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Radiological anomalous area on the Nabarlek minesite – visual interpretation of temporal aerial photography

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1 Introduction

An area of potentially high erosion rate (described as the 'badlands' or 'Unit 7') was identified on the rehabilitated Nabarlek site by Grabham (2000). The area lies adjacent to the western side of the mine pit. The area is devoid of vegetation, extremely erodible and highly saline and was the site of stockpiled evaporation pond and processing plant runoff scrapings in 1988 (Grabham 2000). Subsequent analysis of surface soil samples from the site has shown that they have elevated uranium-series radionuclide concentrations (Hancock et al., in prep), and consequently the area has also been called a 'radiological anomalous area'.

There are therefore two aspects of interest for this area: its high erodibility and radiological nature. Hancock et al. (in prep) provide an erosion and radionuclide assessment of the Nabarlek site. With reference to the area of interest, they found the following: the area has the highest erosion rate determined for the site; is lowering at a rate 300 times that of the background rate and 2500 times that of the adjacent capped pit; has the highest radionuclide concentration (in soil samples); and, contributed the majority of the estimated flux of uranium-series radionuclides (attached to eroded soil particles) to Cooper Creek.

The size, shape and the relationship of this area on the rehabilitated site with previous mining activities has never been accurately defined. This report documents the results of using remotely sensed data to identify the spatial extent of this area during various stages of mining land use. This temporal investigation using aerial photographs was initiated to aid in the planning of a ground-based radiation survey and for defining the location to collect core samples.

1.1 Aim

To use remotely sensed data to identify the spatial location of the radiological anomalous area and relate this to various stages of mining land use.

2 Methods

Aerial photographs captured at various stages of mining operations and rehabilitation were used to identify the spatial location of the area and document any changes in shape of the landform. The specifications of each photograph are outlined in Table 1.

Table 1 Specifications of aerial photographs

Date	Scale	Run	Scanned photo
30/06/1984	1:15000	Run 1 164-166	165 (panchromatic)
*12/04/1988	1:15000	Run 1 045-047	046 (panchromatic)
30/06/1989	1:15000	Run 1 180-182	181 (colour)
03/06/1994	1:15000	Run 1 132-134	133 (colour
27/11/1999	1:15000	Run 2 5821-5828	5826 (colour)

* 1988 photograph not a stereo pair

In addition to the aerial photographs, orthorectified Quickbird satellite data acquired 30/09/2003 was used. The Quickbird data, at 0.6 m spatial resolution, provided a base image to digitally rectify the aerial photos and is the most recent aerial capture from which to assess change. The Quickbird data was considered ideal for this purpose due to the data being orthorectified and of sufficiently fine spatial resolution to characterise the current extent of the radiological anomalous area.

Photos were scanned at 762 dpi to provide 0.5 m pixel resolution. The photographs were registered to the Quickbird image using between 82 and 90 common points. The root mean square (RMS) error ranged between 7.5 and 21.1 (3.8 m and 10.6 m) depending on the polynomial function used (Table 2). Registration points were concentrated around the minesite, with fewer common points identified in the surrounding landscape. As a result, registration was well matched around the minesite and less so outside the mining lease. Delaunay triangulation function (3^{rd} degree polynomial) was used to fit triangles to the irregularly spaced control points in the photos to the Quickbird data. In order to maintain spectral contrast, 'nearest neighbour' resampling method (using the nearest pixel without any interpolation to create the warped image) was applied. The accuracy of the registered photos around the minesite was verified by matching common locations with the Quickbird data and by overlaying vector data of roads and tracks. The RMS error outlined in Table 2 therefore represents the maximum error of the rectification process that applies more to the landscape surrounding the minesite, where fewer control points were identified. On the minesite, geographic offset was not noticeable, suggesting a good fit of digital photographs to the Quickbird data.

Table 2 Number of control points identified and the RMS error for each polynomial function

Date of photo	No. of points	RMS error – 1^{st} degree	RMS error – 2^{nd} degree	RMS error – 3^{rd} degree
30_06_1984	82 points	15.7 (7.85 m)	9.4 (4.7 m)	8.6 (4.3 m)
12_04_1988	86 points	21.1 (10.6 m)	14.5 (7.3 m)	12.6 (6.3 m)
30_06_1989	90 points	19.4 (9.7 m)	10.8 (5.4 m)	9.5 (4.75 m)
03_06_1994	82 points	16.7 (8.35 m)	13.3 (6.65 m)	11.1 (5.55 m)
27_11_1999	82 points	13.7 (6.85 m)	8.5 (4.25 m)	7.5 (3.8 m)

The bare area of interest, surrounded by vegetation, was digitised from the Quickbird data. The area was then overlaid on the aerial photographs for comparison with land use during the various stages of mining. Stereo aerial photographs (available for 1984, 1988, 1994 and 1999) were viewed under a stereoscope to aid interpretation.

Tracks around the pit, bare area and the waste rock dump were digitised from the photographs. The bare landform feature was apparent in the 1994 and 1999 aerial photographs, and was digitised also to show the changing shape of the bare area.

3 Results

The location of the bare area, digitised from the Quickbird data, is shown on the 1989 aerial photograph (Figure 1). The area is to the southwest from the base of the pit. The area identified from the Quickbird data (Figure 2) covers 1055.3 m^2. The north western corner is roughly 317540.7E 8638427.9S, the south western corner is 317563.7E 8638382.9S, and the further most point at the eastern side is 317581.4E, 8638408.1S (coordinates in GDA94).

Figure 1 1989 aerial photograph with the bare area (red), obtained from the Quickbird data overlaid (area is to the south west of the pit)

Figure 2 Extent of the area (red), as interpreted from the Quickbird data

The location of the area, as interpreted from the Quickbird data is overlaid on the 1984 photograph (Figure 3), 1989 photograph (Figure 4), 1994 photograph (Figure 5) and 1999 photograph (Figure 6). Figures 3-6 show the general relationship of the area with the mining activities at the time of aerial photograph acquisition. This relationship was best interpreted using stereo photographs under magnification, the results of which are described in the discussion.

The stereo view highlighted a change in the area being associated with a change in the road network. Figure 8a-d illustrates the changes in road networks around the pit and area of interest during 1984, 1988, 1989 and 1994. These changes are highlighted in Figure 9.

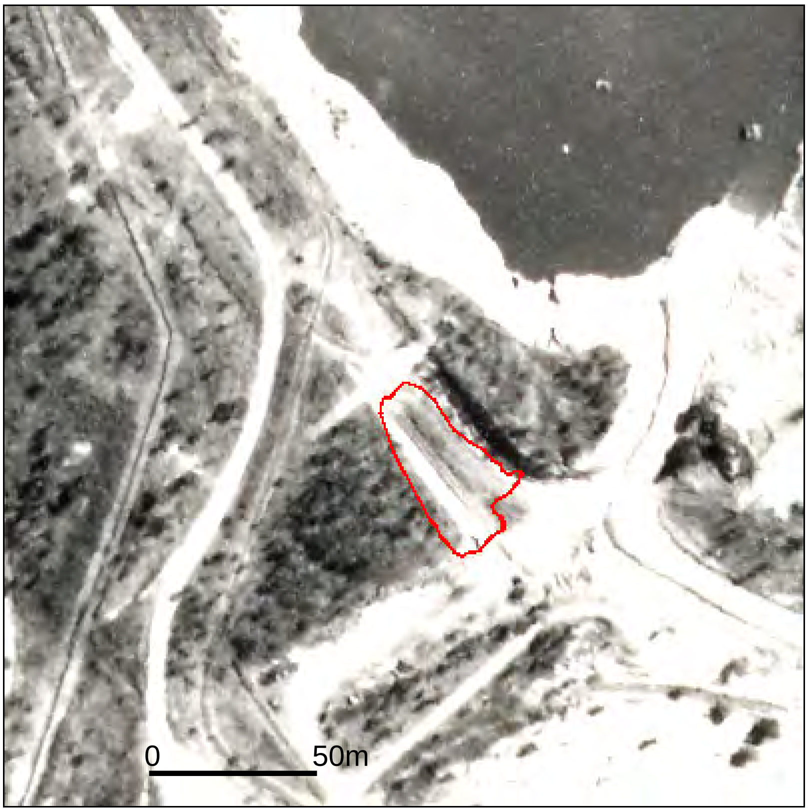

Figure 3 Digitised area (from Quickbird data) overlaid on a subset of the1984 photograph. Part of the pit water occupies the NE corner.

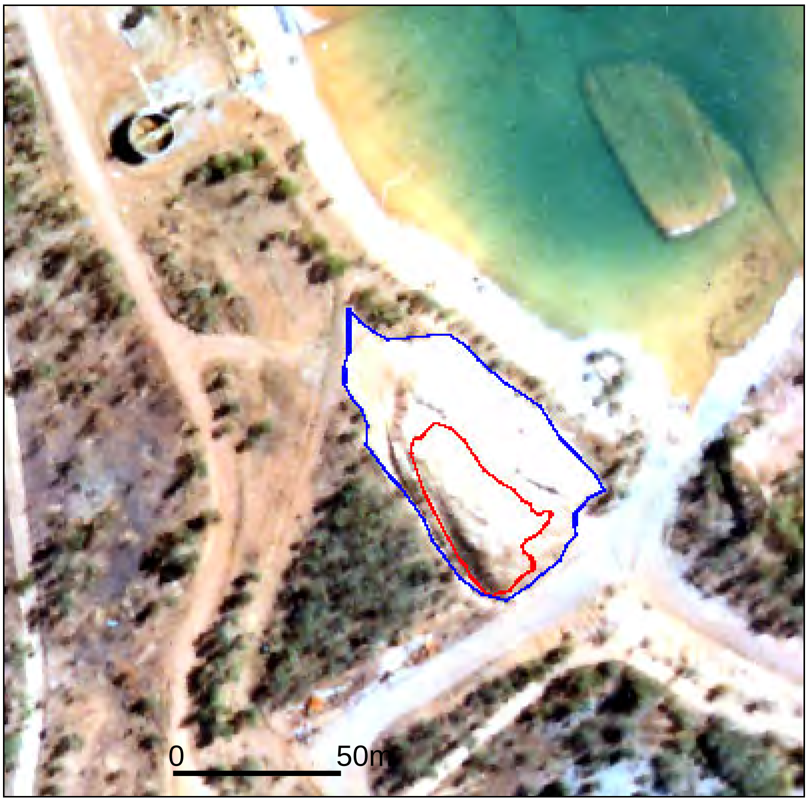

Figure 4 Digitised area (in red from Quickbird data) overlaid on a subset of the 1989 aerial photograph. The extent of the bare area as seen in the 1989 aerial photograph is highlighted in blue.

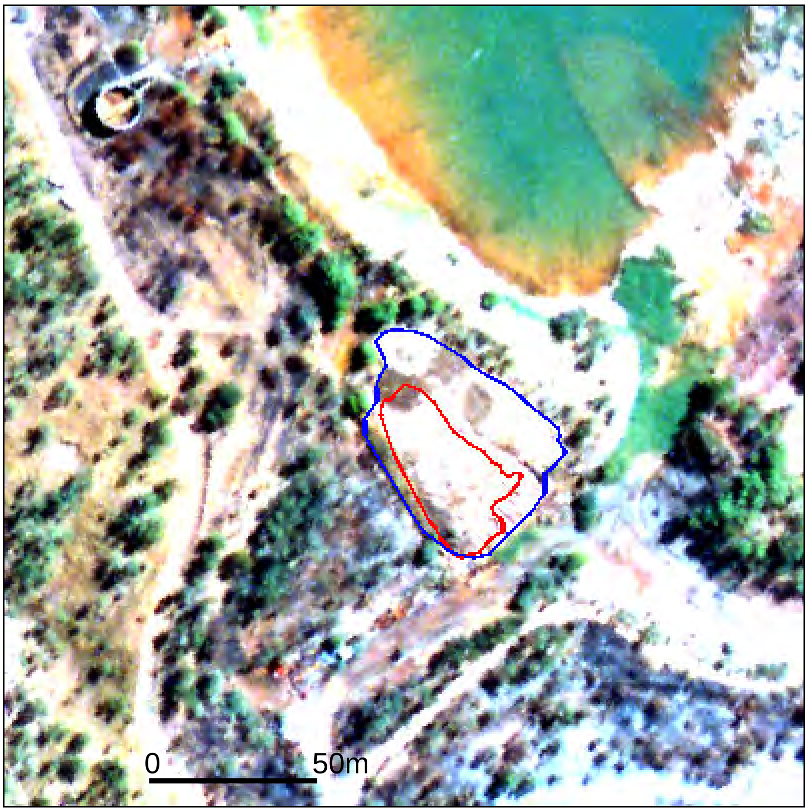

Figure 5 Digitised area (in red from Quickbird data) overlaid on a subset of the 1994 aerial photograph. The extent of the bare area as seen in the 1994 aerial photograph is highlighted in blue.

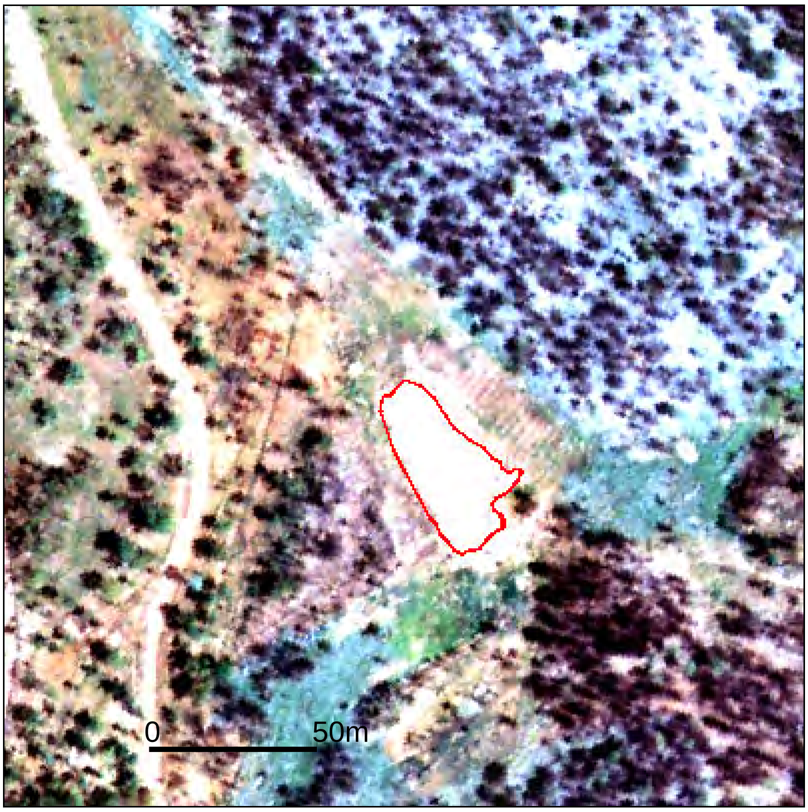

Figure 6 Digitised area (in red from Quickbird data) overlaid on a subset of the 1999 aerial photograph

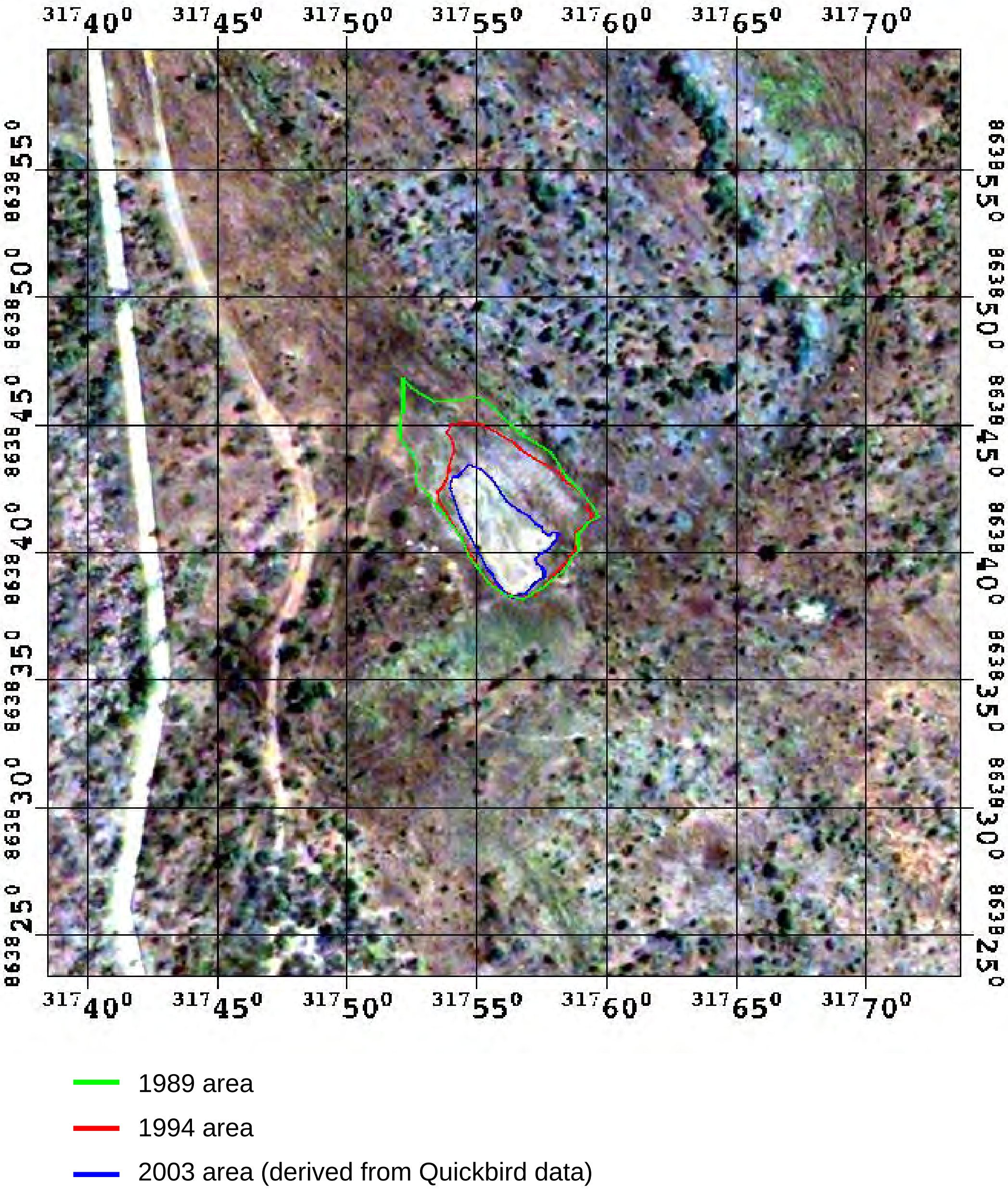

Figure 7 Quickbird data with digitised bare area overlaid from the 1989 (green) and 1994 (red) aerial photograph interpretation and the digitised Quickbird polygon (blue). Coordinates are in GDA94.

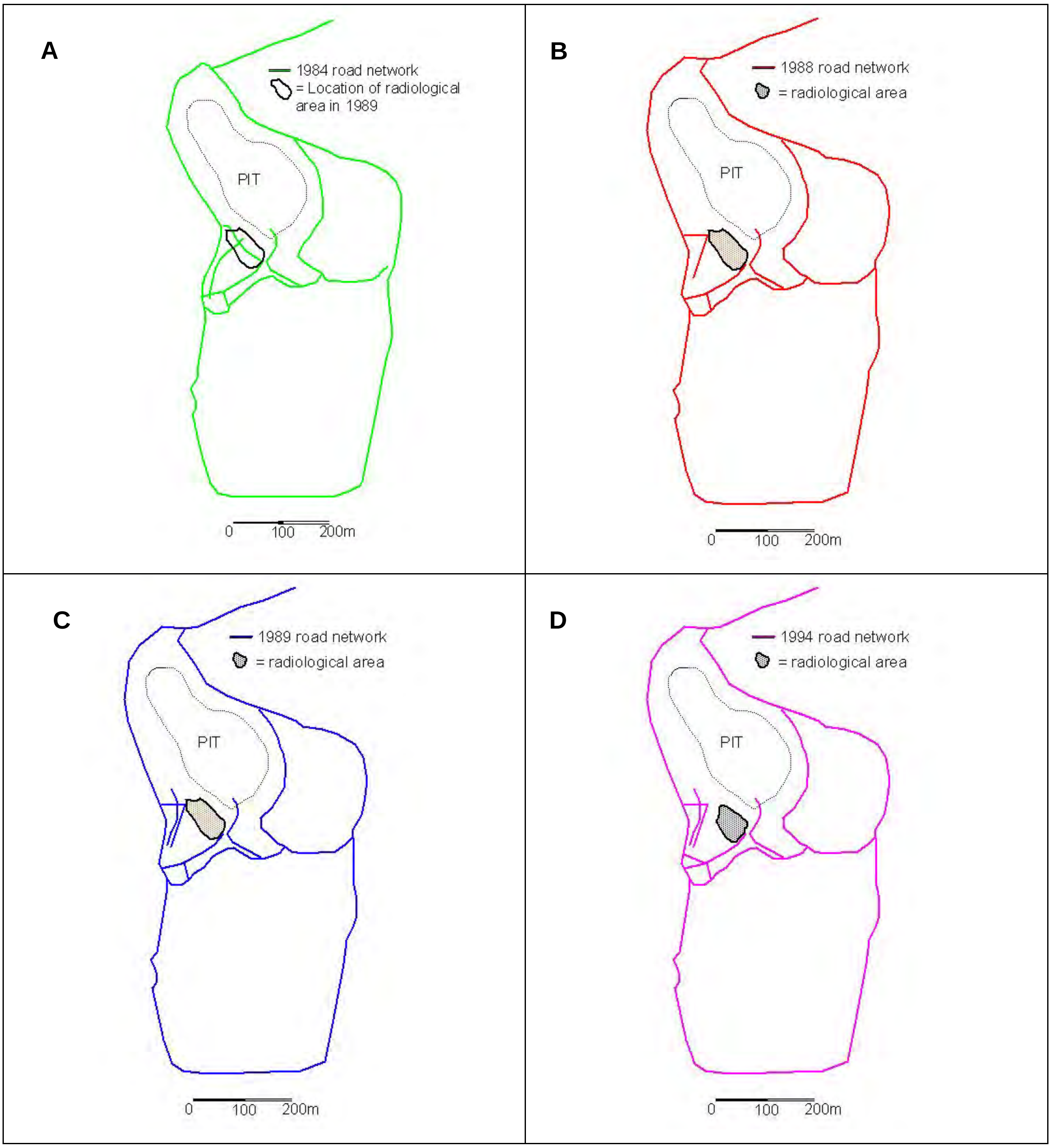

Figure 8 Road networks digitised from aerial photography. A) 1984, B) 1988, C) 1989 and D) 1994.

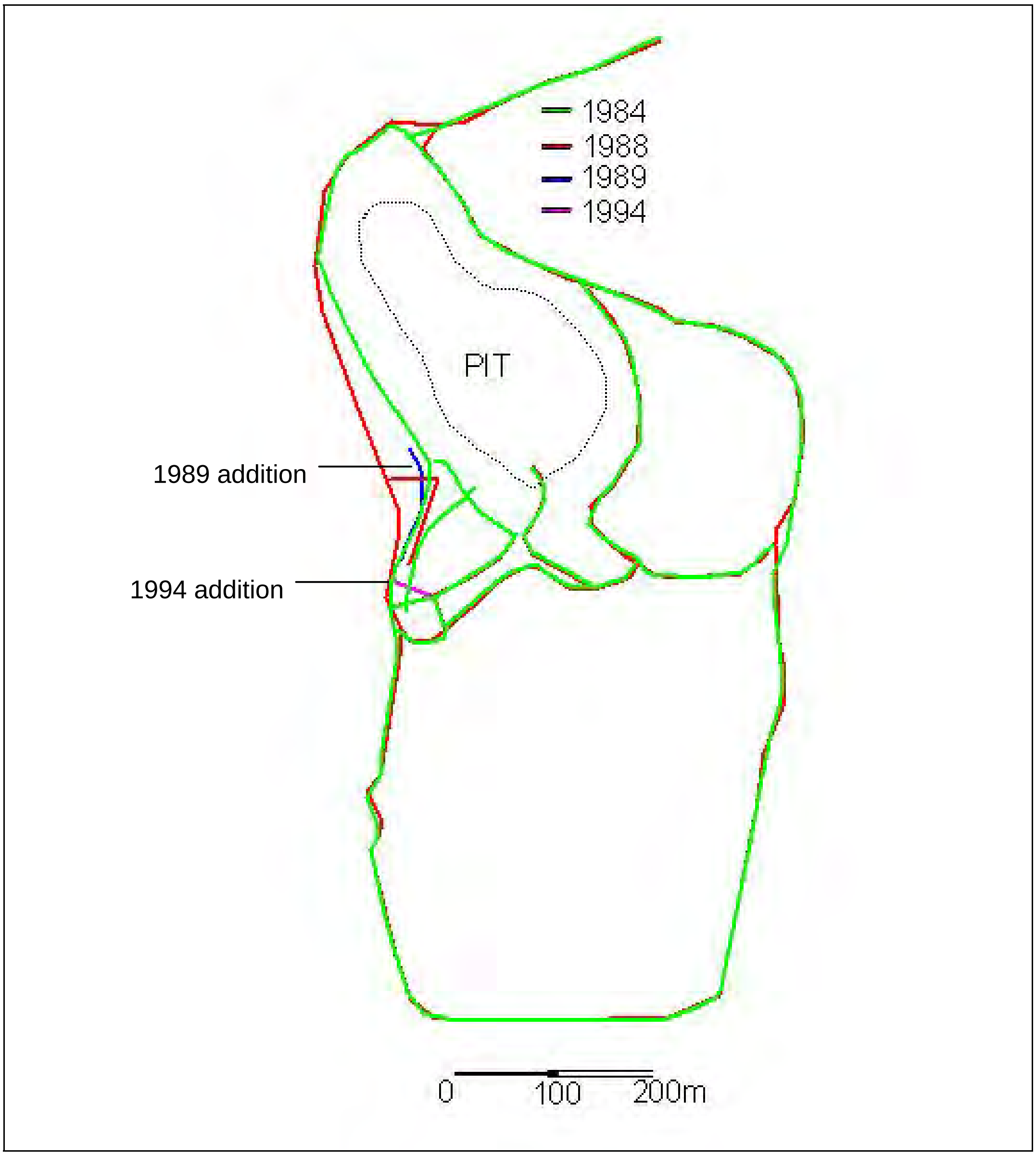

Figure 9 Changes of road networks around the bare area are highlighted. Most of the changes to the road network occurred between 1984 and 1988.

4 Discussion

The current extent of the radiological anomalous area was visualised from the Quickbird imagery as a bare sediment area devoid of vegetation (Figure 2). Whether this area encompasses the real area of *radiological* extent during and post mining operations is unknown, but the results described below suggest that the bare area during mining operations was at times greater than the extent on the rehabilitated surface. The area digitised corresponded to changes in landform over the sequence of aerial photographs and therefore suggests that the general area was a result of mining operations. The area digitised from the Quickbird data corresponds very well with the spatial location of bare sediment in the 1999 aerial photograph (Figure 6), suggesting that the area lacked vegetation at the time of rehabilitation.

The bare area defined on the Quickbird data is overlaid on the 1984 photograph in Figure 3. Under stereo view, the area corresponds to a southeastern sloping landform that is lower in elevation than the vegetated areas bounding the western and eastern side. There appears to be a linear feature on the western edge of the area that was interpreted as a road (Figure 8a), however, to verify this, other sources of information would be required. There does appear to be a network of roads leading to and from the area.

Figure 4 illustrates the 1989 aerial photograph with the area identified from the Quickbird data overlaid. The area corresponds to bare sediment, the boundary of which is greater in the aerial photograph (3323.4 m^2) compared to the Quickbird (1055.3 m^2) area. By contrast to the 1984 interpretation, the area appears to be higher in elevation than the immediate surrounds, visualised as a pile of material. No longer could a linear feature, interpreted as a road (Figure 8c) be seen dissecting the area, but roads intersected the boundary of the area.

Figure 5 illustrates the 1994 aerial photograph with the area identified from the Quickbird data overlaid. Like the 1989 data, the area corresponds to a bare sediment area, the boundary of which is greater in the 1994 aerial photograph (2526.5 m^2) compared to the Quickbird (1055.3 m^2) area, but smaller than that interpreted from the 1989 photo. The decrease in extent in 1994 compared to 1989 is that the northwestern edge has decreased and trees are growing in place. The stereo view showed that the area appears to be at a similar, or higher elevation compared to the immediate surrounds of the area. The edge of the area slopes quite steeply to the southeast. By 1994, there was no obvious road network intersecting the bare area (Figure 8d).

A stereo interpretation of the 1999 photo (Figure 6) shows the area on the rehabilitated landform sloping to the southwest.

Figure 7 illustrates a subset of Quickbird data with the digitised areas overlaid from the 1989 and 1994 aerial photograph interpretation. The digitised Quickbird polygon is overlaid for comparison. For the purpose of ground investigations, it would be logical to include the greater extent of areas that appeared bare in the aerial photographs.

Figure 9 illustrates the changes of road networks around the radiological anomalous area. Most of the changes to the road network to the area occurred between 1984 and 1988. Little change to the road network occurred after 1989.

5 Conclusion

An area lacking vegetation was identified using temporal aerial photography and Quickbird satellite imagery from 1984–2003. This area showed changes in extent, elevation and slope during mining operations and encompasses the post-rehabilitated radiological anomalous area.

6 References

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Hancock GR, Grabham M, Martin P, Evans KG & Bollhöfer A (in prep). An erosion and radionuclide assessment of the former Nabarlek uranium mine, Northern Territory, Australia.