Al Ghat 120 ha Aerial Survey — Quality & Accuracy Report

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Majed Mohammedeid Alharbi Establishment for Aerial Photography (Majed Aerial Solutions) · CR 7052338246 · VAT 312944847800003 · Riyadh, Kingdom of Saudi Arabia · majed@majedsolutions.co

Document control

Item	Detail
Report number	MAS-QA-2026-10-01
Client	[redacted]
Project	Full Aerial Survey & Photogrammetry, Al Ghat, 120 ha
Commercial reference	Tax invoice [redacted] 29 Sept 2026
Acquisition date	30 Sept 2026
Processing	1–3 Oct 2026
Revision	Rev 0 — issued with final deliverables
Prepared by	Majed Alharbi, GACA Remote Pilot Certificate UA-38575; GEOSA-licensed

This report documents how the Al Ghat survey data were acquired and processed, the accuracy achieved, and the limits within which the deliverables should be used. It is a data-quality statement, not a certified cadastral or engineering survey.

1. Executive summary

The 120 ha Al Ghat site was captured in one day with 3,924 RTK-fixed images and processed into a single, fully registered photogrammetric block in KSA-GRF17. All images aligned (3,924/3,924) with a median reprojection error of 0.70 px.

Result	Value
RTK fixed solution	100% of images
Camera-position RMSE, horizontal	**2.87 cm**
Camera-position RMSE, vertical	**3.33 cm**
Camera-position RMSE, 3D	**4.40 cm**
Systematic bias (X / Y / Z)	−0.06 / +0.10 / −0.29 cm
Orthomosaic and model texture resolution	5.0 cm
DSM / DTM grid	5 cm

The RMSE values measure how closely the adjusted photogrammetric solution agrees with the RTK-measured camera positions (internal consistency). Absolute accuracy is governed by the RTK correction source: a single KSA-CORS reference station (QS95) about 32 km from site, with receiver-reported precision of 4–5 cm horizontal and 8–13 cm vertical. RTK-measured field targets agree with the model within approximately 0.1 m where the targets were undisturbed; they are reported as indicative, not as independent validation (Section 6.3).

Fitness for use: suitable for site planning, layout, area and volume estimation, earthworks planning and visual documentation. Design work that needs independently verified accuracy, or any cadastral or legal boundary purpose, requires validation by a licensed survey office (Section 9).

2. Project information

Item	Detail
Site	Al Khalidiyah farm area, Al Ghat, Riyadh Region (≈ N, E)
Area	120 ha (1.2 km²) as agreed, deliverables clipped to the agreed boundary plus margin
Terrain	Mainly flat farmland (palm groves, centre-pivot fields), bare sand and dunes on the western edge, relief and structures in the south-western section
Acquisition	30 Sept 2026, 12:02–16:08 AST (image capture), clear sky, ≈ 40 °C

Item	Detail
Aircraft	DJI Mavic 3 Enterprise with RTK module, 20 MP 4/3 CMOS mechanical-shutter camera
Positioning	Network RTK via KSA-CORS (GEOSA), fixed solution throughout
Software	Epic Games RealityScan 2.1.1; Python validation scripts (pyproj, pandas)
Operator credentials	GACA Remote Pilot Certificate UA-38575; GEOSA licensing; GACA flight authorization obtained for the operation

The client confirmed RTK-based georeferencing without ground control points. Independent ground checkpoints were offered as an optional service and were not part of the agreed scope.

3. Geodetic framework

All deliverables are referenced to the Saudi national frame KSA-GRF17, projected to UTM zone 38N. Heights are ellipsoidal (GRS80) unless stated otherwise.

Item	Value
Horizontal reference	KSA-GRF17, coincident with ITRF2014 at epoch 2017.0 (GEOSA)
Projected CRS	KSA-GRF17 / UTM zone 38N, **EPSG:9358**, central meridian 45° E (EPSG)
Image prior CRS (processing)	KSA-GRF17 geographic 3D, EPSG:9332
Height reference	Ellipsoidal height, GRS80
Orthometric option	KSA-VRF14 via geoid model KSA-GEOID21, available from GEOSA on request (EPSG:10775)
Correction service	KSA-CORS NTRIP, operated by GEOSA (KSA-CORS guide)
Mount point	NEAREST_RTK_KSAGRF17_RTCM_3 (single-base RTK, KSA-GRF17 output)
Reference station	QS95, Trimble NetR9, N 25°49′52.18375″ E 44°35′20.86933″, h 697.951 m

Item	Value
Baseline to site	≈ 32 km

Frame consistency control. The correction stream delivers KSA-GRF17 coordinates. The image priors were therefore declared as KSA-GRF17 in processing, not WGS 84. Declaring them as WGS 84 would apply the WGS 84 → KSA-GRF17 transformation a second time and shift the model by about 0.30 m north-east at this epoch (the transformation degrades by about 2.5 cm per year from 2017.0; EPSG:9334). This setting was verified on a test dataset before production: the residual bias fell from 0.30 m to below 1 mm.

Vertical datum (open item). Deliverables are issued in ellipsoidal heights. If orthometric heights (KSA-VRF14) are required, they can be produced by applying KSA-GEOID21 to the DSM, DTM, contours and XYZ files.

4. Data acquisition

Nine flights captured 3,924 images, every one with an RTK fixed solution. The flat farmland was flown as nadir blocks in overlapping sections; the south-western area with relief and structures was flown with additional oblique passes for the 3D model.

Flight	Block	Images	Capture (AST)	Height above ground (median)	Nadir GSD	RTK fixed
001	Section 1, nadir	244	12:02–12:09	≈ 162 m	4.4 cm	100%
002	Section 2, nadir	437	12:35–12:49	≈ 162 m	4.4 cm	100%
003	Section 3, nadir	541	13:21–13:37	≈ 164 m	4.5 cm	100%
004	Section 3, nadir	186	13:48–13:53	≈ 168 m	4.6 cm	100%
005–009	Section 4, nadir + oblique	2,516	14:29–16:08	≈ 168–183 m	4.6–5.0 cm	100%
Total		**3,924**				**100%**

Heights above ground are derived from camera ellipsoidal heights minus the measured ground level (≈ 629.5 m). GSD is nadir-equivalent; oblique images have coarser GSD toward the far edge and are used for the 3D model only.

Acquisition design

- Adjacent sections overlap by 60–80 m and share one flight-line direction, so they tie into a single block.
- Planned image overlap: nadir 85% forward / 80% side; oblique 80% / 70%.

- Receiver-reported RTK precision across all flights: 4.0–5.6 cm horizontal, 8.3–12.8 cm vertical (mean per flight). The vertical figure reflects the 32 km single-base baseline.
- Raw GNSS observations (.obs, .nav, .MRK) were logged for every flight. Post-processing (PPK) was assessed and not applied, because the nearest KSA-CORS station is the same 32 km station used in real time.

5. Processing

All 3,924 images were aligned in one run into a single component, with no image rejected. A full-resolution mesh of 793.5 million triangles is the geometric master for every height product.

1. **Pre-check.** RTK status, precision and timestamps were extracted from every image (ExifTool) before alignment. No image needed exclusion.
2. **Prior configuration.** Image priors were declared KSA-GRF17 (EPSG:9332). Prior accuracy was set to the field precision: 5 cm horizontal, 10 cm vertical.
3. **Alignment.** High quality, full resolution (downscale 1), Ultra detector sensitivity, 40,000 features per image, Brown4 + tangential2 lens model, final optimisation on.
4. **Reconstruction.** High detail, full resolution → Model 1, 793.5 M triangles (6 h 31 min).
5. **Texturing model.** Model 1 simplified to 250 M triangles, then textured at a fixed 5.0 cm texel size (30 × 8192² textures, texture quality 85%).
6. **Products.** DSM, DTM, contours, XYZ and point cloud from the full-resolution geometry; orthomosaic and textured 3D model from the 250 M textured model (Section 7).

Alignment statistic	Value
Registered images	3,924 / 3,924 (1 component)
Tie points	7,983,860
Projections	32,988,596
Average track length	4.1 images
Reprojection error, median / mean / max	**0.70 / 0.78 / 2.00 px**
Alignment time	1 h 53 min

Why two models. Texturing the full 793 M-triangle mesh would have forced a single texture at 0.36 m per texel, far below the imagery's resolution. Texturing a 250 M-triangle copy at a fixed 5 cm texel keeps full image detail in the orthomosaic and 3D model. Height products still come from the unsimplified mesh, so no geometric detail is lost.

6. Accuracy assessment

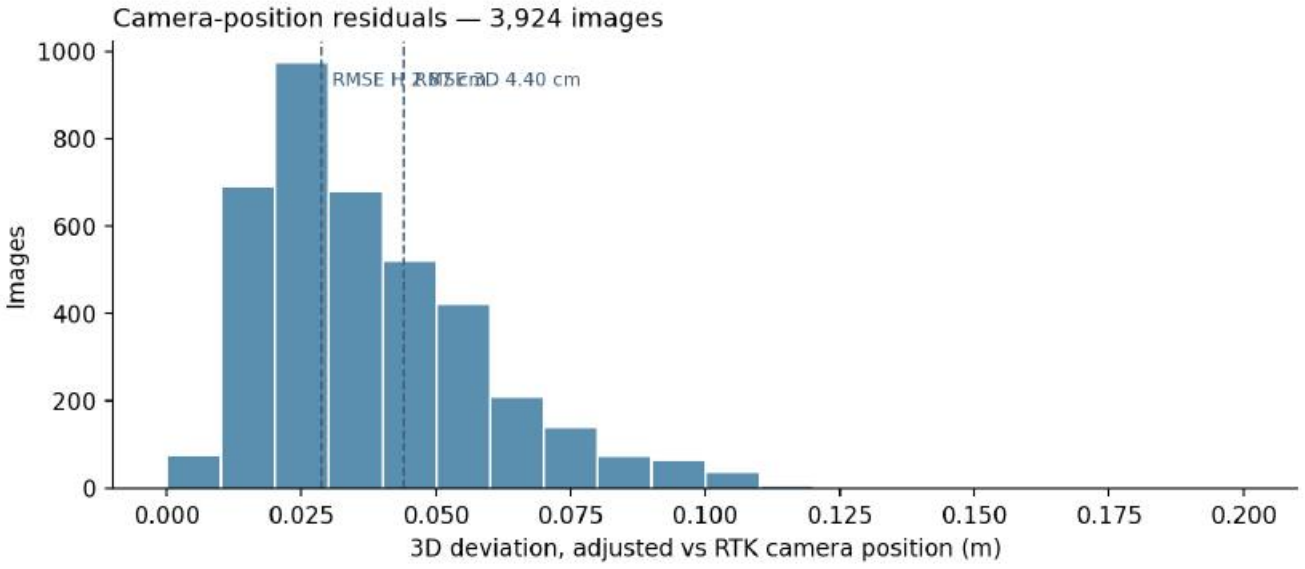
The adjusted block agrees with the RTK-measured camera positions to 2.87 cm horizontally and 3.33 cm vertically, with no systematic bias. Absolute accuracy on the ground is bounded by the RTK correction source, about 4–5 cm horizontal and 8–13 cm vertical.

6.1 Camera-position residuals (internal consistency)

Each image's adjusted position was compared with its RTK-measured position, both in KSA-GRF17 / EPSG:9358.

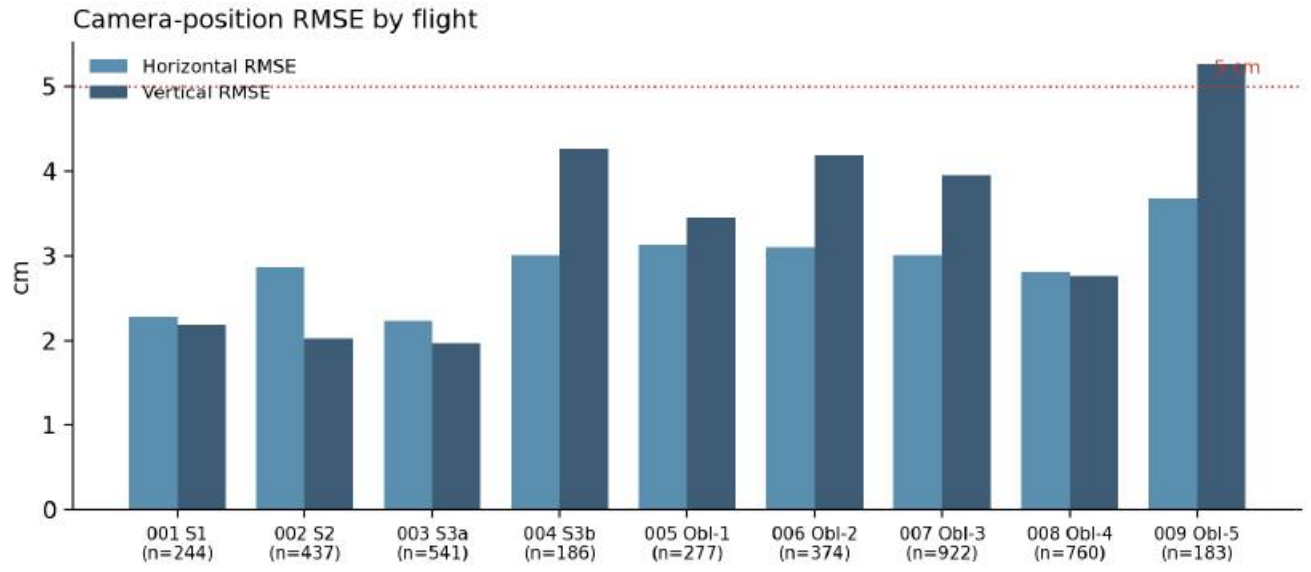
Statistic	X	Y	Z	Horizontal	3D
RMSE (cm)	1.91	2.14	**3.33**	**2.87**	**4.40**
Mean / bias (cm)	−0.06	+0.10	−0.29		

- 95th percentile of 3D deviation: 8.1 cm.
- Images above 10 cm: 59 (1.5%); above 15 cm: 5 (0.1%).
- Larger deviations occur in short bursts on turns, descents and the last flight (Appendix B), each surrounded by well-aligned images.



6.2 Consistency by flight

Every flight sits below 5 cm horizontal RMSE. Vertical RMSE is below 5 cm for eight of nine flights; flight 009 (the last oblique flight, 183 images) reaches 5.3 cm with a +4.6 cm mean offset. It covers the oblique-captured relief area and does not affect the flat-area mapping products.

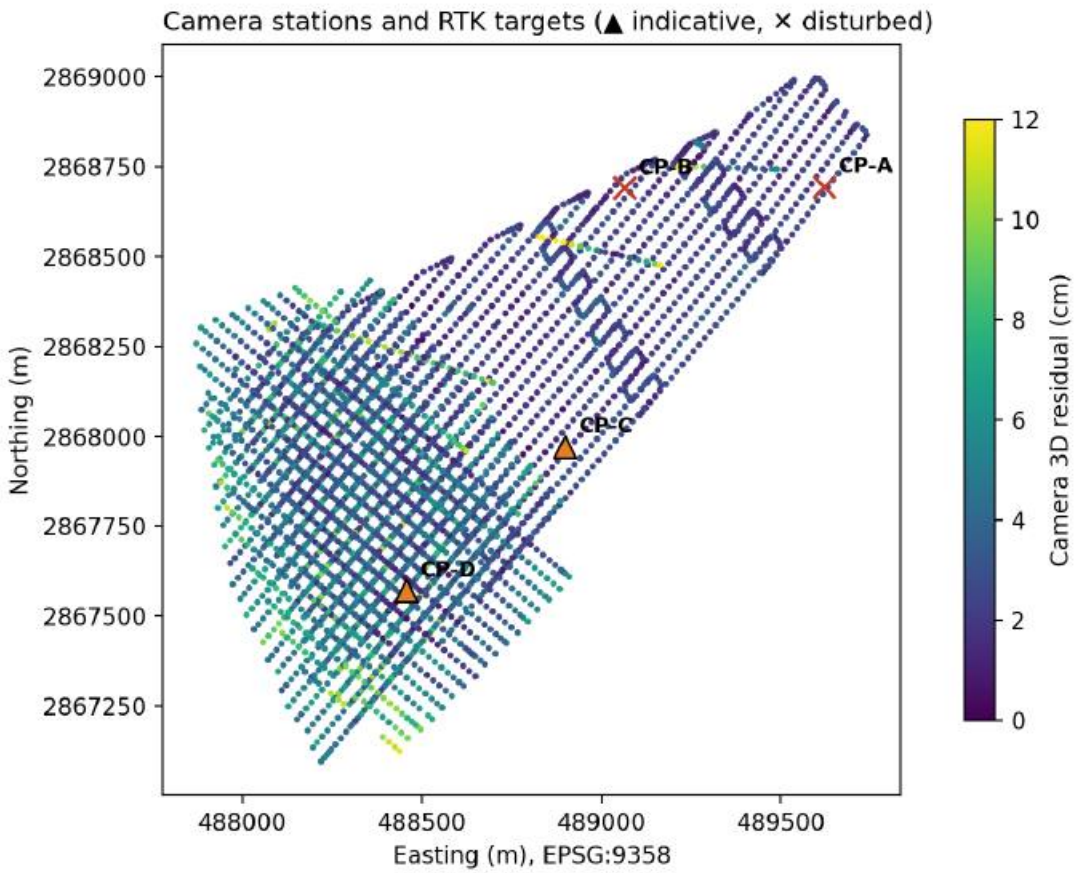


6.3 RTK-measured field targets

Four targets were measured with the aircraft's RTK receiver (fixed solution, KSA-CORS QS95) and marked in the imagery as test points; they did not constrain the solution. The targets were not kept undisturbed between measurement and imaging: each RTK reading followed an automated landing, and the marked images were taken before that landing or after the next take-off. The residuals are therefore **indicative only** and are not used as an independent accuracy statement.

Target	dX (cm)	dY (cm)	dZ (cm)	Horizontal (cm)	Status
CP-C	−12.3	−11.2	+5.1	16.6	Indicative
CP-D	+2.9	+6.3	−0.1	6.9	Indicative
CP-A	—	—	—	67 (total)	Disturbed, excluded
CP-B	—	—	—	55 (total)	Disturbed, excluded

CP-C and CP-D err in opposite horizontal directions, which indicates target disturbance rather than a block offset. Vertical agreement is 5.1 and 0.1 cm. The exclusion rule and timeline are in Appendix A.



6.4 Position against recognised standards

The ASPRS Positional Accuracy Standards, Edition 2 (2023), require a minimum of 30 independent checkpoints for a product accuracy statement and express accuracy as RMSE (ASPRS; USGS summary). This project used no independent checkpoints, by agreement. Its figures are therefore reported as **internal consistency against RTK**, not as an ASPRS accuracy class. An ASPRS-compliant statement would require at least 30 surveyed checkpoints; MAS can provide this as an add-on.

7. Deliverables

Every deliverable listed on invoice [redacted] is supplied in KSA-GRF17 / UTM 38N (EPSG:9358), clipped to the agreed boundary plus a 20–30 m margin.

Deliverable	Format	Resolution / content	Source geometry
Orthomosaic	GeoTIFF, JPEG-YCbCr compressed, tiled	5 cm, RGB	Textured model, 250 M triangles, 5 cm texel
Digital Surface Model (DSM)	GeoTIFF, float32, compressed	5 cm grid, ellipsoidal heights	Full mesh, 793.5 M triangles

Deliverable	Format	Resolution / content	Source geometry
Digital Terrain Model (DTM)	GeoTIFF, float32, compressed	5 cm grid, ground class only	Full mesh, ground-classified
Point cloud	LAZ (LAS 1.4)	≈ 5 cm spacing, RGB, classification	Full mesh, ground-classified
3D model	OBJ + JPEG textures, tiled	250 M triangles, 5 cm texel	Textured model
CAD data	DXF (AutoCAD-compatible)	0.5 m contours from the DTM, site boundary	DTM
Coordinate data	XYZ (ASCII)	1 m ground grid from the DTM	DTM
Quality & Accuracy Report	This document	—	—

7.1 Specification compliance

Invoice requirement	Achieved	Status
Survey of 120 ha site	Full coverage, 3,924 images, 1 component	Met
DJI Mavic 3 Enterprise RTK with GEOSA NTRIP	M3E RTK, KSA-CORS NTRIP, 100% fixed	Met
Horizontal imagery GSD ⩽ 5 cm/pixel	Imagery 4.4–5.0 cm; orthomosaic 5 cm; texture 5.0 cm	Met
Vertical / terrain data GSD ⩽ 5 cm/pixel	DSM and DTM on a 5 cm grid	Met
OBJ, GeoTIFF, LAS/LAZ, DTM, DSM, DWG/DXF, XYZ	All supplied (table above)	Met
Quality & Accuracy Report with horizontal/vertical accuracy and RMSE	This report, Section 6	Met
CRS KSA-GRF17 / SANSRS, vertical reference where required	KSA-GRF17 / EPSG:9358; ellipsoidal heights, orthometric (KSA-VRF14) on request	Met; vertical datum to confirm

A 5 cm grid is the sampling interval of the height products; it is not a statement of 5 cm vertical accuracy. Accuracy is given in Section 6.

8. Sample outputs

The figures below show the processed block; full-resolution products are in the delivery package.

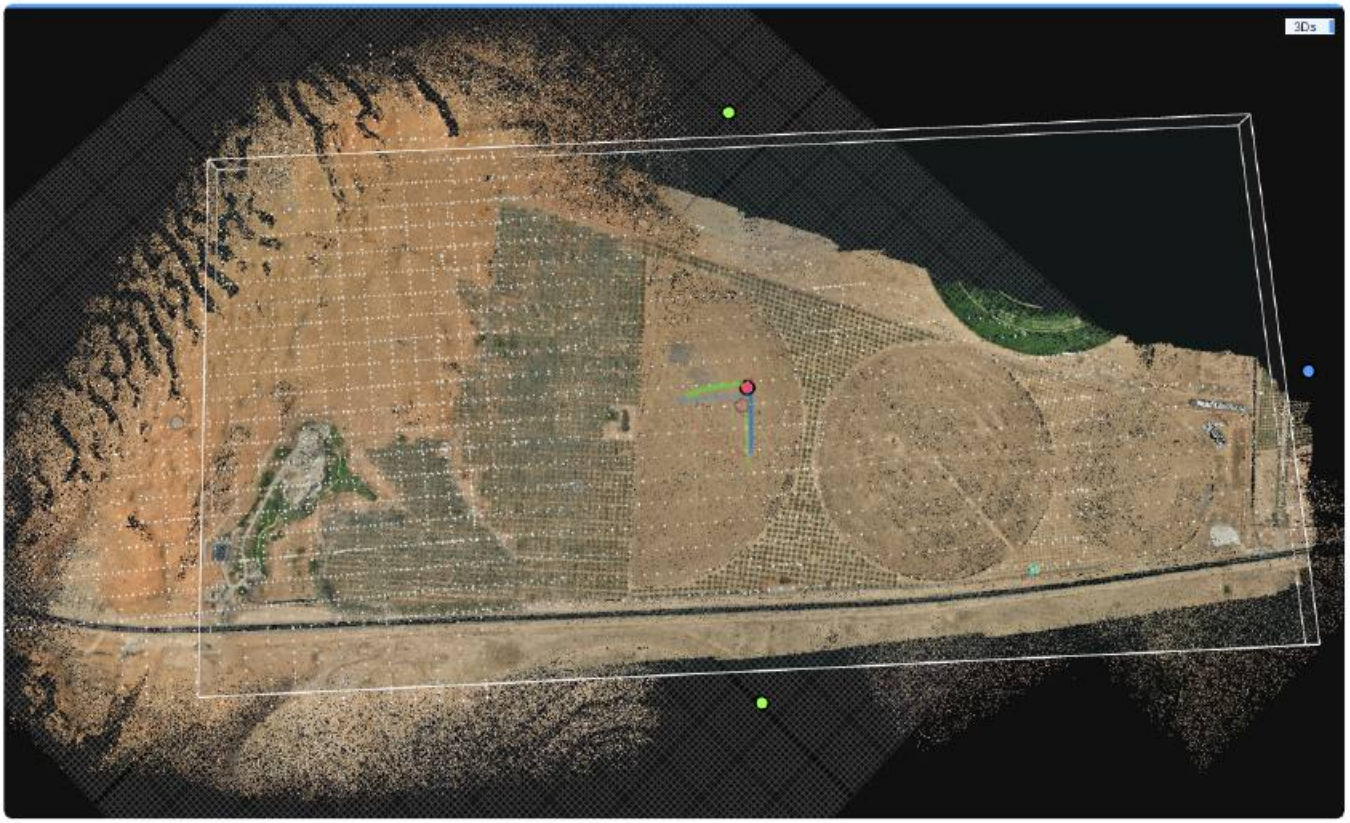


Figure 8.1 — Aligned block over the full site: tie points coloured from the imagery, camera stations shown as white dots. Coverage is continuous from the western dunes to the eastern fields, with no gaps at section seams.

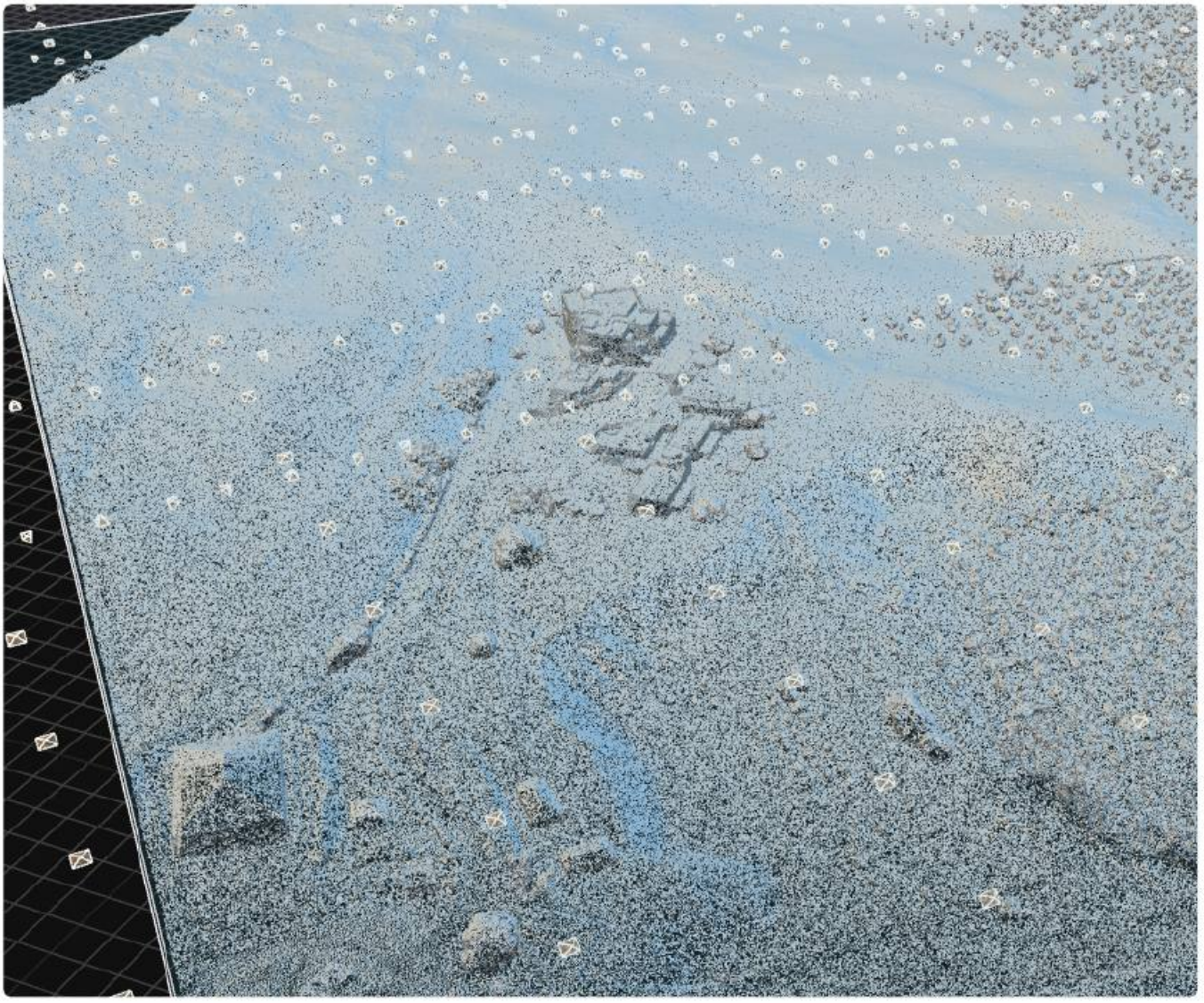


Figure 8.2 — Full-resolution mesh (untextured) in the south-western section. Walls, ruins and small mounds are reconstructed as true 3D geometry.



Figure 8.3 — RTK target measurement: the aircraft placed on a landing-pad target with a fixed solution. Section 6.3 explains why these readings are treated as indicative.

9. Limitations and fitness for use

The data are fit for planning-grade and visualisation use; engineering design that depends on a verified absolute accuracy needs independent validation first.

Use	Suitability
Site planning, layout, area measurement, visual documentation	Suitable
Earthworks planning, cut/fill and volume estimation	Suitable, with vertical uncertainty of about ± 10 cm
Detailed engineering design, levelling tolerances below 10 cm	Validate first with surveyed checkpoints
Cadastral, title or legal boundary survey	Not suitable; requires a licensed survey office

Known limitations

- **No independent checkpoints.** Accuracy figures are internal consistency against RTK (Section 6). The RTK reference is a single station about 32 km away; residual atmospheric and orbit error of a few centimetres may be common to all images and cannot be detected without independent ground control.
- **Vegetated areas.** Under palm canopy and dense vegetation the DTM is interpolated from surrounding ground, not measured. Contours there are estimates.
- **Western dunes.** Steep shadowed slopes have lower tie-point density; DSM and DTM detail is reduced locally.
- **Flight 009 vertical offset.** The last oblique flight shows a +4.6 cm mean vertical offset on 183 images in the relief area (Section 6.2).
- **Grid spacing is not accuracy.** The 5 cm DSM/DTM grid describes sampling density, not vertical accuracy.
- **Heights are ellipsoidal.** Orthometric heights (KSA-VRF14) require applying KSA-GEOID21; available on request.
- **Imagery date.** The data represent the site on 30 Sept 2026. Later changes on site are not captured.

10. References and standards

1. GEOSA — National geodetic infrastructure: KSA-GRF17 (ITRF2014/IGS14, epoch 2017.0), KSA-VRF, KSA-GEOID. geosa.gov.sa

2. GEOSA — Getting Started with the KSA-CORS Network, v1.0. ksacors.geosa.gov.sa
3. EPSG:9358 — KSA-GRF17 / UTM zone 38N. epsg.io/9358
4. EPSG:9334 — ITRF2014 to KSA-GRF17 (1), with the GEOSA SANSRS technical summary. epsg.io/9334
5. EPSG:10775 — KSA-GRF17 to KSA-VRF14 height (KSA-GEOID21). epsg.io/10775
6. ASPRS — Positional Accuracy Standards for Digital Geospatial Data, Edition 2 (2023): summary of changes. asprs.org
7. USGS National Geospatial Program — Adoption of ASPRS Edition 2 accuracy reporting. usgs.gov
8. LIDAR Magazine — The ASPRS Positional Accuracy Standards, Edition 2 (Oct 2023). lidarmag.com

Processing reports supplied with the data: RealityScan Overview, Component Registration and Selected Model reports (project ALGHAT, 2 Oct 2026); camera-residual table (3,924 rows); field RTK screenshots.

Appendix A — RTK target log and exclusion rule

Rule (applied to all four targets alike): a target is valid for independent checking only if it was undisturbed between its RTK reading and the images in which it was marked. All four readings were taken after an automated landing, without re-centring the aircraft, and no target met the rule.

Target	Easting (m)	Northing (m)	Ground h (m)	RTK reading	Images marked	Event between
CP-A			629.851	12:10:55	12:02–12:03 (5)	Landing
CP-B			628.862	12:33:12	12:42–12:44 (7)	Take-off
CP-C			628.582	13:39:02	13:22–13:27, 13:53 (5)	Landing and take-off
CP-D			630.230	14:47 / 14:52 (2 readings)	14:32–14:38 (6)	Landing

Ground heights = antenna reading minus 0.120 m (13.4 cm measured to the top of the antenna dome, minus an estimated 1.4 cm to the phase centre; uncertainty ± 1.5 cm). CP-A was read with 8 GPS satellites and 10.4 cm vertical standard deviation. CP-D's two readings agree within 2.1 cm horizontal and 1.6 cm vertical.

Field-protocol improvement for future projects: fixed photo-identifiable targets separate from the take-off point, measured with the aircraft re-centred, or surveyed with a dedicated GNSS rover.

Appendix B — Camera groups outside the 12 cm threshold

Images	Time	Pattern	Assessment
#225–229	12:08:57–12:09:04	dZ ≈ −11 to −12 cm	Return-to-home descent and turn
#660–669	12:48	dY ≈ +15 cm, dZ ≈ −12 cm	Short RTK disturbance in flight 002
#3838–3913 (selected)	16:01–16:08	Vertical offset	Flight 009, +4.6 cm mean offset

About 50 of 3,924 images (1.3%). Each group is surrounded by well-aligned images and has no measurable effect on the mapping products.

Appendix C — Glossary

Term	Meaning
GSD	Ground sample distance: ground size of one image pixel
RMSE	Root mean square error: the square root of the mean of squared differences
RTK / PPK	Real-time / post-processed kinematic GNSS positioning
KSA-CORS	GEOSA's national network of continuously operating GNSS reference stations
DSM / DTM	Digital surface model (top of objects) / digital terrain model (bare ground)
Texel	One pixel of a 3D model's texture, here 5 cm on the ground
Ellipsoidal height	Height above the GRS80 ellipsoid, not above mean sea level