9. Resource estimation: Uranium at Harties 1-4 and New Machavie

9.1 Introduction

As described under the SAMREC (2009) code, a measured mineral resource is described as a resource for which the grade, densities, and tonnage can be given with a relatively high degree of confidence. An inferred mineral resource is a resource for which the grade, tonnage, etc. cannot be estimated with a high degree of confidence. The New Machavie TDF can be categorised as a "measured mineral resource" since the tonnage, shape, physical character and grade of U was estimated with a high degree of confidence, whilst the Harties 1-4 TDF can be classified as an inferred mineral resource with a low level of confidence. For this reason, the focus of this chapter will mainly be on New Machavie, with some mention of Harties.

9.2 Objectives and motivation

The objective of this section is to estimate the U content of a gold TDF. Included in this objective is the modelling of the location and the spread of U within the TDF, together with estimation of the ore grade of U.

This section proposes the use of radiometric methods, rather than conventional bulk sampling and wet analyses (ICP-MS), for estimating the U resources of gold TDFs. As this method is significantly less expensive, it will save costs and increase the detail of the modelling results since more data is gathered at a fraction of the cost compared to conventional methods.

9.3 Methodology

As discussed in previous chapters, the New Machavie TDF was drilled at 60 m intervals and some parts were drilled at 30 and 15 m intervals. Samples were taken at 10 cm intervals at each drill hole using a core sampling system. Each hole was logged using a down-hole natural gamma spectrometer and samples were assayed in a laboratory with a lead-shielded natural gamma spectrometer (Section 4.4). Seventy randomly selected samples were analysed for U content using acid digestion and ICP-MS analyses. These samples were then used to calibrate and correct spectrometric results. The calibrated results were then used to construct 3D models of the U ore and to calculate the grade. The models were constrained by a digital elevation and stratigraphic model, obtained by an elevation survey and the depths of bedrock below the TDF as measured during drilling. The results of the statistical comparison showed that the down-hole spectrometry proved to be the most accurate and reliable method. The ore grade was determined using this method with comparisons of the distribution of U made from the laboratory assays.

9.4   Harties 1-4

9.4.1   Natural gamma scintillometry

As part of the initial feasibility study of this project, Harties 1-4 was drilled along a profile to a depth of 6 metre. Profile A-A', which is plotted in a north-south direction, was drilled along the transect indicated in Figure 4.1. Detailed elevation data were not collected, therefore a relative elevation profile was used. Each borehole was logged using a natural gamma scintillometer. Results in CPS were converted to ppm by using ICP-MS results of samples taken at 1 m intervals, and using the matrix equation as described previously (Section 5). Natural gamma scintillometry only measures the total counts at a specific point and does not differentiate between the radionuclides that produced the radiation (IAEA, 2003). For this reason, CPS is converted to equivalent U (eU) in ppm since U, and the daughter products of U, tend to dominate the radioactive portion of the material (Richards, 1981., Aswathanarayana, 1985., IAEA, 2003). Prior to modelling the data, normality was checked and highly erroneous data was removed (readings exceeding 4 sigma). The data were then interpolated using IDW with a strong directional weight algorithm to produce cross-section A-A' (Figure 9.1). This figure represents the north-south cross-section which also shows the profile of the TDF from the upper beach of the TDF (left) to the location of the old penstock drain (right), a few metres away from borehole S30. The position of each borehole is indicated, i.e. S2, S4, etc.
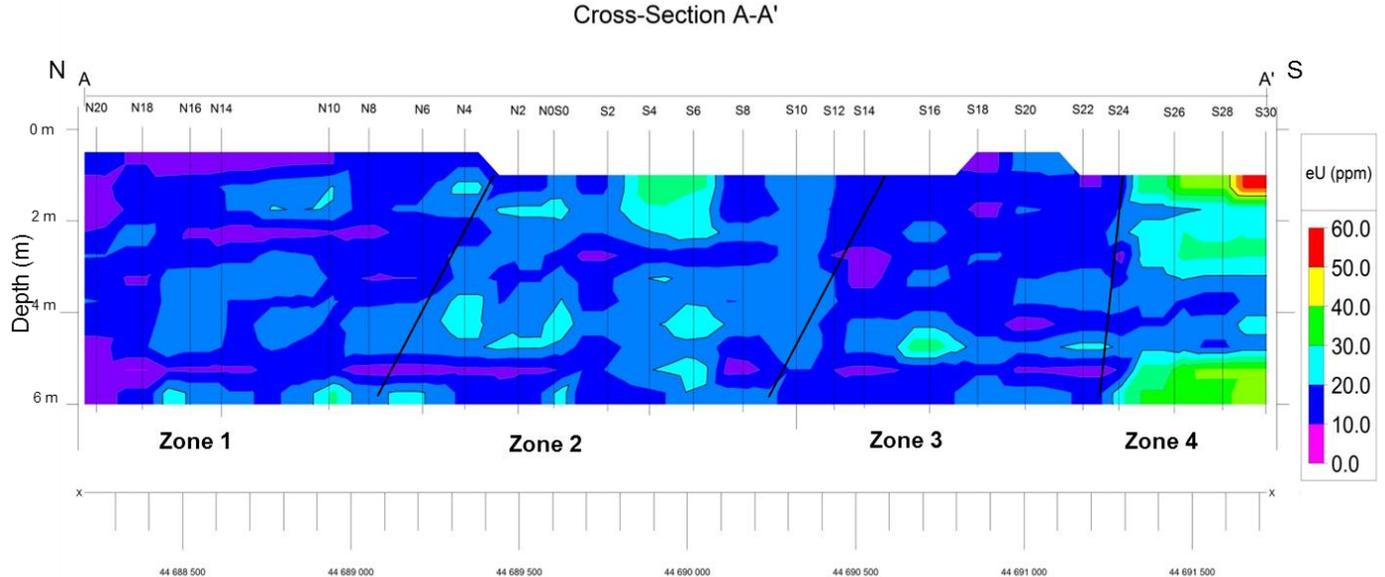

Figure 9.1: Harties 1-4 eU Profile

The general trend observed in Figure 9.1 shows low eU in the north and high eU in the south. Other trends observed can be broken down into four zones as indicated in Figure 9.1. Zones 1

and 3 indicate a relative decrease in eU compared to zone 2, whilst zone 4 has a very high eU content. A number of factors may be responsible for the formation of these zones including hydraulic properties of the TDF, particle size variation due to the depositional method, oxygen penetration, etc. Without further research the effects cannot be explained in detail.

As a preliminary application, the results of Harties showed that variation in U does occur within gold TDFs. Higher U grades can be expected towards the centre of the TDF where particle size is also the smallest. Further research is needed to quantify the effects of spatial variability of the concentration of U as an ore body in gold TDFs.

9.5   New Machavie

9.5.1   Surface natural gamma spectrometry

The results of the surface natural gamma survey done on New Machavie is indicated in Figure 9.2 and Appendix C. Higher U content were found on the lower side slopes of the TDF and to the southern side of the TDF (Figure 9.2). During the drilling phase, it was found that the flow direction of water within the TDF was towards the south-east of the TDF, where the saturated zone was found closest to the surface of the TDF. The topography of the study area is lower to the south-east, meaning that the natural flow direction is maintained within the TDF. Consequently, mobilised radionuclides have accumulated in these lower and wetter areas as they are in the process of leaching (as seen in the results of the U migration modelling, Section 8). During field measurements, care was taken to prevent the effect of vertical attenuation of the slopes from increasing gamma readings and thus concentration data.

Down-hole probing and sampling showed increased U with depth in the southern area, which correlates well with the surface data. Field observations confirmed leaching of fluid from the lower southern slope of the TDF where the saturated zone was also observed to be higher during drilling. The top of New Machavie TDF presented a noticeable decrease in U content compared to lower sections in the TDF, which can be attributed to the mobilisation and subsequent leaching of U during the oxidation of the tailings, as well as the insolubility of radionuclides in the saturated zone where reduction of radionuclides to immobile occur.
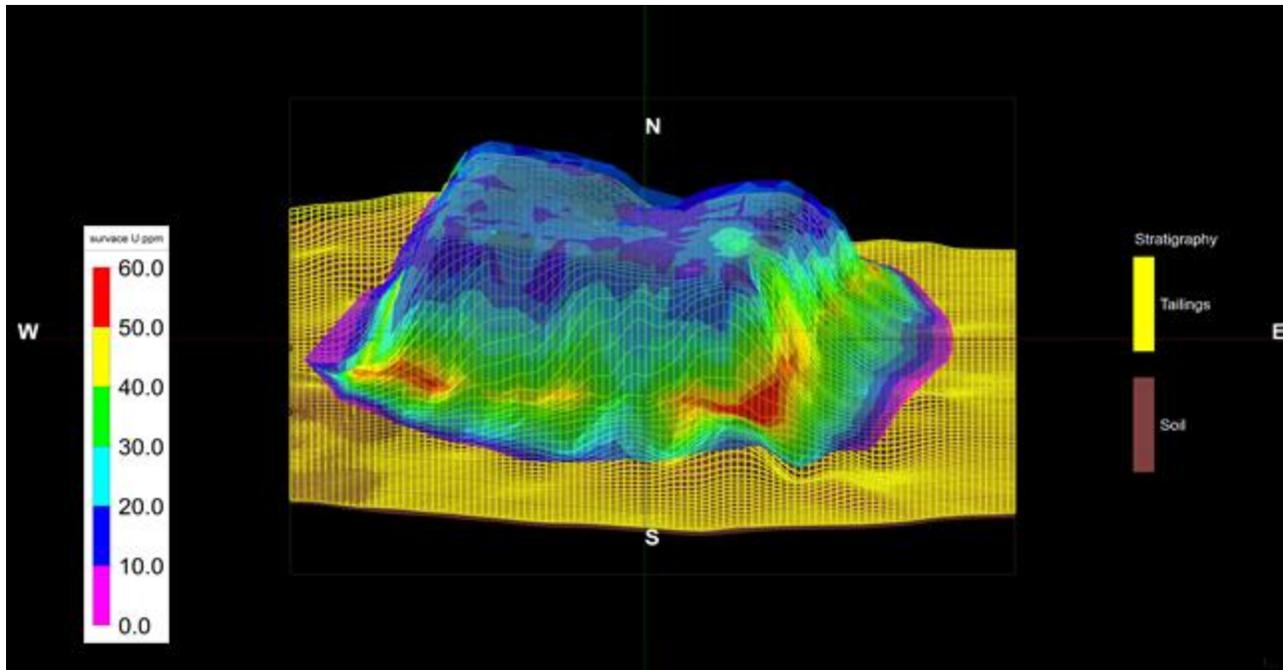
Figure 9.2: Surface natural gamma spectrometry

9.5.2 Uranium resource estimation

Elevation and stratigraphic (tailings and soil) modelling was used to calculate the volume of the New Machavie TDF which showed that the TDF has a total volume of 81834.62 m^3. With an average density of 1400 kg/m^3 (Vermeulen, 2001), this equates to 114568.468 tons of tailings material contained within the TDF.

Table 9.1 expresses the percentage composition of the TDF as classified by 5ppm U content ranges and calculated from volume, mass and concentration data. The total U content of New Machavie equates to 2376722.91 g. Although this is a relatively low grade ore, one must consider that U will be mined alongside gold, meaning that U can be used to offset certain production costs, whilst maximising the turnover of the mining operation. Table 9.1 also expresses that 59% of the U content of the TDF is between the ppm ranges of 20 and 35.

Appendix B is the results of the laboratory sample assays and shows similar results as the down-hole spectrometry; however, with lower resolution as samples were taken every 10 cm compared to the 2 cm sampling interval of the down-hole data.

Table 9.1: U content of New Machavie

U (ppm) range and U ore grade (g/ton)	Percentage of volume (calculated using Rockworks 15)	Tons of tailings	Total U composition (g)
0 – 5	2.11	2417.394717	6043.486793
5 – 10	13.3	15237.60651	114282.0488
15-Oct	19.67	22535.61805	281695.2256
15 – 20	12.66	14504.3683	253826.4453
20 – 25	15.17	17380.0369	391050.8302
25 – 30	19.49	22329.3948	614058.3571
30 – 35	10.57	12109.88728	393571.3366
35 – 40	3.92	4491.084024	168415.6509
40 – 45	2.85	3265.201395	138771.0593
45 - 50	0.11	126.025317	5986.202558
50 - 55	0.15	171.852705	9022.267013
Total U content (g)			2376722.91

9.5.3 Down-hole natural gamma, uranium modelling results

Profile B9 (Figure 9.3) and Appendix A indicates that U concentrations ranging between 20 – 35 ppm occurs below the oxidized zone (light blue to green) Profiles were drawn along profile lines indicated in Figure A.5. Within the oxidized zone, U is mobile and leachable; however, some variations were observed, Figures A.7, A.11, A.16 and A.24. In these profiles U concentrations of up to 40 ppm can be found closer to the surface (left side of Figure A.11, 30 – 400ppm range at surface). These cases occur at the southern and eastern slopes respectively as seen in Figures A.1 and A.3. Figures A.1 to A.4 relates well with the surface natural gamma results, indicating higher U content at the south-eastern corner of the TDF.
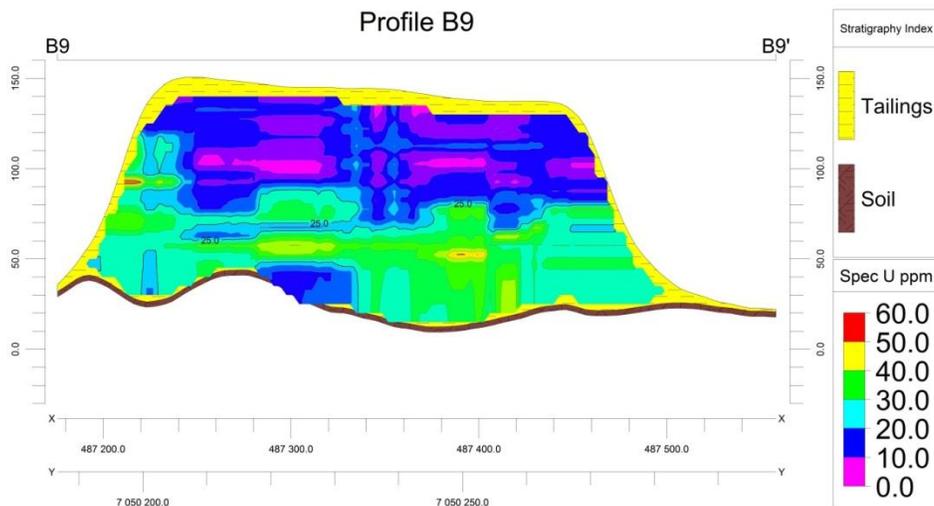
Figure 9.3: Profile B9 down-hole U

9.5.4 Grid spacing

Grid spacing refers to the distance between sampling points as located in a grid formation. Grid spacing affects models since the detail or resolution of data, as well as the accuracy of interpolation methods, is influenced. Closer spacing delivers more accurate results and increased resolution when interpolated but naturally comes at a significantly higher cost. McKillup & Dyar 2010

On New Machavie, a section of the TDF (south-eastern pool) was drilled at 15 m grid spacing, in order to evaluate the effect of grid spacing on the modelling results. Figures 9.5 to 9.7 show three profiles at different grid spacings; 15, 30 and 60 m grid spacings, respectively. The 60 m spacing profile shows only slight variations with respect to the 30 m spacing profile. The 15 m grid spacing shows more detail than the 30 and 60 m grids, for example only one portion within the 0 to 5 ppm range (pink) is seen in the 30 and 60 m profiles, whilst the 15 m profile shows 3 areas (Figures 9.5 – 9.7). Ideally one would drill at a 15 m grid spacing for the best modelling results, depending on the purpose of the project. For this resource estimation, a grid spacing of 60 m was accurate and cost effective.
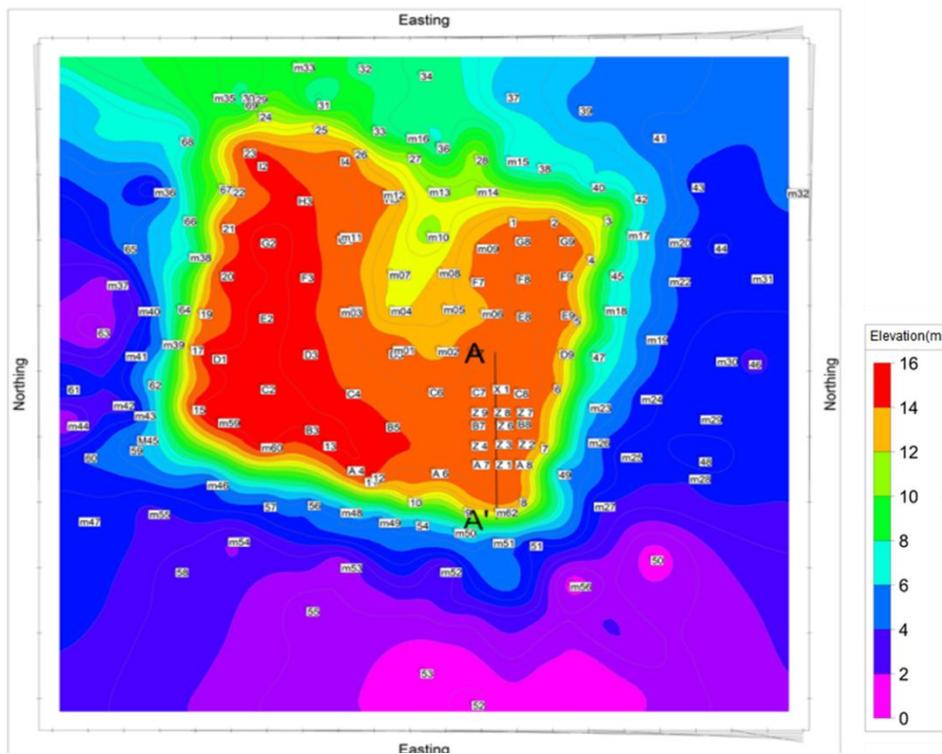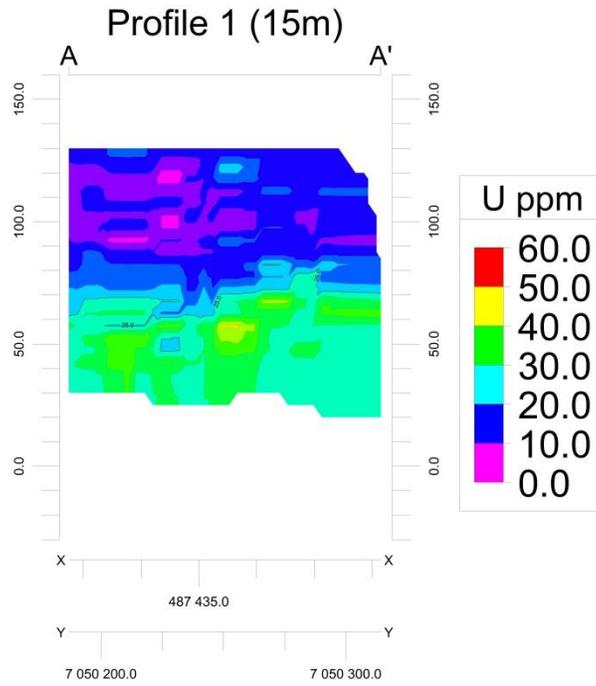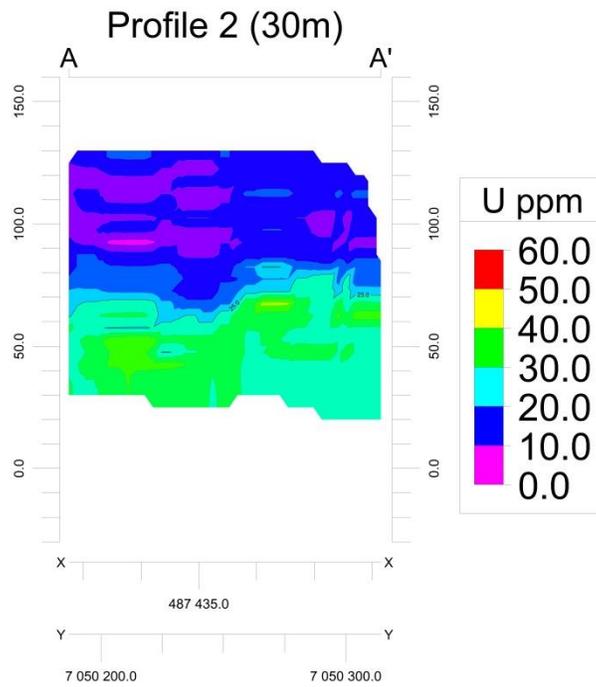

Figure 9.4: Profile location of grid spacing tests

Figure 9.5: 15 m grid spacing

Figure 9.6: 30 m grid spacing

Figure 9.7: 60 m grid spacing

9.6   Conclusion

U grade varies between 0 and 55 g/ton within the New Machavie TDF (Table 9.1). The highest content occurs lower in the TDF suggesting that mobilisation of the upper portions have occurred as the tailings were deposited without segregation, based on U content. This mobilisation either moved U lower in the TDF or into the surrounding environment. The total U content of the TDF was estimated as 2376.72291 kg which is only viable to mine if gold is mined concurrently. The New Machavie TDF showed higher U content on the slopes than expected. The oxidation zone of gold TDFs can always be found on the side slopes as well as on top. The highly oxidized environment of the side slopes should favour mobilization and leaching of U away from the TDF. However, in the New Machavie TDF higher U content is seen. The climate in the area indicates that evaporation exceeds precipitation which will allow leachate near the surface to move towards the surface due to evaporation. The results of the surface natural gamma and the natural gamma down-hole probing complemented each other. A possible reason may be that leach water (pore water in the process of flowing from the TDF) with higher U content was detected where the formation of iron oxides allowed the adsorption and immobilisation of U in oxide crusts (Photo 9.1); however, further research is needed to give a proper explanation.

Photo 9.1: Formation of iron oxides at New Machavie (Photo by P.W. van Deventer)