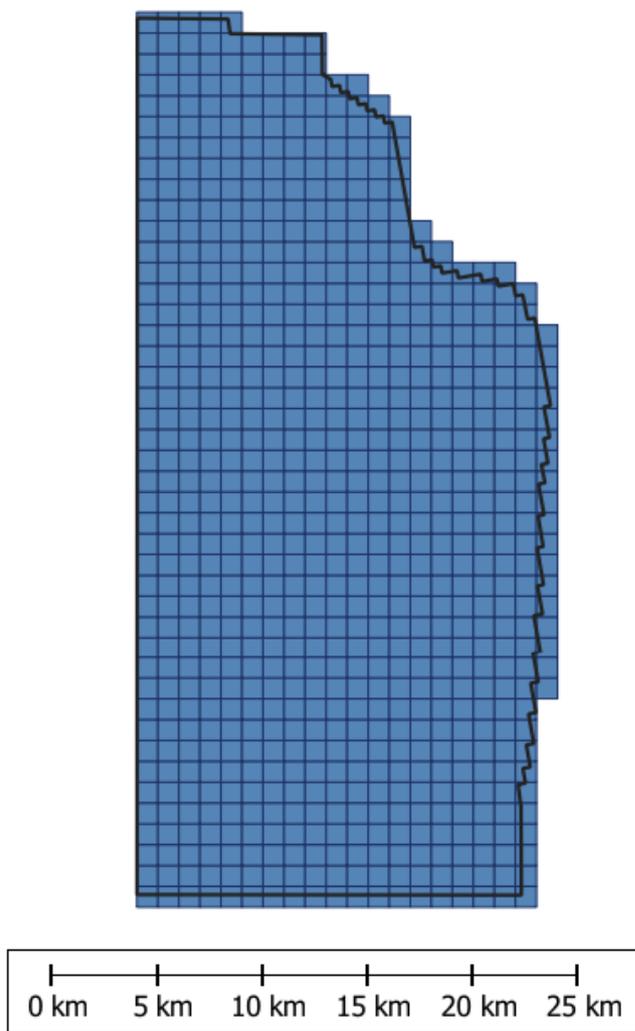


Figure 2.14: Beetaloo Basin tile index.

### 2.3.3 Ground Control Locations

The GCP collection for LiDAR verification was conducted at 23 sites across the project AOI. Beetaloo Energy provided GCPS over the Beetaloo Basin AOI, which were used; the survey achieved high accuracy, with 3D positional uncertainty ranging from 0.07m to -0.10m at a 95% confidence level. All positional and vertical checks showed minimal differences, confirming the reliability and consistency of the data across all sites.

Figure 2.15 below shows the geographic location of ground control points for the Beetaloo Basin project area.

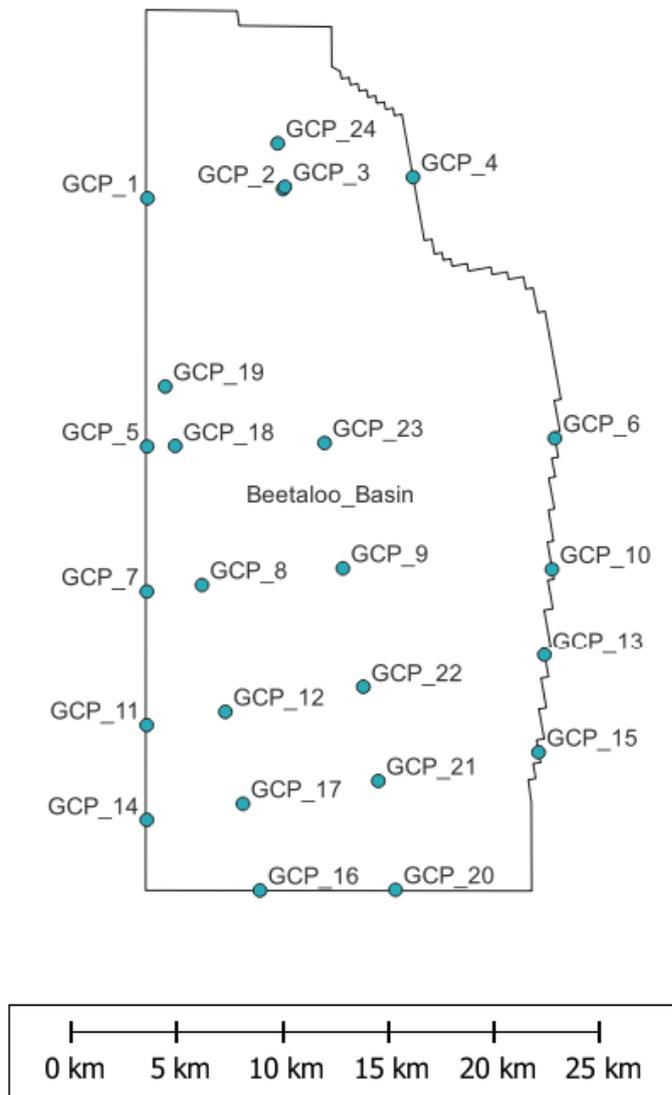


Figure 2.15: Beetaloo Basin GCP locations.

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### 3. Accuracy Validation Report

GNSS-IMU was processed using Applanix PP-RTX. The results of the session show positional accuracy better than 0.05m in xy and better than 0.08m in z for most of the trajectory. After georeferencing the LiDAR data with the smoothed best trajectory files and the LiDAR calibration parameters, the laz data was created in GDA2020 MGA53, and AHD derived from Ausgeoid2020. For each run, channel 1 and channel 2 were kept separated for the best strip align processing. The following session presents the relative and absolute accuracy results.

#### 3.1.1 Relative vertical accuracy results

Figure 3.1 and Figure 3.2 below shows the vertical overlaps pre-adjustment and post-adjustment for Beetaloo Basin Renewables project areas. In blue are the lower dz and red/pink the highest values, the scale is within 0.5m at the worst-case scenario.

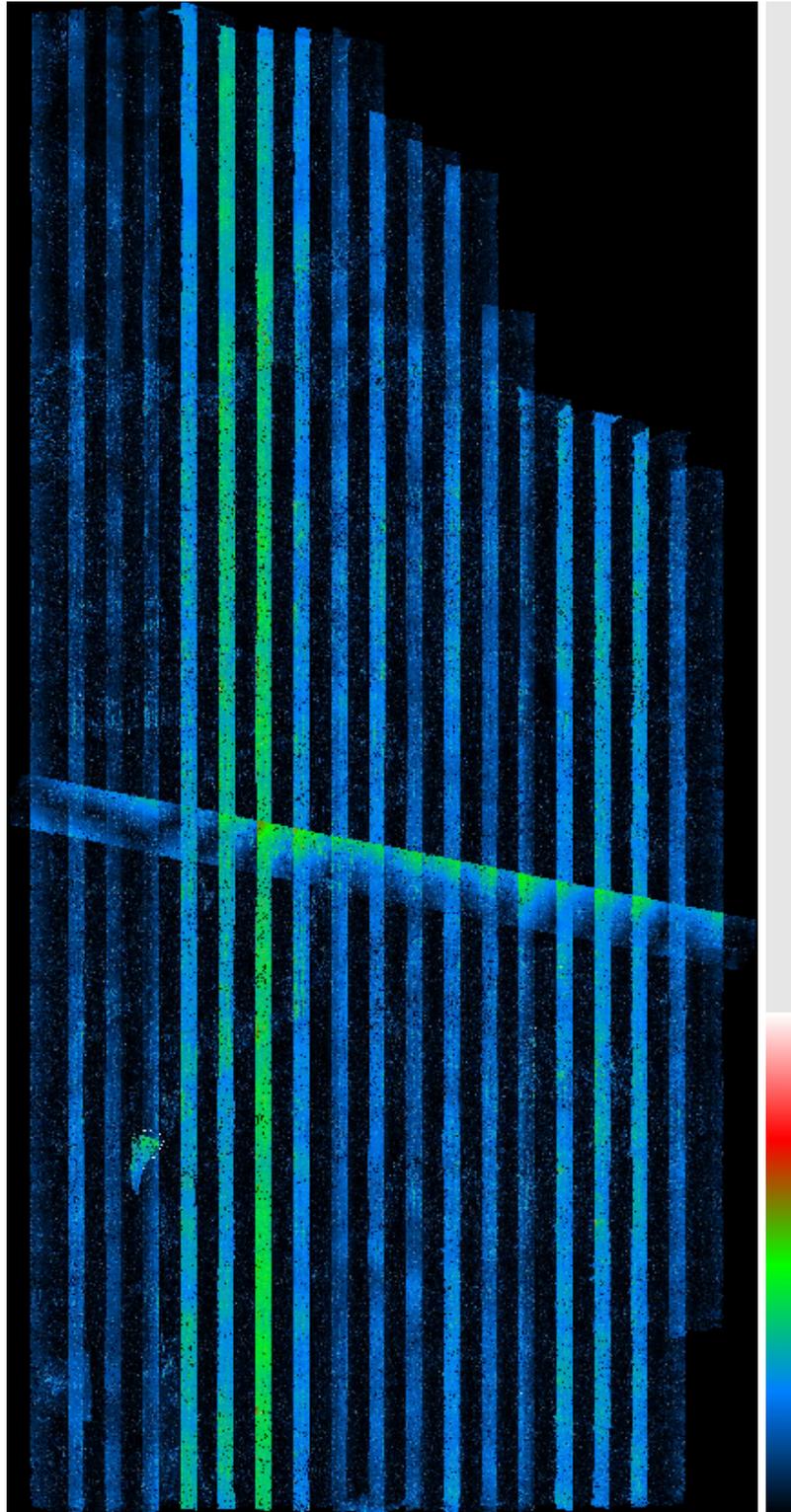


Figure 3.1: Flight line matching registered image/graphic illustrating a swath height prior to adjustment.

After flight line matching, the differences in z between lines have improved, as shown in Figure 3.2 (mostly blue). There is excellent alignment between neighbouring swaths for both project areas.

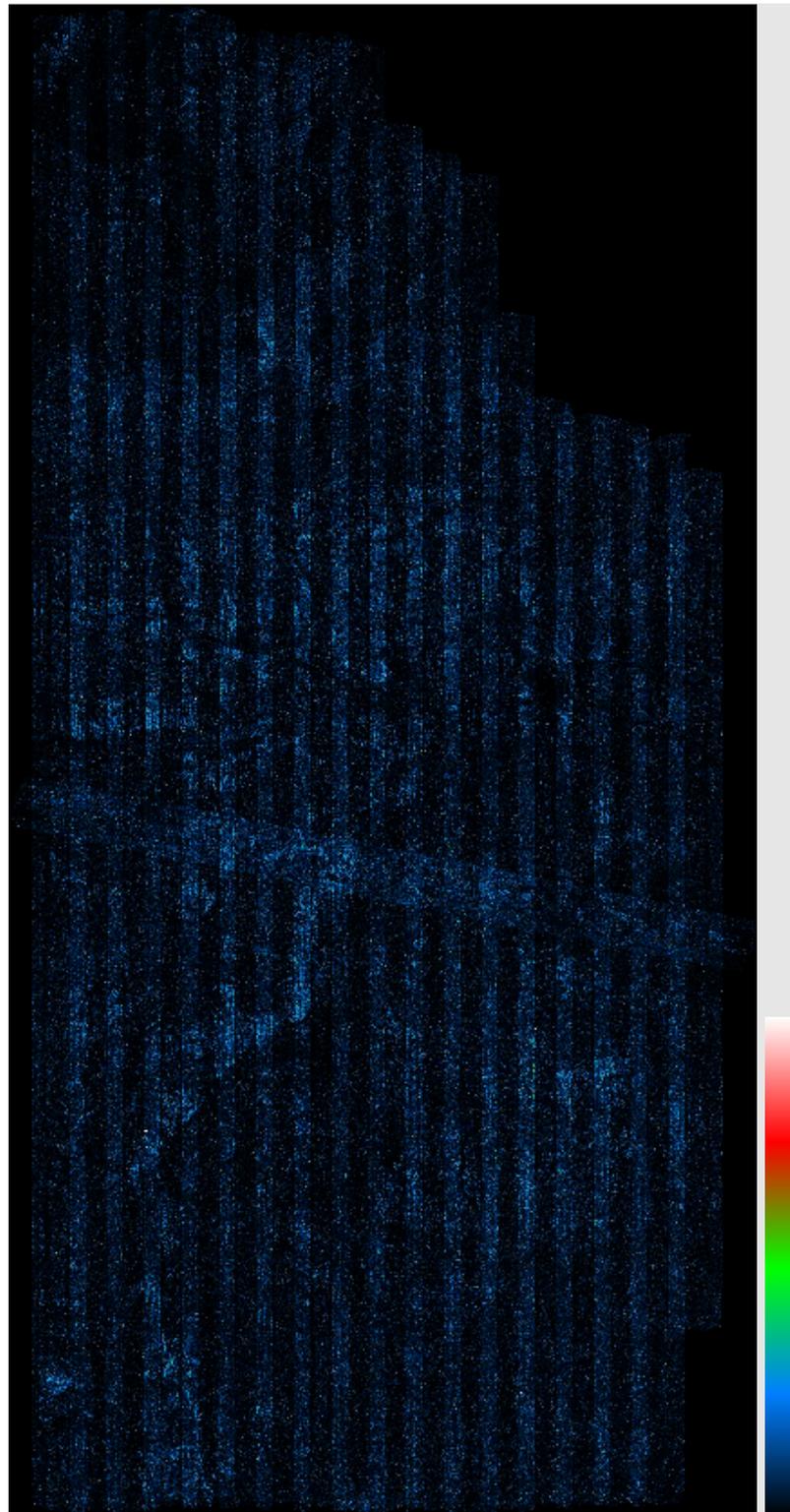


Figure 3.2: Flight line matching registered image/graphic illustrating a swath height post adjustment.

### 3.1.2 Absolute vertical accuracy results

The absolute vertical accuracy is reported using the ground surface model, from a TIN surface version for the AHD dataset. Visual checks have also been performed on the regular surface.

The LiDAR surface was created using all points with max triangle of 10m and max slope of 45 degrees. LiDAR points were checked to ensure there was no noise in the classification prior to applying any adjustment.

The LiDAR checks made pre-adjustment were prior to clipping of the project data to the AOI. Post-adjustment checks were made after LiDAR data had been clipped; as a result, some control comparisons were reported as outside.

Table 3.1: Statistical summary of DZ of ground control points

Beetaloo Basin HeadNode GCP Results					
GCP Name	GCP E (m)	GCP N (m)	GCP Z (m)	LiDAR Z (m)	Diff (m)
GCP1	509095.9	8153729.0	222.23	222.18	-0.05
GCP2	515513.2	8154168.3	237.83	237.73	-0.10
GCP3	515592.1	8154277.9	250.83	250.78	-0.05
GCP4	521661.0	8154734.7	219.63	219.68	0.05
GCP5	509080.2	8141880.7	231.53	231.53	0.00
GCP6	528378.6	814226.0	219.93	219.97	0.04
GCP7	509065.0	8134955.1	258.43	258.47	0.04
GCP8	511673.2	8135265.3	250.63	250.64	0.01
GCP9	518345.5	8136063.5	228.03	227.97	-0.06
GCP10	528238.9	8136011.6	214.53	214.51	-0.02
GCP11	509058.6	8128493.8	259.23	259.25	0.02
GCP12	512780.5	8129132.9	238.93	238.98	0.05
GCP13	527883.5	8131865.3	228.93	228.91	-0.02
GCP14	509062.8	8123973.2	258.73	258.71	-0.02
GCP15	527607.5	8127198.6	236.83	236.84	0.01
GCP16	514421.0	8120607.0	258.53	258.46	-0.07
GCP17	513611.2	8124741.8	255.83	255.82	-0.01
GCP19	509932.3	8144740.4	249.73	249.80	0.07
GCP20	520836.5	8120634.9	284.13	284.11	-0.02
GCP21	520019.7	8125830.7	266.83	266.77	-0.06
GCP22	519312.9	8130329.0	253.73	253.67	-0.06
GCP23	517476.3	8142045.9	224.73	224.63	-0.10
GCP24	515259.5	8156351.5	210.63	210.60	-0.03
<b>Average</b>					<b>-0.01</b>
<b>Minimum</b>					<b>-0.10</b>
<b>Maximum</b>					<b>0.07</b>
<b>StDev</b>					<b>0.05</b>

### 3.1.3 Absolute vertical accuracy summary

Table 3.1 show the ground control points used and the differences in height for this project. The average difference is -0.01m between LiDAR and GCP. Due to great alignment, no vertical adjustments have been applied to this dataset. Based on this table and the statistics summary, the vertical absolute accuracy of the LiDAR dataset is **0.05m at a 68% confidence level.**

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## 4. Project Closure

The data meets the project specification of a point density of 16ppsm, with vertical absolute accuracy requirements of  $\pm 10\text{cm}$  @ 68% confidence interval being achieved. All derived products from LiDAR and imagery exceed project expectations. Also supplied is a metadata statement for this project.

# Bettaloo Energy\_Beetaloo Basin\_delivery-report\_2025 Rev 0

Final Audit Report

2025-10-29

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-  Signer j.seeto@fugro.com entered name at signing as Jordan Seeto  
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-  Document e-signed by Jordan Seeto (j.seeto@fugro.com)  
Signature Date: 2025-10-29 - 1:33:35 AM GMT - Time Source: server

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