DUNWICH IRRIGATION AREA – COMPARING AIRBORNE LASER SCANNING WITH PHOTOGRAMMETRY

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Summary

Report on Airborne Laser Scanning (ALS) trials conducted over the Dunwich Irrigation Area on North Stradbroke Island.

A digital terrain model was required under dense vegetation. Our client, Redland Shire Council, considered two options. One approach was to use existing 1:10,000 aerial photography, exposed just after a fire had reduced the vegetation on the site. The second approach was to use Airborne Laser Scanning.

The existence of aerial photography exposed with little vegetation over the site, plus ALS data captured through dense vegetation offered an interesting comparison of the two survey methods.

CONTENTS **Page Nos.**

1. BACKGROUND

In July 2000, Redland Shire approached AAM GeoScan on the possibility of using Airborne Laser Scanning (ALS) to acquire a digital terrain model over the Dunwich Irrigation area. The site extends over 50 hectares, with vegetation cover varying from scattered established eucalypts through to predominantly dense plantation pine regrowth. Figure 1 shows the project area from the main road.

The terrain model was required to an accuracy of 0.2m and was required for the design of an irrigation scheme associated with the proposed sewerage treatment plant at Dunwich.

Instead of proceeding with the ALS survey, Redland Shire Council adopted a proposal by Cottrell, Cameron and Steen to stereodigitise the terrain model utilising existing aerial photography. A DTM was created using 1:10,000 photography which had been exposed over the site just after it had been cleaned up by fire which significantly reduced the amount of vegetation.

The photogrammetric approach provided a solution for the task at hand, and also offered a terrain definition with which to compare the ALS data under dense vegetation. A single swathe of ALS was flown over the centre of the project site.

Redland Shire commissioned AAM Surveys to acquire a stereo pair of 1:10,000 aerial photographs to record the site (Figure 2).

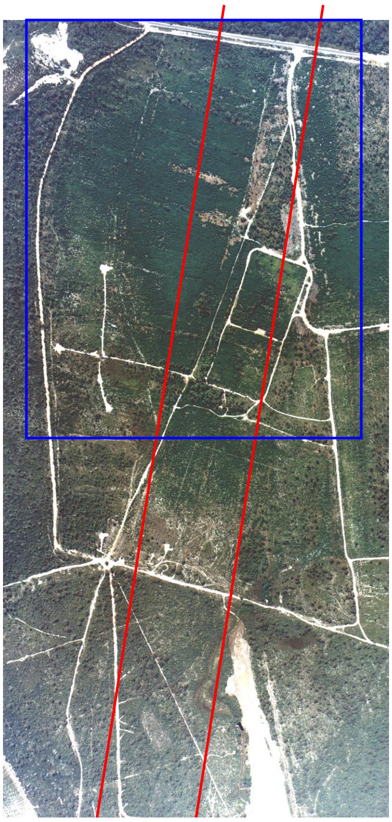


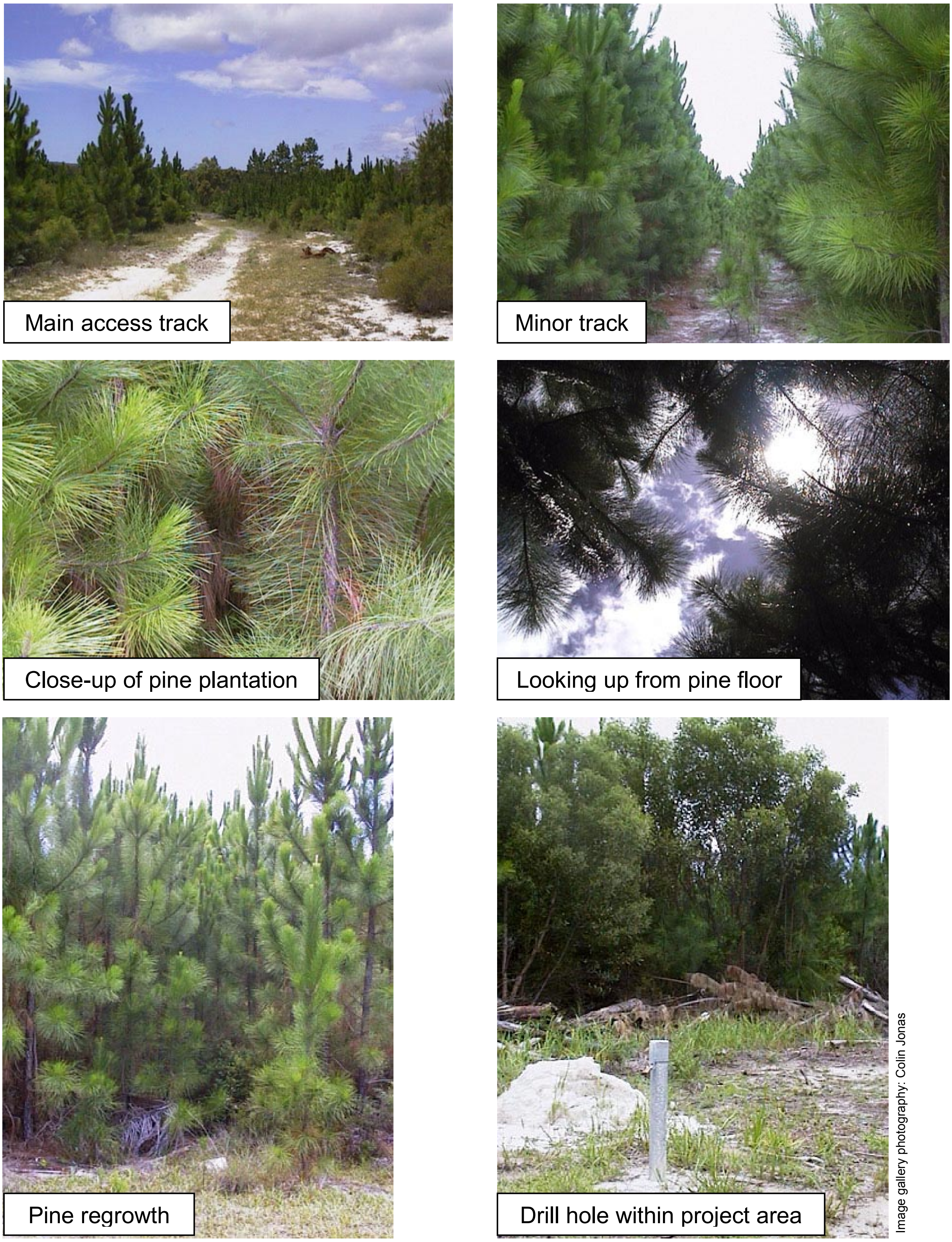
Figure 2
Aerial photograph showing site as at 20.09.2000.
ALS coverage in red.
Photogrammetric coverage in blue.

Figure 1
Project site from the Main Road

2. ALS VEGETATION PENETRATION

The ALS system emitted 10,000 laser points per second, which produced an average point separation of 1.4m. Due to the vegetation density, only 20.2% of the laser pulses penetrated through the vegetation to the ground. This resulted in an average *ground* point separation of 3.2m. Figure 3 provides an image gallery of the site, giving an indication of the vegetation density across the site.

Figure 3 – Photo Gallery showing vegetation density



Main access track

Minor track

Close-up of pine plantation

Looking up from pine floor

Pine regrowth

Drill hole within project area

Image gallery photography: Colin Jonas

3. RESULTS

AAM GeoScan compared the ALS survey with the photogrammetric data by:

1. comparing photogrammetric spot heights with the ALS terrain model;
2. comparing contours derived from the ALS under vegetation with those plotted directly from the aerial photography of cleared terrain;
3. constructing a profile through the site showing the two terrain models and the vegetation canopy;
4. displaying contours derived from the ALS over the vegetation shown on the current aerial photography.

3.1 Comparing spot heights

There were 561 photogrammetric spot heights within the ALS data swathe. A measure of the agreement between the photogrammetric measurements and the ALS terrain model was obtained by deriving an elevation from the ALS terrain model at each of the spot height locations. Analysing the 561 differences showed:

mean difference	:	0.003 m
standard error	:	0.301 m
minimum difference	:	-1.26 m
maximum difference	:	1.36 m

The mean difference of 0.003m is statistically insignificant. It shows that the ALS's kinematic GPS survey (using a base station in Toowong and Ausgeoid98 geoid corrections) fits well with the local survey control used for the photogrammetric survey. Control for the photogrammetry was obtained by a GPS Real Time Kinematic survey, with an estimated accuracy of 0.02m horizontal and 0.05m height.

The standard error of 0.301m represents error contributions from a number of different sources, including:

- measurement errors in the ALS (typically 0.15m rms);
- measurement errors in the photogrammetry (estimated to be 0.10m to 0.15m);
- interpolation errors in the ALS (with an average ALS ground point spacing of 3.2m, the height at each photogrammetric spot height was interpolated from the ALS data. This compares the ALS *model* with discrete photogrammetric *measurements*);
- forest litter on the floor, where the classification software was unable to identify a laser strike on fallen trees or dense undergrowth as "non-ground" strikes;
- changes in the terrain between the two surveys, most notably from clearing work done after the fire (see Figure 4).

Figure 4
Piles of wood stacked after the fire can appear as changed terrain shapes

It is difficult to quantify the contribution each component made to the 0.301m standard error.

Gross errors caused by changes in terrain between surveys can be removed from the calculations by removing those discrepanceies greater than three times the standard error. There were only five such spot heights where the photogrammetric elevation differed from the ALS terrain model by more than 0.903m, and so could reasonably be assumed to be due to changes in terrain shape. Recomputing the remaining 556 differences showed:

mean difference	:	0.005 m
standard error	:	0.282 m
minimum difference	:	-0.82 m
maximum difference	:	0.79 m

Assigning a standard error of 0.12m to the photogrametric survey, propagation of variances dictates that the standard error of the ALS *terrain model* is $\sqrt{(0.282^2 - 0.12^2)} = 0.25$m.

Therefore, the accuracy of the ALS terrain model, including errors of interpolation and mis-classification, can be estimated to be 0.25m.

This represents quite an encouraging level of accuracy, given the density of vegetation indicated by the proceeding photographs.

3.2 Comparing contours

Figure 5 shows photogrammetric contours in blue and contours derived from the ALS terrain model in red and brown.

Terrain shapes defined by the two surveys are very similar. As usual in such comparisons, the photogrammetric contours are much smoother than those derived from the ALS model. This is due to a combination of two reasons.

Firstly, the ALS dataset will contain some noise in the terrain model due to low non-ground laser strikes being incorrectly classified as "ground". In vegetated terrain, such mis-classifications are usually due to laser strikes hitting forest litter lying on the forest floor.

The second reason is that photogrammetric contours are usually generalised. When photogrammetrists plot a contour, they usually skip minor irregularities in the terrain and record a cartographically appealing generalisation of the terrain shape.

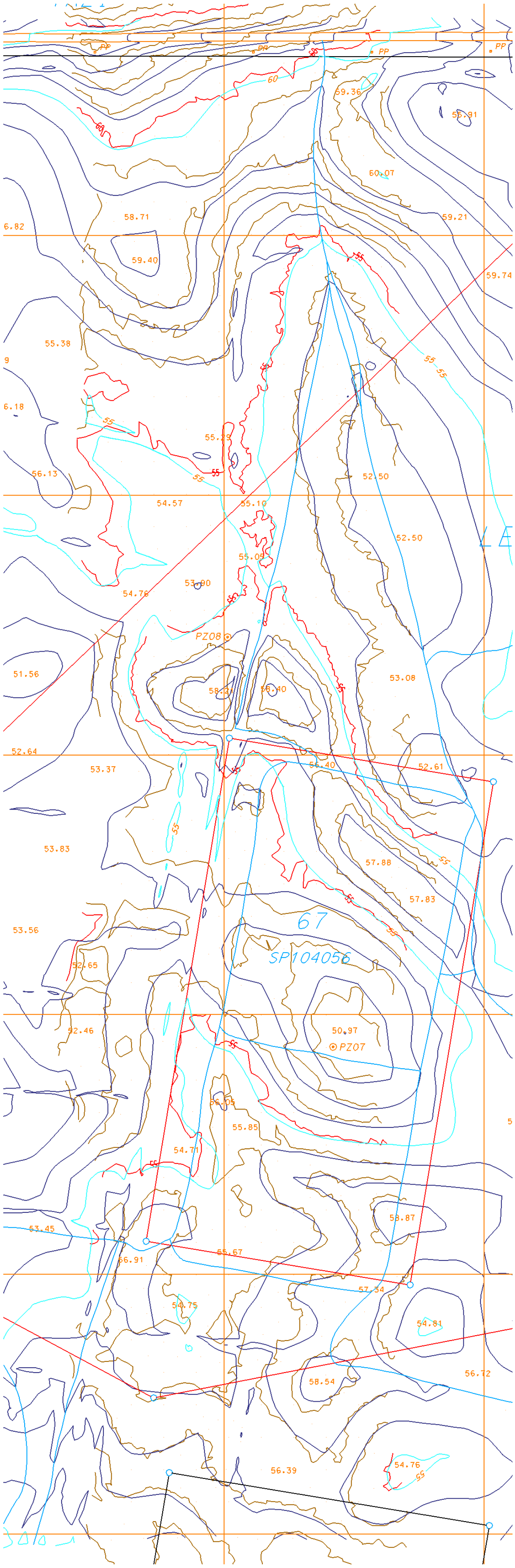


Figure 5
ALS contours overlaid on photogrammetric mapping

ALS contours in red and brown.

Photogrammetric contours shown in blue and black.

3.3 Constructing profile

Another method of comparing the two surveys is by constructing a profile. Figure 6 shows a profile line running the length of the project area. The red profile shows the photogrammetric surface derived from contours and DTM spot heights, the brown shows the ALS terrain and the green shows the ALS vegetation canopy.

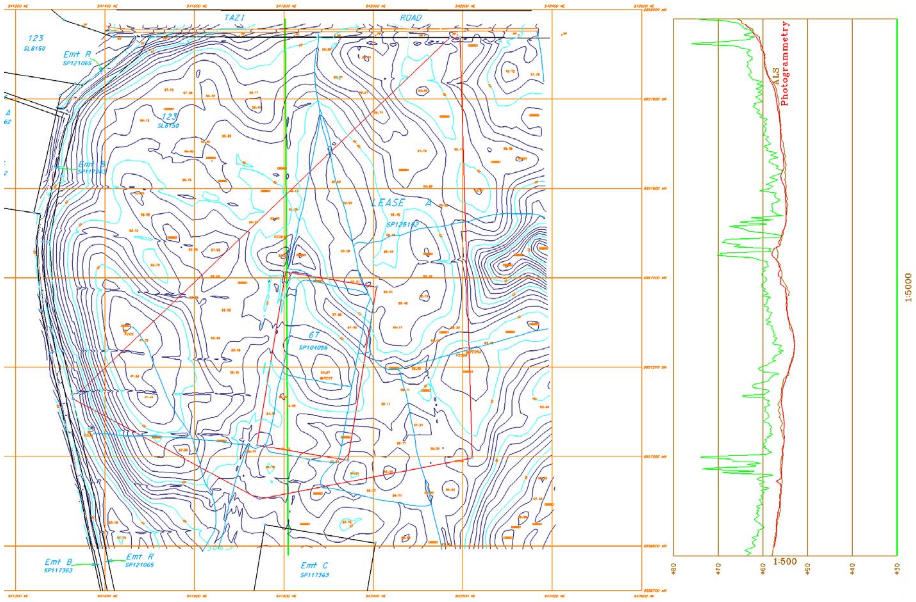
There are three places where the ALS DTM sits significantly below the photogrammetric surface. In each case, this occurs at the crest of a small hillock and is due to the ALS classification software incorrectly deciding that the top of the hillock is a “non-ground” feature. The classification of laser strikes for this project adopted a generalised classification algorithm; these minor errors which lose the hillock tops could be improved by altering the classification algorithms.

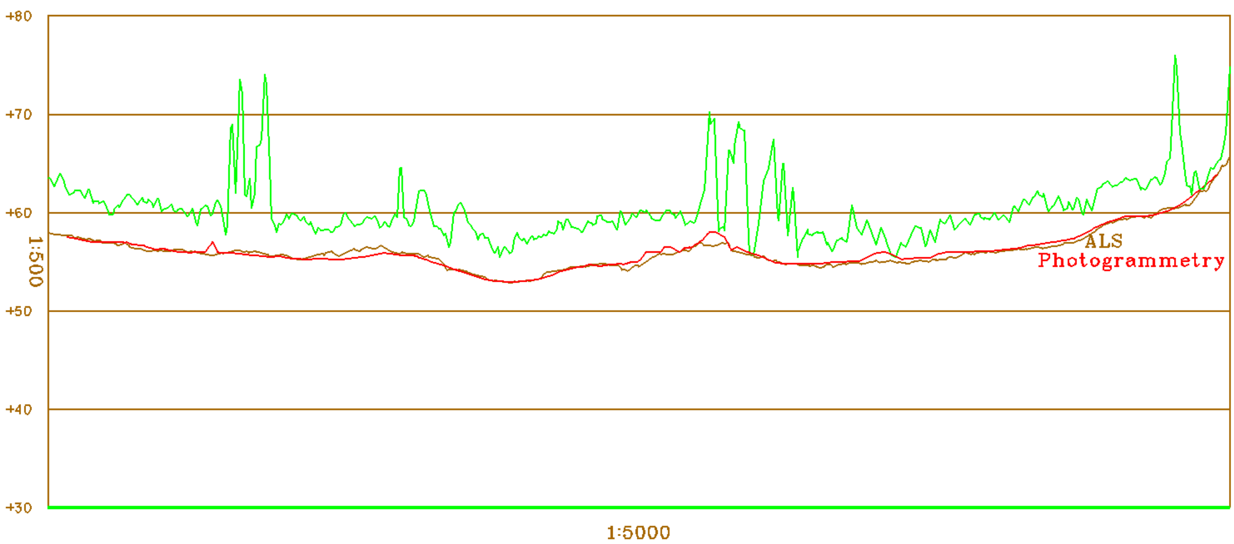
The profile also shows how the ALS survey has detected small undulations in the terrain, whereas the photogrammetric survey has applied a generalisation to the terrain shape.

The vegetation profile shows the result of a classification routine aimed at defining the vegetation *canopy*. All non-ground laser strikes that were beneath the top of the canopy were suppressed from the vegetation model. The degree of generalisation of the canopy top can be tailored to suit the tree size and laser intensity.

Figure 6

Profile across the project site. Overall view (right) and enlarged profile (below)





3.4 Displaying contours and photo

Overlaying one metre contours from the ALS terrain model over the current aerial photography gives an indication of how noise in the terrain model (as identified by irregular contours) varies with the vegetation coverage.

One can see in Figure 7 that the contours in the more heavily vegetated areas are more jagged than those in the cleared areas.

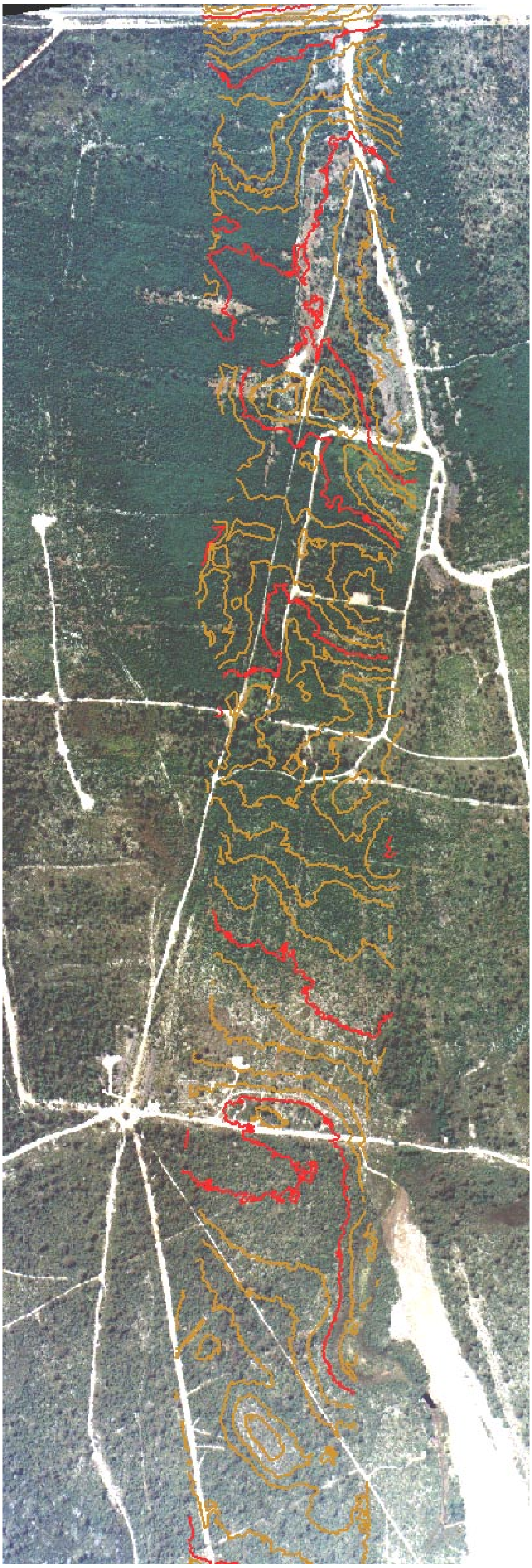


Figure 7
ALS contours overlaid on current aerial photography.

4. CONCLUSION

A digital terrain model (DTM) was required under (predominantly) dense plantation pine regrowth, but the vegetation was sufficiently dense to preclude the use of common survey techniques such as photogrammetry or RTK GPS. More radical suggestions would have involved the use of a bobcat to clear lines through the vegetation, or perhaps utilise very long GPS antenna supports to lift the antenna above the level of vegetation.

Airborne Laser Scanning (ALS) is a broad-acre terrain modeling technique known to offer a degree of vegetation penetration but it was not clear how well the laser strikes would define the terrain under the trees.

The immediate needs of the project were met by the fortuitous discovery of suitable aerial photography over the site, exposed just after the level of vegetation had been significantly reduced by fire. This offered a means to acquire a terrain definition unaffected by trees, and provide a useful comparison with an ALS surface acquired through the existing vegetation cover.

The accuracy of the terrain model produced by ALS was assessed using 561 photogrammetric spot heights. This comparison showed that there was no significant mean difference between the two surfaces. Terrain shapes were very similar using the two survey techniques, with the photogrammetric data offering smoother (but not necessarily more accurate) contour definitions

The accuracy of the ALS terrain model, including errors associated with interpolation and mis-classification was estimated to be 0.25m; an encouraging level of accuracy, given the density of vegetation across the site. Comparing profile lines across the site suggested that minor classification errors represented the greatest contributor to the ALS errors.

In summary, if the project area had not been captured on aerial photography after the fire, an Airborne Laser Scanning survey would have offered a terrain definition with a standard error of 0.25m just slightly outside of the nominated 0.2m level. No other conventional survey technique would have provided a cost-effective solution, other than perhaps a process that cleared lines of vegetation across the site. It is doubtful whether site management and environmental considerations would have made this option feasible.

Experiences gained on this site can be extended to other projects with comparable vegetation coverage. The site photographs provided above indicate a dense level of vegetation (especially at ground level and slightly above), but with some levels of visibility towards the sky.

This project demonstrated the usefulness of having ALS in the surveyors' toolbox. It was not the most appropriate solution here, as existing aerial photography (without vegetation) provided a more accurate and more cost effective solution. However, if the aerial photography had not existed, then the ALS system would have provided a terrain (and vegetation) model capable of supporting the design process. These trials reinforced the notion of using the most appropriate measurement technology for each project.

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5. APPENDIX - METADATA

DATA CHARACTERISTICS

Characteristic	Description
Photogrammetry	
Photoscale	1:10,000 Consolidated Rutile
Date of photography	30.06.1996
Vegetation cover	light / cleaned
Terrain model	20m grid of DTM spot heights and breaklines with 1m contours
Estimated accuracy	0.1 to 0.15m
Airborne Laser Scanning	
Laser density	1.4m estimated point density, separated into ground & non-ground
Laser penetration	20.2%
Terrain model	3.2m estimated point density

REFERENCE SYSTEMS – Airborne Laser Scanning

	Horizontal	Vertical
Datum	AGD84	AHD
Projection	AMG Zone 56	N/A
AMG Distortion Grid	QLD_0900	N/A
Geoid Model	N/A	Ausgeoid98
Reference Point	BJBbase, Toowong	BJBbase, Toowong

SOURCE DATA – Airborne Laser Scanning

	Source	Description	Ref No	Date
Primary control	AAM Surveys	Static GPS		1999
Photography (current)	AAM Surveys	1:10,000 prints	AAM2234-2c	20.09.00
Laser Scanning	AAM Geodan	10,000 Hz	810047	21.08.00
Photogrammetry	Cottrell, Cameron and Steen	Total station/ level pts	3009_3d.dxf	16.08.00

ACCURACY

	Measured Point	Derived Point	Basis of Estimation
Difference between ALS and photogrammetry		0.30	Comparing 561 photogrammetric DTM spot heights with heights derived from the ALS terrain model
Photogrammetry	0.12		Deductive estimate
ALS		0.25	Propagation of variances

ACCURACY NOTES:

- Values shown represent standard error (68% confidence level or 1 sigma), in metres
- “Derived points” are those interpolated from a terrain model.
- “Measured points” are those observed directly.
- Standard errors shown above are derived from the differences between data supplied in this volume and test points. An allowance has been made for errors in the test points.
- Comparison between 561 photogrammetric DTM spot heights and heights derived from the terrain model revealed a mean elevation difference of 0.003m.
