THE CARNAMAH RADIOMETRIC TEST RANGE.

A review of the ground calibration methods used to date.

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ABSTRACT

Following the publication of the AGSO Record 1995/60 in 1995, annual aircraft spectrometer calibrations to derive the sensitivity coefficients (counts per second per unit concentration), and the height attenuation coefficients for each IAEA window, have been requirements for government and some company contracts.
To derive these coefficients, an aircraft is flown along a strip of land with known average concentrations of Potassium (K), Uranium (U) and Thorium (Th), at a series of controlled altitudes.
Ideally, the ground radioisotope concentrations should be uniform each side of the centre line in the plane normal to the flight path, for a distance equal to approximately three times the maximum flying height.
This uniformity will affect *the degree of correlation between the airborne data and the ground data* as well as the degree to which the observed height attenuation coefficients *fit the theoretical model of radiation attenuation with altitude.* See AGSO 1995/60 app. C. and **Figure 2**
The Carnamah test range has not been thoroughly checked for lateral homogeneity. However, data from height attenuation stacks yields the expected Th, U, K, T/C theoretical values, which would indicate the range performs as though it were homogenous.

The test range ground concentration information is gathered (at the same time the aircraft is flying the range), using a suitably CALIBRATED and stabilised, 256 channel, portable spectrometer. This data is then used to produce the sensitivity coefficients for the aircraft spectrometer.

A full discussion of calibration range criteria can be found at Appendix C of Record 1995/60.

INTRODUCTION

In 1995 the only recognised Australian calibration ranges were in the Eastern States of Australia. The majority of the geophysical aircraft in Australia are based in Perth, Western Australia. This made it difficult to perform calibrations on a regular basis.
Early in 1996, Greg Steemson, (then of DOME W.A.) organised a committee consisting mainly of the Perth based operators, to select a suitable test range.
After suitable scrutiny it was decided that the proposed Pinjarra Test Range was unsuitable due to the large number of landowners involved, the nature of the farming activities and the Southern end of the range being in a flood irrigation area.
It was necessary to choose an alternative site. After researching all the available radiometric data close to the Perth area, it was decided that a suitable site existed under a high voltage power line in the Carnamah area.
During 1997 this test range has been used by most of the Perth based operators of airborne spectrometers.

While it is acknowledged in the AGSO 1995/60 paper (appendix B), that the portable spectrometer used to calibrate the test range should be **calibrated**, there are no instructions describing the methodology, frequency or recording of the calibration.

The method for taking the ground readings is not specified, with spot readings, walking while integrating readings and travelling in a vehicle while accumulating readings being mentioned. The walking option raises the question of obstruction due to the operator's legs. The vehicle option adds a background contribution and requires a specialised hardware set-up.
Both the latter methods can produce variable ground results when done by different personnel.

This variability must be avoided when attempting to calibrate aircraft spectrometers such that similar systems calibrated by different companies yield similar counts/unit concentration figures.

DISCUSSION

To successfully calibrate an airborne system it is logical that the hand held spectrometer used to survey the range, have calibration credentials traceable to an acceptable source. This calibration should be performed annually, an interval similar to that required of the aircraft system. This spectrometer should be checked against local calibration pads at the time the annual calibration is performed, then a confirmation check performed before and after it is used to calibrate the test range.

The Test Range (measured at the power poles) has average mineral concentrations approximately as follows:

Dry soil = K = 3.11%, U = 4.05 ppm, & Th = 36.76 ppm.

Damp/Wet soil = K = 2.86%, U = 3.73 ppm, & Th = 33.97 ppm

The majority of the range consists of ploughed wheat paddocks with Granite outcropping. The monuments consist of three power poles (about 4 metres apart) at approximately 300 metre intervals. Either rocky outcrop (at the northern end), or ploughed paddocks separate them. Originally, the ground spectrometer surveys consisted of approximately 76 readings taken at approximately 100 metre intervals. See **Table 1.**

The readings taken at the poles are, for the most part, relatively repeatable. However there can be large variations from one side of the poles to the other. The reading location should be standardised to that indicated on the station list. **Table 2**.

Readings taken between poles are, for the most part, in ploughed paddocks and therefore cannot be monumented. In places there are considerable variations in concentration within a small area, due to the rocky nature of the soil.

The Test Range should be flown visually whenever possible, as it is not straight between the end points.

TEST RANGE LOCATION

The test range is located approximately 9 kms East of the township of Carnamah (approximately 300 kms North of Perth), on the Moora to Bunjil road. The start or Northern most end, is accessed from the bitumen Carnamah – Bunjil / Belvoir road. The test range follows the high voltage power line South for approximately 8 kms, crossing one secondary gravel road and ending at a second gravel road 6.5 kms from the old town site of Winchester. The Southernmost end crosses a large seasonal creek bed and this area should be treated with caution in the winter months. See **Figure. 1**

How to get there.

From Perth take the Great Northern Highway, past Bindoon turn left onto the Midlands Road to Moora – Coorow. Approximately 80 kms North of Moora the road crosses a causeway alongside a small lake system. This water is shallow and fresh enough to do an instrument background check.
At Carnamah proceed east on the Bunjil Road for about 9 kms where the road climbs a low, scrub covered rocky hill and passes under the three-strand high voltage power line. Turn right through the gate under the power line.
If the weather conditions are suitable, the range can be exited at the Southern end and by proceeding to the South/West, back onto the Midlands Road at Winchester.
The majority of the Test range is located on a single property so access permission is not a major issue.

The property owner's details are: -

Mr. Alan Griffiths
P.O. Box 50
Carnamah
W.A. 6517.

Tel. 08 99511213
Fax 08 99511344

Test range end co-ordinates.

The test range has the following WGS84 UTM end co-ordinates: -

400879E 6715819N
401579E 6708270N
ZONE = 50

These co-ordinates are rounded to extend the line slightly past the first and last readings.
The power line does not fall in an absolutely straight line; rather it has a gentle curve along the region of the test range.
If the aircraft is not following the line visually, but navigating via DGPS, then a navigable mid point should be picked from the list of pole locations in **Table 2.**

RADON TEST LINE

A suitable Radon test line exits over the nearby Yarra Yarra salt lake. The K, U, Th concentrations on this 2.5 Km line are so low they can be ignored. The surface of the lake is 20 m lower than the lowest point on the test line. The end points in WGS84 UTM's are:

387141E 6708650N
387141E 6706150N

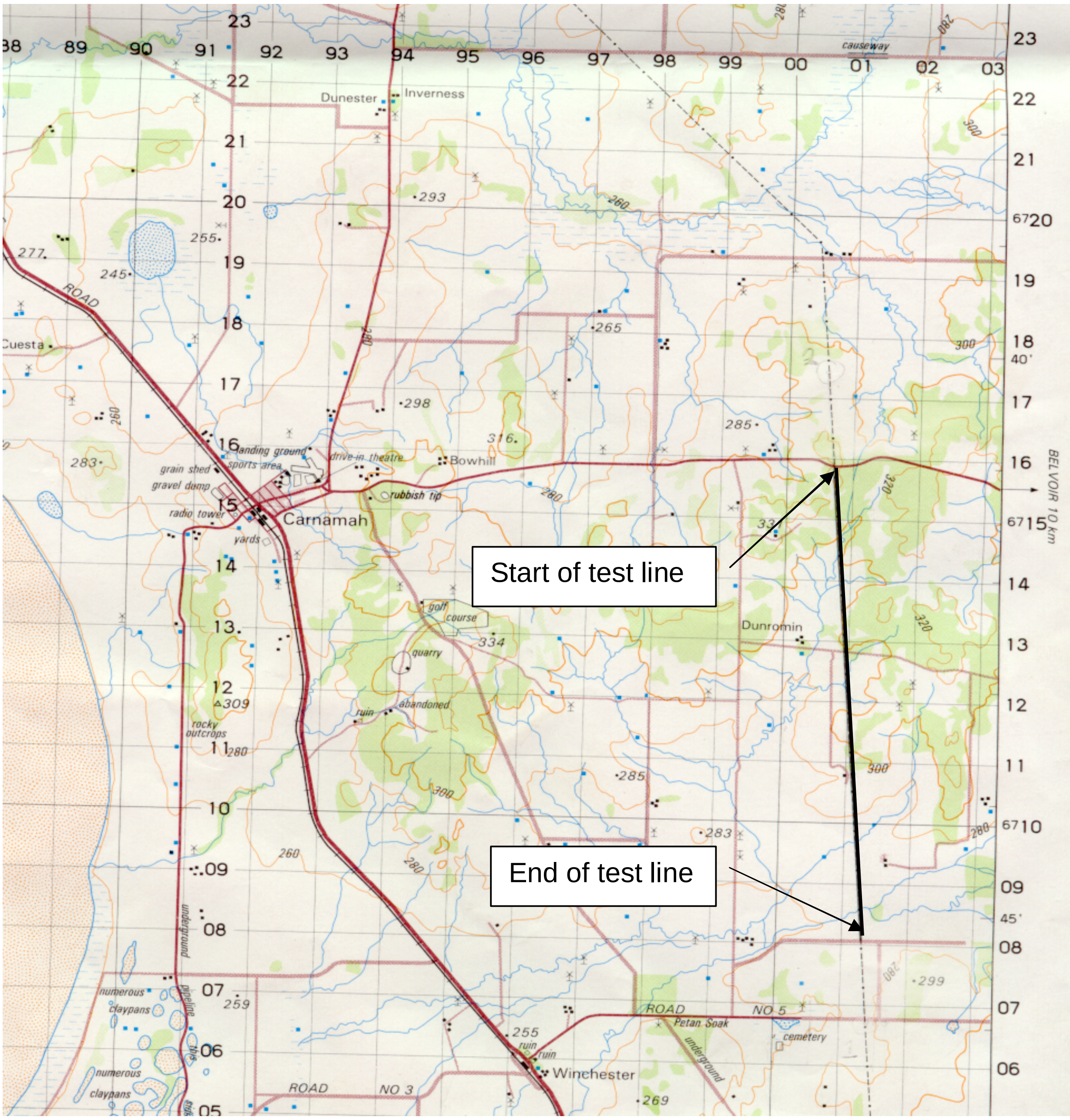


Figure. 1. Location map of the Carnamah Test Range.

ORIGINAL 1997 PROCEDURE

The range has been used approximately 6 times during 1997. The ground survey readings have been taken at the 25 power poles and at 100 metre intervals ***between*** the poles. **Table 1** provides the full station list.

A modified station list for 'Pole Only' use is included. This has a column for filling in the reading number logged in the spectrometer as well as the pertinent weather details for the range (this is important, as the weather and soil moisture have a marked effect on the range concentration numbers). See **Table 2.**

The results have shown some variability. The main problem would seem to be the accurate location of the sample points *between* the power poles. In surveys prior to that in Jan 1998, there were cases of too many or too few readings for the 76 data points. This resulted in considerable confusion as to just which readings should be attributed to which station.
Readings have historically been taken by accumulating a 100-second sample while moving the sensor around a three metre square, pausing at the corners for 20-25 seconds. This method introduces less concentration sensitivity errors than walking the spectrometer, and also reduces the 'nugget effect'. However, it does not lend itself to reproducibility. A good method of taking a reproducible spectrometer reading at a monumented station would be to fit a frame to the sensor such that it was positioned approximately 0.5 m above the surface and stationary. The sensor cable should be of sufficient length to let the operator position the console at least three metres from the sensor. Position the vehicle at least 10 metres from the sensor.

An analysis of six of the surveys to date indicates that when lightly edited, the averages obtained when only the 25 pole locations are sampled, are within $\pm$ 3% for Uranium and $\pm$ 2% for Potassium and Thorium, of the averages of all 76 data points. The means of the six differences are at worst 1.04% for Thorium and close to 0.5% for K and U. **(Figure. 3 & Table 3.)**

Profiles of co-located ground and 40 metre altitude downward continued Potassium, Uranium and Thorium data compare favourably for both the 76 station (all stations) and poles only data sets. (**Figures 8, 9 & 10.)**

The sampling of the 'poles only' stations has a great attraction when compared to sampling all the points for the following reasons:

- The time taken to make the readings is halved. This has merit when it is remembered that at present the ground crew is departing Perth at 04:30 and getting back after 18:00, and in summer the temperature is in the high 30's.
- The sample stations can be permanently monumented as ploughing does not extend close to the poles.
- As the station number is painted on the appropriate pole, it should reduce the incidence of station confusion.

SOME TEST RANGE REQUIREMENTS

Good vehicle access.

The 300 kms drive from Perth is already pushing the ground accessibility point.

A manageable spectrometer.

Keep the system limited to a hand held spectrometer in point reading mode if possible.

Unambiguous marking of the station monuments.

The power poles have the station numbers painted on them.

Ground calibration to be achieved in one working day.

If all 76 stations are sampled or the whole 8 kms is walked taking 100 second readings, then the time on the range plus the time to get there and back is excessive.

Reproducibility.

This is possibly the most important issue. The hand held spectrometer should have a traceable calibration history and be checked pre and post range. The locations sampled on the range must be reproducible. The ability to reproduce aircraft spectrometer concentration sensitivities during subsequent range calibrations (assuming the actual range activity is identical) is equally important as the absolute accuracy of the results.

PROCESSING THE OBSERVATIONS

Density/Geometric Correction Factors.

These are used to modify the numbers derived from a set of "**finite"** calibration pads to make them look "**infinite**" and are particular to a specific sized sensor in a specific location on a given pad. They are used primarily to calibrate elemental concentration sensitivity (counts/unit conc). To this end they are relatively redundant for stripping calculations, however, as some programs solve for all the calibration constants (stripping and sensitivity etc.) in one pass, they may be required as an entry.

Filtering.

Filtering the 'full' data set and the 'poles only' data set prior to averaging, did little to improve the percentage deviation between the two, however, it did introduce a marked positive offset in the percentage difference. See **Table 3.**

Seasonal variations.

There are obvious seasonal variations in the averaged concentrations for the range, however the profiles indicate a good degree of correlation in the sampling of the data set. **See Figures. 4 - 7.**

Height attenuation coefficients.

The exponential coefficients are a good approximation for the 40 -150 m altitudes. However, if any Radon contribution is not accounted for, then the coefficients for Uranium and Total Count may be severely compromised. Much discussion has resulted in the following sets of theoretical (Monte Carlo simulated) height attenuation coefficients. (Dr. Jens Hovgaard of RSI and Pavel Jurza of SGC - personal communication).

Isotope	Jens	Pavel
K	-0.0094	-0.0097
U	-0.0084	-0.0087
Th	-0.0074	-0.0075
T/C	-0.0074	-0.0075

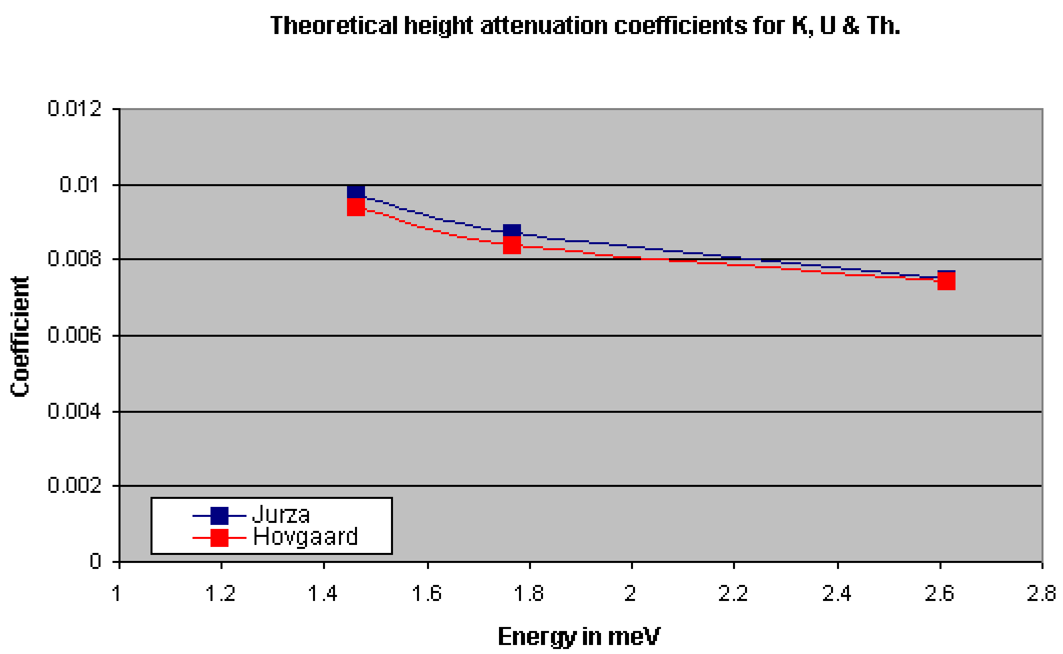


Figure. 2. Theoretical height attenuation coefficients.

- There are many reasons why the calculated coefficients may not match these numbers (range isotope concentration variations, flying height variations, radon etc), however these figures are a very good datum.
- There is general agreement that the coefficients should meet the criteria **Th<U<K**.

RECOMMENDATIONS

- That any hand held spectrometer used be calibrated annually on the CSIRO pads in Sydney. Also against a suitable local pad as a reference.
- That the hand held spectrometer sensitivity be checked on the local reference pad before and after each range calibration to confirm correct operation.
- That the Test Range monuments consist of wooden pegs located 3 meters on the indicated side of the central power pole, in line with the overhead wire.
- That the readings be taken 0.5 metres above the ground, with no operator within 5 metres and the vehicle no closer than 10 metres (use the sensor tripod available).
- That no filtering be applied to the subsequent data set prior to averaging.
- That the theoretical height attenuation figures provided by Dr. Jens Hovgaard be used in all calculations, and the sensitivity coefficients only be derived from the range observations. (Height attenuation is not an instrument dependent variable).

REFERENCES

R. L. Grasty and B. R. S. Minty 1995. A guide to the technical specifications for airborne gamma-ray surveys. AGSO Record 1995/60

J. Hovgaard and P. Jurza 1998. Personal communication.

CARNAMAH TEST RANGE DATA .

GROUND MONUMENT DETAILS

STATION	EASTING AGD66	NORTHING AGD66	LATITUDE AGD66	LONGITUDE AGD66	DISTANCE Metres	Description of ground station.	Surface condition.	Target.
1	400708.4	6715843.6	-29.6822	115.9752		Flagged tree approximately 35 paces in from gate. #1 painted on rock.	Bush out/crop.	
2	400731.5	6715782.7	-29.6827	115.9755	65.2	Flagged tree.	Bush out/crop.	
3	400730.5	6715738.8	-29.6831	115.9754	43.9	Flagged tree. Green paint on rock.	Bush out/crop.	
4	400737.8	6715668.6	-29.6837	115.9755	70.6	Power pole. Read South.	Bush out/crop.	pole
5	400747.7	6715581.6	-29.6845	115.9756	87.6	Just to South of flat rock, #5 in green on rock.	Plough v/rocky.	
6	400760.1	6715460.3	-29.6856	115.9757	121.9	5 metres to North of rock pile, #6 painted on rock pile.	Plough rocky.	
7	400771.9	6715347.9	-29.6866	115.9758	113.1	Power pole. Read South.	Plough soil.	pole
8	400776.7	6715265.1	-29.6874	115.9759	82.9	Green #8 on small rock.	Bush out/crop.	
9	400790.7	6715157.8	-29.6884	115.9760	108.2	Flagged tree.	Bush out/crop.	
10	400803.9	6715051.4	-29.6893	115.9761	107.2	Power pole. Read North.	Bush out/crop.	pole
11	400817.3	6714956.8	-29.6902	115.9763	95.5	20 metres South of gate.	Plough soil.	
12	400822.7	6714886.1	-29.6908	115.9763	70.9	Near trees, #12 painted on rock.	Plough soil.	
13	400832.3	6714795.2	-29.6916	115.9764	91.5	No mark, midway between points 12 and 14.	Plough soil.	
14	400844.3	6714697.1	-29.6925	115.9765	98.8	Power pole. Read North.	Soil (boggy).	pole
15	400849.6	6714581.0	-29.6936	115.9766	116.2	15 metres North of gate. Rock cairn.	Plough soil.	
16	400867.5	6714491.1	-29.6944	115.9767	91.7	Just in paddock 30 metres south of gate. #16 painted on rock.	Plough soil.	
17	400878.3	6714367.0	-29.6955	115.9768	124.6	Power pole. Read North.	Plough soil.	pole
18	400889.3	6714255.0	-29.6965	115.9770	112.5	Mid paddock. Flagging in tree 30 metres to West.	Plough soil.	
19	400903.3	6714150.3	-29.6975	115.9771	105.6	North side of contour bank.	Plough soil.	
20	400913.4	6714050.1	-29.6984	115.9772	100.7	Power pole. Read North.	Fallow soil,	pole
21	400922.7	6713923.9	-29.6995	115.9773	126.6	5 metres North of lone tree.	Plough soil.	
22	400936.6	6713805.9	-29.7006	115.9774	118.8	South side of contour bank.	Plough soil.	
23	400951.9	6713706.5	-29.7015	115.9775	100.6	Power pole. Read North.	Plough out/crop.	pole
24	400960.6	6713612.1	-29.7023	115.9776	94.8	100 metres South of pole.	Plough soil.	
25	400969.9	6713516.0	-29.7032	115.9777	96.6	To west of lone tree.	Plough soil.	
26	400984.8	6713403.7	-29.7042	115.9779	113.2	Power pole. Read North.	Plough soil.	pole
27	400997.1	6713258.7	-29.7055	115.9780	145.5	Flagged tree.	Bush out/crop.	
28	401011.9	6713136.4	-29.7066	115.9781	123.2	Power pole. Read North.	Plough out/crop.	pole
29	401022.6	6713041.8	-29.7075	115.9782	95.2	100 metres South of pole.	Plough soil.	
30	401032.8	6712954.6	-29.7083	115.9783	87.8	#30 painted on rock.	Fallow out/crop,	
31	401043.4	6712857.1	-29.7091	115.9784	98.1	Power pole. Read North.	Plough soil.	pole
32	401051.7	6712746.5	-29.7101	115.9785	110.9	30 metres south of gate. Flagged tree.	Bush out/crop.	
33	401060.0	6712663.4	-29.7109	115.9786	83.5	Flagged tree.	Bush out/crop.	
34	401073.6	6712573.0	-29.7117	115.9787	91.5	Power pole. Read South.	Plough soil.	pole
35	401088.3	6712435.1	-29.7129	115.9788	138.6	South side of creek.	Plough soil.	
36	401098.4	6712340.4	-29.7138	115.9789	95.3	80 metres North of pole.	Plough soil.	
37	401108.3	6712257.1	-29.7146	115.9790	83.9	Power pole. Read North.	Plough soil.	pole

38	401121.0	6712141.1	-29.7156	115.9792	116.7	Paint on rock pile.	Plough soil.	
39	401134.1	6712011.7	-29.7168	115.9793	130.0	South side of little creek.	Plough soil.	
40	401143.8	6711918.7	-29.7176	115.9794	93.5	Power pole. Read North.	Plough soil.	pole
41	401156.9	6711785.3	-29.7188	115.9795	134.0	15 metres North of contour bank.	Plough soil.	
42	401170.9	6711663.3	-29.7199	115.9796	122.9	Edge of bush, #42 painted on rocks.	Bush out/crop.	
43	401182.4	6711572.0	-29.7207	115.9797	92.0	Power pole. Read North.	Soil outcrop	pole
44	401190.8	6711465.3	-29.7217	115.9798	107.0	South side of pile of rocks. #44 painted on rock.	Bush out/crop.	
45	401199.2	6711370.4	-29.7226	115.9799	95.3	20 metres South of fence in paddock.	Plough soil.	
46	401209.6	6711268.7	-29.7235	115.9800	102.2	Power pole. Read South.	Bush soil	pole
47	401218.3	6711160.1	-29.7245	115.9801	109.0	South edge of bush.	Bush soil	
48	401227.7	6711040.7	-29.7255	115.9802	119.8	25m North of fence.	Plough soil.	
49	401240.2	6710945.8	-29.7264	115.9803	95.7	Power pole. Read North.	Bush soil	pole
50	401244.9	6710833.6	-29.7274	115.9803	112.3	20 metres South of bush in paddock.	Plough soil.	
51	401248.8	6710749.6	-29.7282	115.9803	84.1	100 metres North of pole.	Plough soil.	
52	401252.6	6710660.1	-29.7290	115.9804	89.6	Power pole. Read North.	Plough soil.	pole
53	401265.7	6710536.1	-29.7301	115.9805	124.7	100 metres South of pole.	Plough soil.	
54	401272.8	6710444.7	-29.7309	115.9806	91.7	100 metres North of pole.	Plough soil.	
55	401275.9	6710338.4	-29.7319	115.9806	106.3	Power pole. Read North.	Plough soil.	pole
56	401282.8	6710209.2	-29.7330	115.9806	129.4	20 metres South of gate.	Plough soil.	
57	401291.3	6710102.5	-29.7340	115.9807	107.0	100 metres North of pole.	Plough soil.	
58	401298.7	6710002.6	-29.7349	115.9808	100.1	Power pole. Read North.	Plough soil.	pole
59	401311.0	6709881.7	-29.7360	115.9809	121.5	100 metres South of pole.	Plough soil.	
60	401319.1	6709784.8	-29.7369	115.9810	97.3	100 metres North of pole. Between drains.	Bush soil	
61	401327.6	6709685.1	-29.7378	115.9811	100.0	Power pole. Read North.	Plough soil.	pole
62	401333.2	6709568.2	-29.7388	115.9811	117.1	10 metres North of fence.	Plough soil.	
63	401343.5	6709460.3	-29.7398	115.9812	108.5	100 metres North of pole.	Plough soil.	
64	401351.6	6709360.7	-29.7407	115.9813	99.9	Power pole. Read North.	Plough soil.	pole
65	401357.7	6709253.5	-29.7417	115.9813	107.4	100 metres South of pole.	Plough soil.	
66	401365.7	6709150.6	-29.7426	115.9814	103.2	100 metres North of pole.	Plough soil.	
67	401370.6	6709057.2	-29.7434	115.9815	93.5	Power pole. Read North.	Plough soil.	pole
68	401380.0	6708936.3	-29.7445	115.9815	121.2	100 metres South of pole.	Plough soil.	
69	401387.8	6708842.0	-29.7454	115.9816	94.6	100 metres North of pole.	Plough soil.	
70	401396.6	6708751.6	-29.7462	115.9817	90.9	Power pole. Read North.	Plough soil.	pole
71	401405.1	6708634.8	-29.7473	115.9818	117.0	100 metres South of pole, 20 metres north of creek, impassable in winter.	Plough soil.	
72	401411.8	6708526.2	-29.7482	115.9818	108.8	20 metres South of creek, 80 metres North of power pole.	Plough out/crop.	
73	401419.0	6708449.8	-29.7489	115.9819	76.7	Power pole. Read North.	Plough soil.	pole
74	401428.0	6708324.3	-29.7501	115.9820	125.9	100 metres South of pole.	Plough soil.	
75	401434.0	6708232.2	-29.7509	115.9820	92.3	100 metres North of pole.	Plough soil.	
76	401438.1	6708126.4	-29.7519	115.9821	105.9	Power pole. Read North.	Plough soil.	pole

Table 1. Details of the sample sites at Carnamah.

CARNAMAH TEST RANGE POWER POLE DETAILS

STATION	EASTING AGD66	NORTHING AGD66	LATITUDE AGD66	LONGITUDE AGD66	DISTANCE Metres	STATION DESCRIPTION.	SURFACE CONDITION.	TARGET.	READING NUMBER.
4	400737.8	6715668.6	-29.6837	115.9755	0.0	Power pole. Read South.	Bush out/crop.	pole	
7	400771.9	6715347.9	-29.6866	115.9758	322.5	Power pole. Read South.	Plough soil.	pole	
10	400803.9	6715051.4	-29.6893	115.9761	298.2	Power pole. Read North.	Bush out/crop.	pole	
14	400844.3	6714697.1	-29.6925	115.9765	356.6	Power pole. Read North.	Soil (boggy).	pole	
17	400878.3	6714367.0	-29.6955	115.9768	331.9	Power pole. Read North.	Plough soil.	pole	
20	400913.4	6714050.1	-29.6984	115.9772	318.8	Power pole. Read North.	Fallow soil,	pole	
23	400951.9	6713706.5	-29.7015	115.9775	345.8	Power pole. Read North.	Plough out/crop.	pole	
26	400984.8	6713403.7	-29.7042	115.9779	304.6	Power pole. Read North.	Plough soil.	pole	
28	401011.9	6713136.4	-29.7066	115.9781	268.6	Power pole. Read North.	Plough out/crop.	pole	
31	401043.4	6712857.1	-29.7091	115.9784	281.1	Power pole. Read North.	Plough soil.	pole	
34	401073.6	6712573.0	-29.7117	115.9787	285.7	Power pole. Read South.	Plough soil.	pole	
37	401108.3	6712257.1	-29.7146	115.9790	317.8	Power pole. Read North.	Plough soil.	pole	
40	401143.8	6711918.7	-29.7176	115.9794	340.2	Power pole. Read North.	Plough soil.	pole	
43	401182.4	6711572.0	-29.7207	115.9797	348.9	Power pole. Read North.	Soil outcrop	pole	
46	401209.6	6711268.7	-29.7235	115.9800	304.5	Power pole. Read South.	Bush soil	pole	
49	401240.2	6710945.8	-29.7264	115.9803	324.4	Power pole. Read North.	Bush soil	pole	
52	401252.6	6710660.1	-29.7290	115.9804	286.0	Power pole. Read North.	Plough soil.	pole	
55	401275.9	6710338.4	-29.7319	115.9806	198.0	Power pole. Read North.	Plough soil.	pole	
58	401298.7	6710002.6	-29.7349	115.9808	336.5	Power pole. Read North.	Plough soil.	pole	
61	401327.6	6709685.1	-29.7378	115.9811	318.8	Power pole. Read North.	Plough soil.	pole	
64	401351.6	6709360.7	-29.7407	115.9813	325.4	Power pole. Read North.	Plough soil.	pole	
67	401370.6	6709057.2	-29.7434	115.9815	304.1	Power pole. Read North.	Plough soil.	pole	
70	401396.6	6708751.6	-29.7462	115.9817	306.7	Power pole. Read North.	Plough soil.	pole	
73	401419.0	6708449.8	-29.7489	115.9819	302.5	Power pole. Read North.	Plough soil.	pole	
76	401438.1	6708126.4	-29.7519	115.9821	324.0	Power pole. Read North.	Plough soil.	pole	

Background readings (300 seconds over water) are taken at the small dam South of Coorow. Power pole readings are taken on the indicated side approximately 3 metres out from the base of the centre pole, under the centre wire (a wooden peg marks spot). Weather report - Cloud cover................Wind direction................ Temp........Soil condition ....dry/damp/wet. Recent rain.-.yes/no.

Table 2. Details of the power poles at Carnamah.

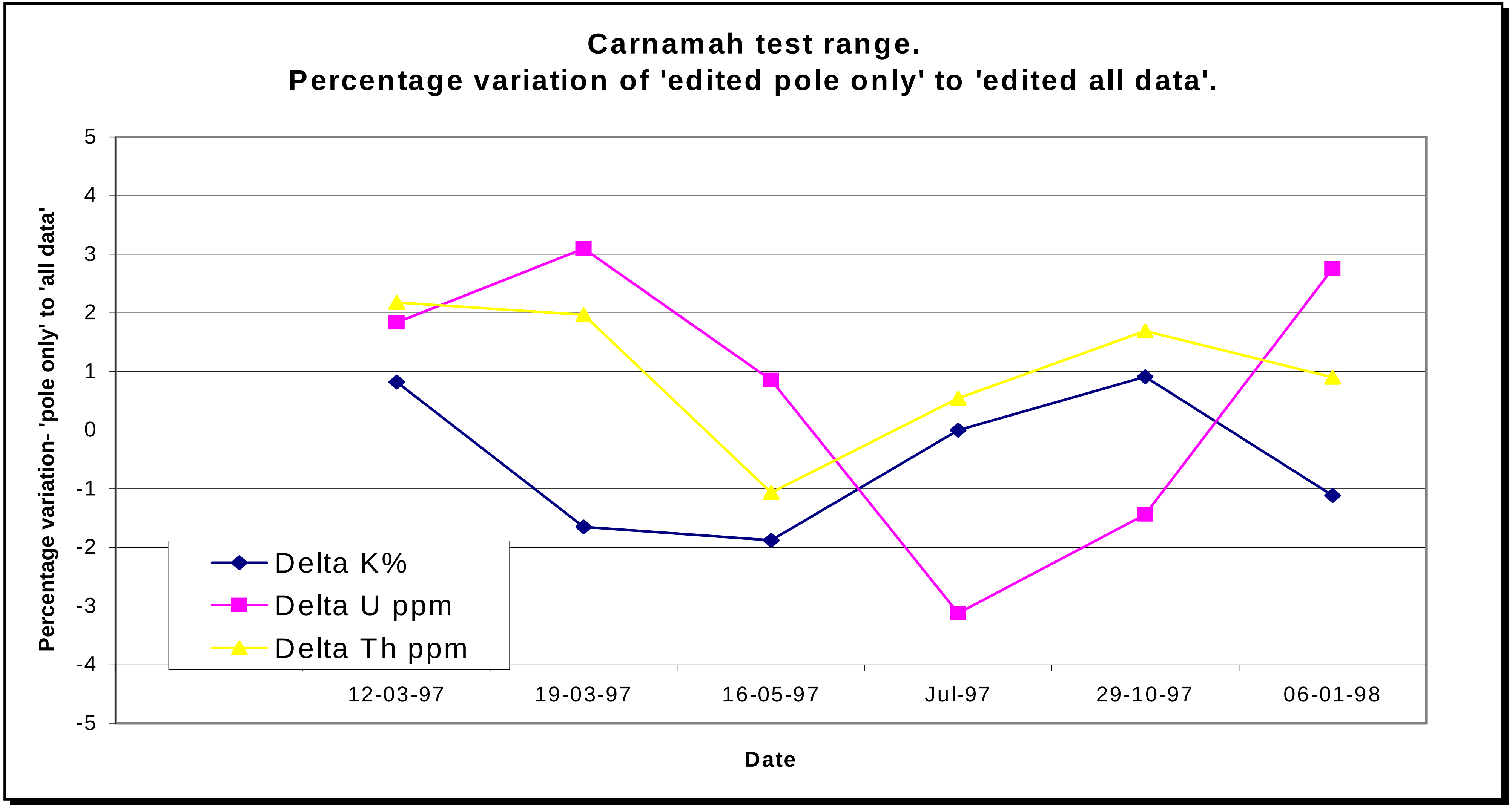


Figure. 3. Comparison of averages of ‘all data points’ to ‘poles only’.

	FILTERED EDITED ALL DATA			FILTERED EDITED POLE DATA			% DIFFERENCE.		
				Three point filter 1*[n-1]+2*[n}+1*[n+1}/4					
Date	**Mean K%**	**Mean U ppm**	**Mean Th ppm**	**Mean K%**	**Mean U ppm**	**Mean Th ppm**	**Delta K %**	**Delta U ppm**	**Delta Th ppm**
	All points.	**All points.**	**All points.**	**Poles only**	**Poles only**	**Poles only**			
12-03-97	3.66	4.89	40.08	3.71	5.00	41.72	1.37	2.25	4.09
19-03-97	3.63	4.83	39.56	3.57	5.03	40.87	-1.65	4.14	3.31
16-05-97	3.15	4.61	35.18	3.15	4.75	35.67	0.00	3.04	1.39
Jul-97	3.30	4.80	34.90	3.31	4.73	35.50	0.30	-1.46	1.72
29-10-97	3.30	4.17	39.03	3.34	4.16	40.24	1.21	-0.24	3.10
06-01-98	3.60	5.06	38.58	3.56	5.24	39.32	-1.11	3.56	1.92
Mean	3.44	4.73	37.89	3.44	4.82	38.89	0.02	1.88	2.59

No filter on data points.

Date	**Mean K%**	**Mean U ppm**	**Mean Th ppm**	**Mean K%**	**Mean U ppm**	**Mean Th ppm**	**Delta K %**	**Delta U ppm**	**Delta Th ppm**
	All points.	**All points.**	**All points.**	**Poles only**	**Poles only**	**Poles only**			
12-03-97	3.66	4.90	40.43	3.69	4.99	41.31	0.82	1.84	2.18
19-03-97	3.63	4.84	39.64	3.57	4.99	40.42	-1.65	3.10	1.97
16-05-97	3.20	4.67	35.66	3.14	4.71	35.28	-1.88	0.86	-1.07
Jul-97	3.30	4.80	34.95	3.3	4.65	35.14	0.00	-3.12	0.54
29-10-97	3.30	4.18	39.12	3.33	4.12	39.78	0.91	-1.44	1.69
06-01-98	3.60	5.08	38.61	3.56	5.22	38.96	-1.11	2.76	0.91
Mean	3.45	4.75	38.07	3.43	4.78	38.48	-0.49	0.66	1.04

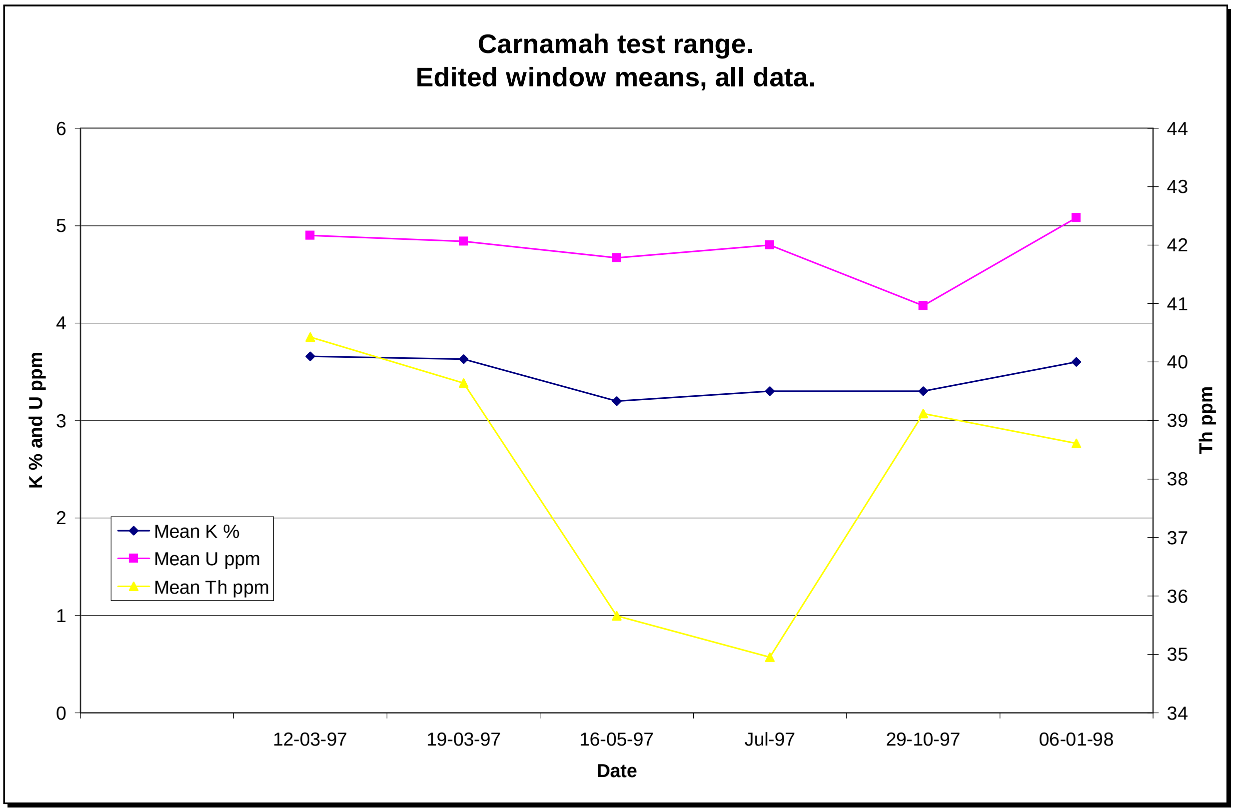
Table 3. Averages of edited data set windows raw and filtered.

Station	03-Mar-97			19-Mar-97			16-May-97			Jul-97			29 Oct 1997 (GR256)			6 Jan 1998 (GR320)		
	K %	U ppm	Th ppm	K %	U ppm	Th ppm	K%	U ppm	TH ppm	K %	U ppm	Th ppm	K %	U ppm	Th ppm	K%	U ppm	TH ppm
1	4.93	7.44	38.70	5.43	6.21	30.40	4.42	7.17	38.15	4.75	6.09	34.81	4.83	5.43	28.67	5.15	4.94	37.40
2	5.24	7.97	40.12	4.87	7.43	48.32	4.35	6.28	41.70	4.23	6.80	44.25	4.45	6.39	45.84	5.21	7.81	42.90
3	5.55	4.64	64.30	5.64	4.62	52.53	5.82	3.01	46.96	5.25	4.86	55.86	5.01	3.85	54.20	5.63	4.89	48.99
4	5.56	7.02	66.42	5.13	6.15	59.08	4.63	7.79	50.65	5.15	8.84	51.95	4.99	7.51	62.00	5.17	6.70	50.15
5	5.30	8.08	51.44	5.60	6.19	48.39	4.63	8.84	51.20	4.72	***9.00***	43.81	5.32	3.80	47.51	5.90	7.49	41.77
6	4.75	3.44	28.33	4.71	3.78	29.21	4.23	5.43	24.71	4.63	5.73	27.04	4.32	2.68	25.98	4.59	3.08	29.82
7	3.53	4.47	19.11	4.27	3.05	20.90	3.60	2.72	18.55	3.64	2.76	18.07	3.88	2.29	17.94	3.85	4.36	18.46
8	3.47	3.54	16.85	3.36	2.50	15.88	3.04	3.22	14.88	2.58	2.89	14.52	2.97	2.56	16.60	3.46	2.49	16.85
9	2.74	0.70	14.42	3.20	0.92	15.56	2.67	2.06	14.88	2.85	1.64	12.61	2.73	1.12	14.25	3.06	2.05	15.32
10	4.13	4.70	37.57	3.94	3.97	31.91	3.33	5.45	27.50	3.33	4.66	27.95	3.90	3.29	28.99	4.11	4.00	26.72
11	4.48	3.42	27.19	4.33	3.73	28.94	***3.86***	***2.39***	***25.86***	3.97	3.06	23.73	3.79	3.21	25.14	4.35	4.67	26.50
12	3.82	3.88	19.56	3.98	2.88	24.75	***3.52***	***3.95***	***23.42***	3.46	2.89	24.78	3.31	4.17	25.79	3.78	3.66	19.23
13	3.60	1.80	19.61	3.51	2.46	19.32	***3.19***	***2.59***	***18.10***	3.13	2.25	15.06	3.26	3.29	18.51	3.48	2.94	17.72
14	3.39	3.63	35.47	3.49	3.92	40.78	***3.15***	***4.01***	***34.19***	3.12	3.73	30.97	3.38	2.85	32.08	3.35	2.49	37.06
15	4.37	2.76	17.90	4.52	3.36	29.12	***3.51***	***3.38***	***40.51***	3.47	4.48	24.95	3.80	2.35	25.28	4.20	3.20	27.54
16	3.38	6.26	45.92	3.78	5.11	53.91	***3.29***	***4.35***	***42.92***	3.09	5.93	47.87	4.05	8.00	55.00	3.61	5.56	43.87
17	3.84	4.40	38.19	3.52	5.34	34.84	***2.97***	***3.74***	***34.13***	3.08	5.66	30.87	3.32	3.64	39.44	3.02	3.29	41.75
18	4.03	5.71	67.21	4.06	7.80	63.00	***3.59***	***5.69***	***53.74***	3.89	5.25	59.60	3.93	3.95	68.75	4.43	5.75	64.79
19	3.44	5.57	70.62	3.01	7.97	81.83	***2.88***	***5.69***	***64.05***	2.91	***8.00***	65.68	3.13	7.49	71.29	3.49	7.45	61.09
20	3.93	5.69	43.79	3.97	6.24	40.98	***3.51***	***5.60***	***33.77***	3.90	3.66	35.96	3.53	4.27	36.26	3.96	5.13	40.74
21	4.11	4.11	31.39	4.03	3.89	30.71	3.51	5.60	33.77	3.95	4.76	26.90	3.88	4.07	32.27	4.02	4.32	34.87
22	3.57	7.59	76.74	3.60	6.83	48.03	2.79	5.98	46.98	3.07	***8.00***	66.37	2.77	5.70	60.67	3.60	7.49	76.84
23	4.19	4.16	50.76	3.88	4.49	51.24	3.53	5.28	33.09	3.64	4.82	37.80	3.44	4.11	52.79	3.95	5.99	42.35
24	3.95	3.26	15.88	3.96	1.85	17.36				3.52	3.55	22.19	3.72	1.52	23.02	3.97	3.11	17.17
25	4.00	4.69	33.05	3.97	3.81	31.15	3.40	3.86	25.06	3.46	4.50	30.19	3.37	3.22	31.76	3.66	4.49	31.31
26	4.85	3.64	36.36	4.72	5.04	31.50	4.49	4.70	29.10	4.47	4.20	33.44	4.63	2.91	31.57	4.82	3.39	31.59
27	4.59	2.66	24.39	4.76	2.64	26.43	4.01	3.90	23.74	4.16	4.53	18.91	4.05	3.10	25.07	4.53	3.49	22.40
28	4.67	4.88	29.95	4.43	4.32	32.66	4.14	4.53	24.86	4.17	4.21	29.67	4.16	4.31	31.31	4.63	6.83	29.25
29	4.38	3.80	21.19	4.48	4.30	21.64	3.73	4.00	21.79	4.19	3.56	21.74	4.03	3.15	23.40	4.13	4.91	22.47
30	5.42	2.48	27.86	4.86	5.25	30.46	5.03	3.92	24.28	4.96	4.61	20.07	4.63	2.32	25.94	4.92	4.82	24.05
31	4.98	5.31	28.59	5.04	4.08	26.28	4.23	3.79	22.89	4.31	4.27	24.65	4.25	3.40	30.73	5.10	4.96	26.01
32	4.10	3.60	26.53	4.20	4.18	23.75	3.60	4.24	27.28	3.86	3.31	19.10	3.70	3.33	25.71	4.15	2.70	27.90
33	3.54	2.76	27.49	3.70	4.04	21.97	3.55	2.17	23.78	3.55	3.30	24.18	3.36	2.29	27.76	3.58	2.08	26.37

34	4.57	2.74	28.06	4.27	2.89	28.91	3.78	3.13	28.52	4.07	4.27	24.33	3.98	3.07	25.15	4.59	4.38	24.02
35	4.06	3.50	30.90	4.49	2.47	24.01	3.78	2.73	26.61	3.65	3.31	27.73	3.62	3.93	33.08	3.92	4.22	29.91
36	2.58	5.12	37.52	2.55	5.48	42.65	2.28	5.41	32.93	2.34	5.86	36.24	2.47	5.80	36.64	3.15	4.79	33.69
37	2.95	4.16	30.77	2.64	4.69	32.53	2.62	5.29	25.42	2.58	3.92	29.99	2.56	4.55	31.94	2.73	4.78	34.47
38	3.12	3.56	18.10	3.35	2.10	22.80	2.76	3.59	21.67	2.85	3.71	17.94	2.88	2.21	22.31	2.89	3.49	21.26
39	3.71	3.85	32.15	3.85	3.46	27.57	3.17	4.45	31.60	3.35	5.14	29.47	3.40	3.23	27.17	3.55	5.69	29.83
40	3.49	3.69	23.46	3.29	3.11	23.48	2.67	3.85	21.19	3.08	3.65	22.33	2.98	3.06	29.15	3.21	3.54	27.60
41	3.05	2.78	23.27	3.09	2.93	22.32	2.49	3.35	20.76	2.91	2.19	19.92	2.77	3.14	23.03	3.40	2.88	21.25
42	5.43	4.48	29.10	5.76	3.59	35.48	4.81	5.28	28.44	4.74	6.03	23.61	4.56	4.40	34.57	5.42	5.82	29.92
43	5.39	4.83	37.67	5.32	4.68	38.64	4.83	4.35	33.47	4.80	3.99	36.17	5.18	4.31	40.99	5.54	5.75	37.95
44	5.39	4.03	31.01	5.62	5.91	28.71	4.93	2.84	28.69	4.87	4.65	30.74	4.61	3.56	33.33	5.41	4.01	31.77
45	4.51	4.92	21.51	4.75	4.36	22.27	3.96	4.81	18.79	4.30	4.96	17.21	3.95	4.42	23.15	4.39	5.39	22.32
46	3.67	4.61	31.70	3.91	4.23	32.28	3.13	3.66	30.11	3.45	4.35	23.70	3.39	4.51	27.14	3.69	5.65	26.86
47	2.90	3.74	29.16	2.81	4.84	21.80	2.92	2.56	23.91	2.22	3.62	19.85	2.25	3.00	21.88	2.68	3.76	26.65
48	4.51	2.28	15.68	4.63	2.14	13.73	3.69	2.46	15.09	4.09	2.66	17.92	4.03	1.91	18.18	4.04	4.08	21.79
49	4.00	3.29	39.27	3.86	3.09	31.68	3.37	4.74	30.57	3.74	3.23	24.72	3.50	2.87	31.72	3.58	4.29	36.23
50	3.16	6.52	71.99	3.43	8.06	66.87	3.44	4.92	59.99	3.68	5.27	56.95	3.32	5.09	64.80	3.90	6.69	61.30
51	3.15	7.60	83.19	2.86	9.83	83.89	2.44	9.80	72.05	2.88	5.99	67.78	2.81	6.53	77.34	3.03	10.16	84.64
52	2.91	8.25	***85.00***	2.78	***10.00***	***85.00***	2.17	8.60	87.16	2.94	***9.00***	78.76	2.68	7.39	79.31	3.16	7.93	73.10
53	2.40	10.57	75.90	2.46	8.99	73.21	2.25	9.40	59.22	2.65	7.70	63.10	2.20	7.43	72.46	2.41	9.74	60.60
54	1.96	11.38	87.86	1.93	10.81	92.20	2.08	8.29	84.62	2.15	9.20	65.99	2.13	9.17	87.46	2.05	11.88	91.59
55	1.81	10.00	***70.00***	1.76	11.41	***70.00***	1.77	6.09	69.67	1.75	9.04	63.22	1.99	6.68	66.70	1.97	10.60	68.54
56	1.97	7.81	51.33	2.10	5.85	58.47	2.02	6.61	39.27	2.25	6.05	46.10	2.20	6.43	44.45	2.19	6.59	46.61
57	2.41	3.63	33.30	2.25	5.21	40.55	2.29	3.69	33.51	2.05	4.54	31.53	2.44	4.95	31.91	2.41	4.64	31.82
58	2.80	4.76	36.00	2.94	4.31	33.48	2.85	3.62	24.14	2.95	3.07	28.29	2.91	***3.00***	29.95	3.35	3.06	25.23
59	2.67	5.75	43.04	2.68	4.73	43.17	2.24	3.49	38.79	2.29	4.75	39.14	2.47	3.84	42.48	2.49	4.09	44.44
60	2.69	5.93	64.03	2.79	5.25	65.75	2.32	4.75	62.95	2.16	5.73	59.19	2.53	2.56	69.44	2.62	6.70	71.32
61	2.67	5.22	58.58	2.64	6.71	59.97	2.37	4.97	51.70	2.51	5.30	51.20	2.35	***5.00***	60.15	2.36	8.56	61.30
62	2.60	5.20	68.72	2.23	8.16	65.62	2.22	5.84	53.27	2.37	6.12	55.44	2.18	4.39	62.38	2.13	7.26	69.41
63	2.63	4.77	60.35	2.82	6.55	58.05	2.29	4.50	53.75	2.33	6.26	44.79	2.47	4.81	54.12	2.81	5.07	58.49
64	2.92	4.71	53.26	2.80	5.08	54.12	2.39	4.21	45.41	2.54	4.43	48.18	2.70	***4.00***	58.67	2.60	6.30	60.65
65	2.84	4.96	49.57	2.95	4.75	44.31	2.52	4.30	41.45	2.87	3.36	44.10	2.72	4.39	48.84	3.12	5.08	43.18
66	2.48	6.24	50.63	2.67	3.37	53.23	2.26	4.99	44.50	2.50	6.28	41.50	2.22	4.81	55.14	2.71	4.14	51.36
67	2.74	5.85	49.52	2.60	5.99	52.48	2.39	5.20	43.71	2.35	4.03	44.81	2.18	5.69	49.97	2.43	5.32	57.59
68	3.05	5.34	35.72	2.83	3.26	32.96	2.59	6.21	31.32	2.46	5.46	29.45	2.71	4.70	34.19	2.75	4.00	43.19
69	3.06	3.98	43.42	2.83	3.68	43.85	2.49	4.19	38.98	2.80	4.50	34.68	2.66	5.94	39.54	2.97	4.15	38.87
70	2.53	6.06	34.70	2.67	5.29	35.78	2.14	4.72	34.52	2.62	4.38	28.63	2.49	***4.00***	43.51	2.57	5.73	41.16
71	2.75	5.62	35.81	2.93	4.24	34.95	2.62	4.90	30.41	2.49	4.90	31.72	2.67	4.41	32.61	2.84	5.01	34.55
72	2.69	4.26	29.76	2.83	4.56	29.11	2.68	3.51	25.78	2.67	3.51	25.98	2.50	4.07	28.63	3.10	3.43	27.94
73	3.01	3.75	27.23	3.22	3.23	27.98	2.61	4.86	20.80	2.58	2.71	25.64	2.79	3.63	27.65	3.18	3.72	25.64

74				2.94	1.91	22.42	2.81	3.77	18.79	2.46	3.44	21.51	2.45	4.17	22.15	2.87	3.94	21.84
75				2.51	4.84	39.20	2.10	4.09	27.83	1.84	4.54	33.85	2.13	4.50	39.01	2.34	5.21	33.97
76				2.21	3.54	34.06	1.95	2.93	26.98	1.79	4.12	27.30	2.16	2.57	29.48	2.09	3.76	29.63
Edited mean	3.66	4.90	40.43	3.63	4.84	39.64	3.20	4.67	35.66	3.30	4.80	34.95	3.30	4.18	39.12	3.60	5.08	38.61
Raw mean	3.66	4.90	40.79	3.63	4.87	40.05	3.20	4.66	35.54	3.30	4.89	34.95	3.30	4.11	39.12	3.60	5.08	38.61
				Note Data in italics has been either moved or changed.														
					Pt 19			Pt 11										
				5.68	4.06	67.61	3.87	4.68	24.07				Pt 4		74.79			
				Point removed from data.			Point remover from data.						Pt 16		94.03			
													Points modified in data set.					

Table 4. All station data ‘edited’.



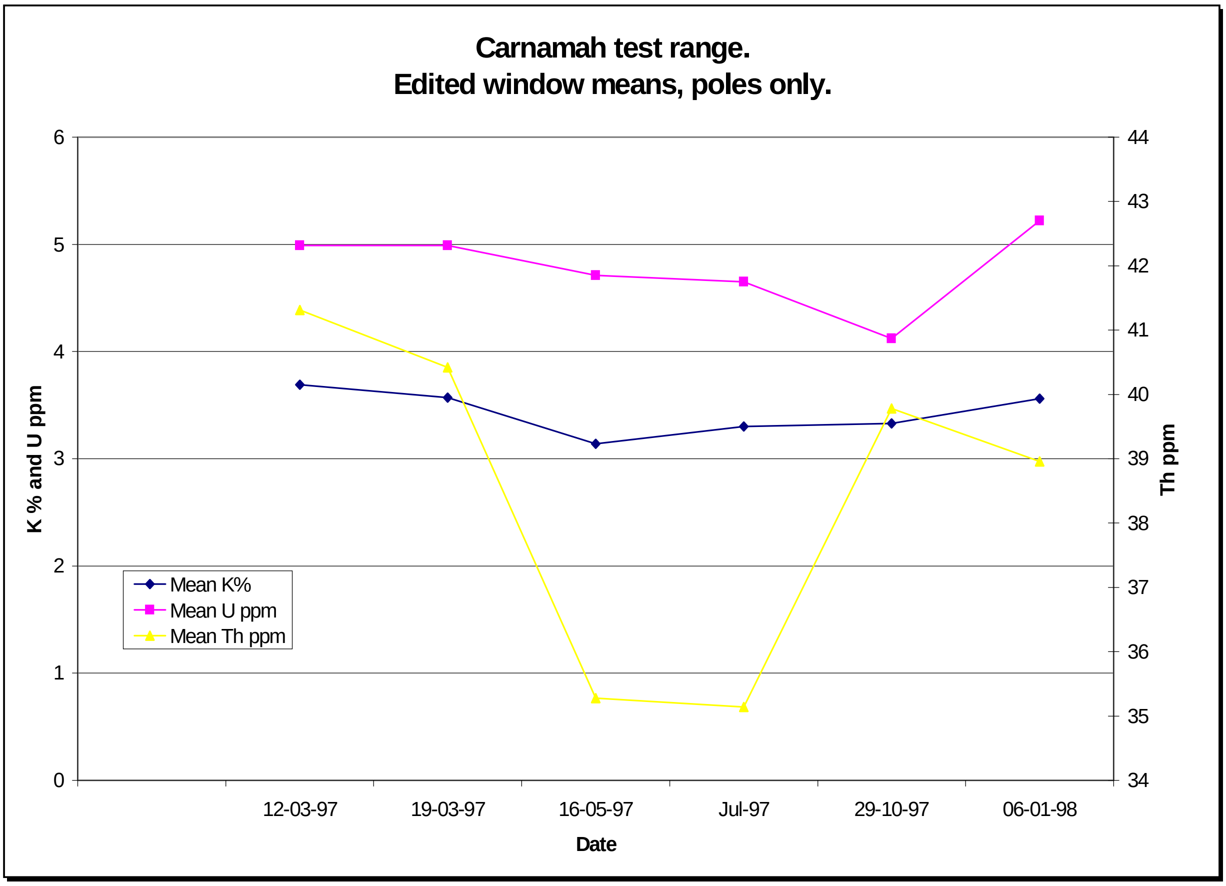
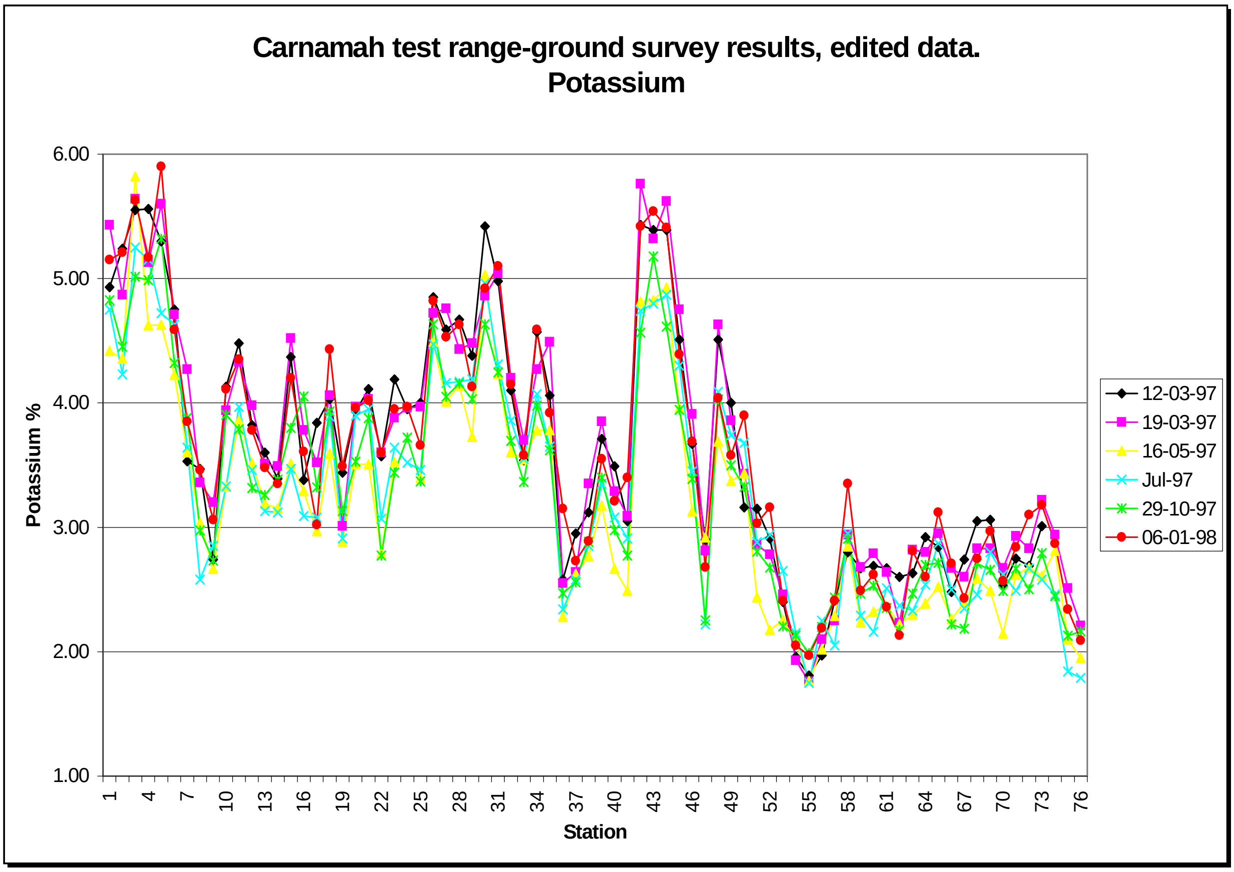


Figure. 4. Averages of “all data” and “poles only”



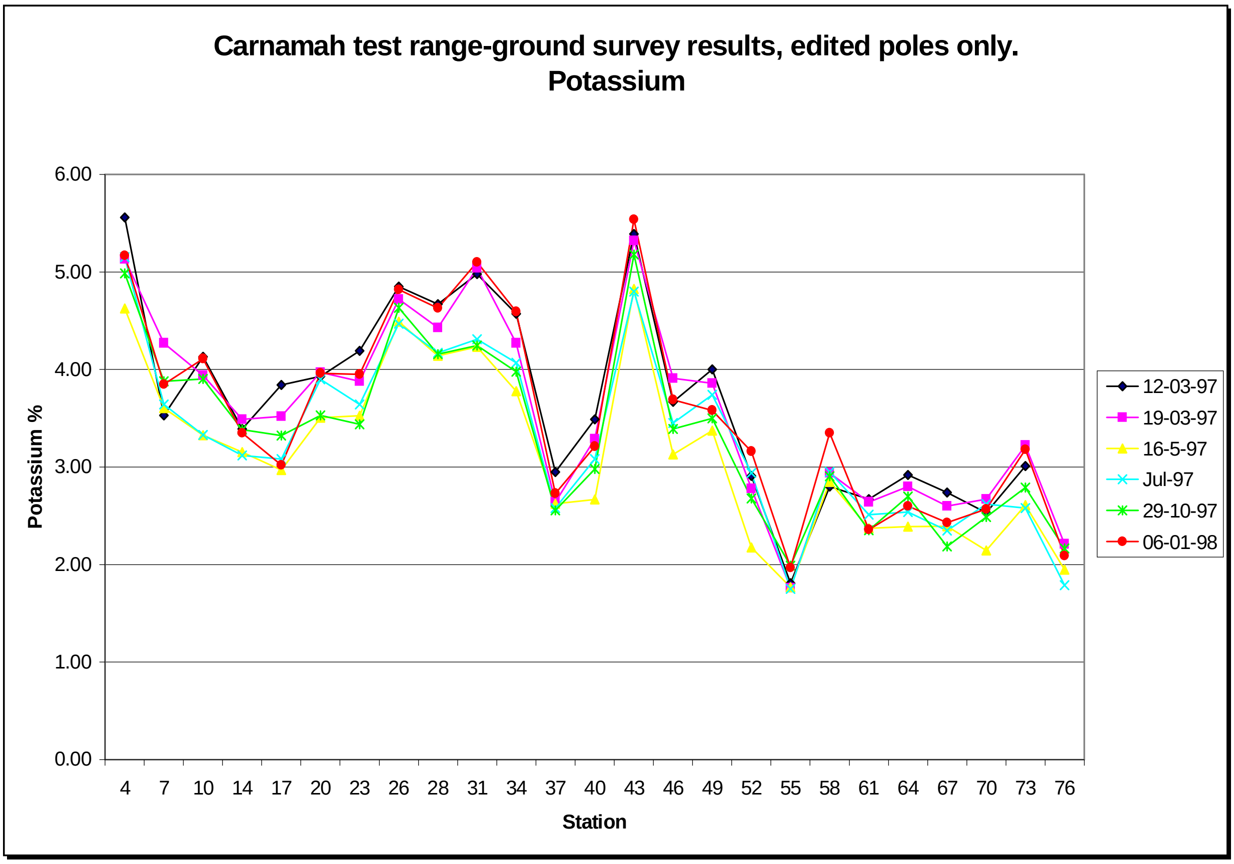
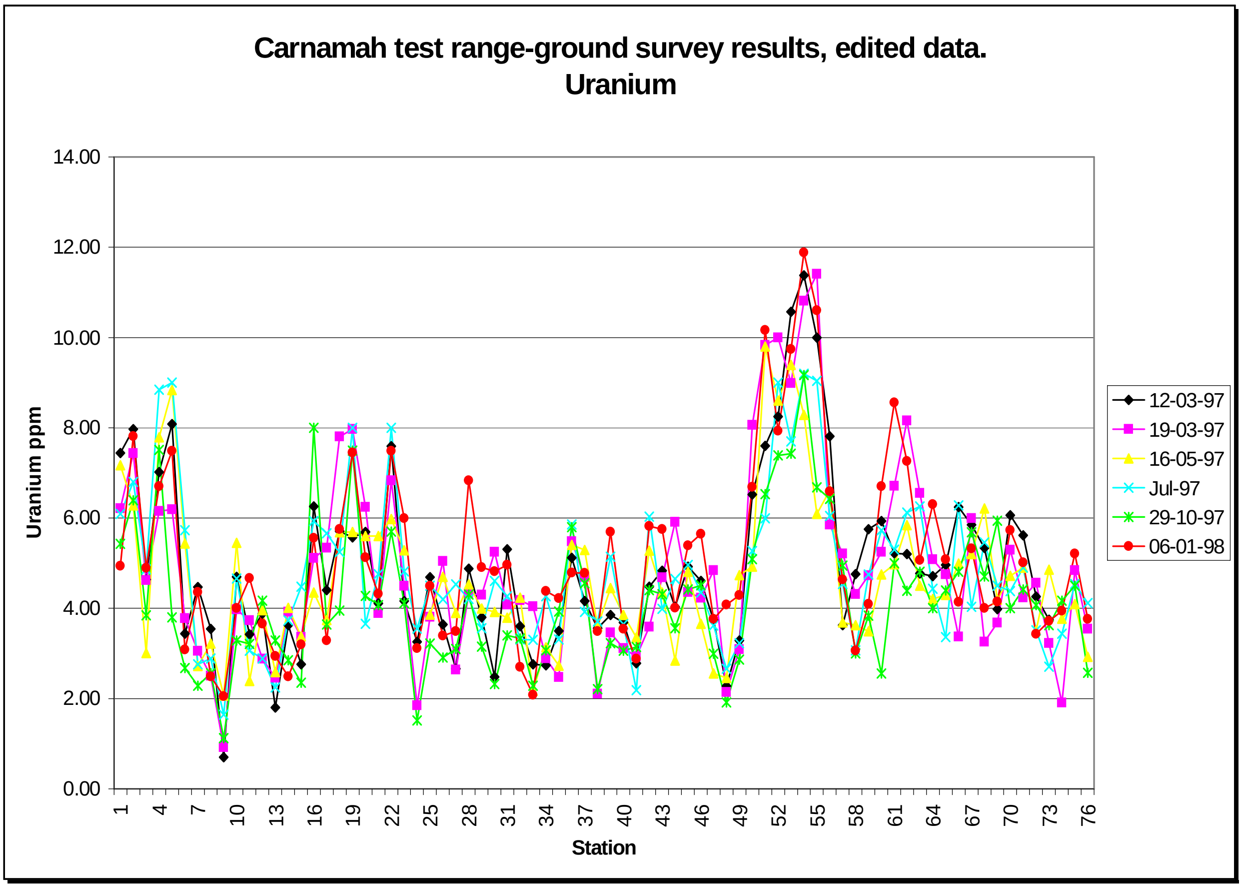


Figure. 5. Edited Potassium data.



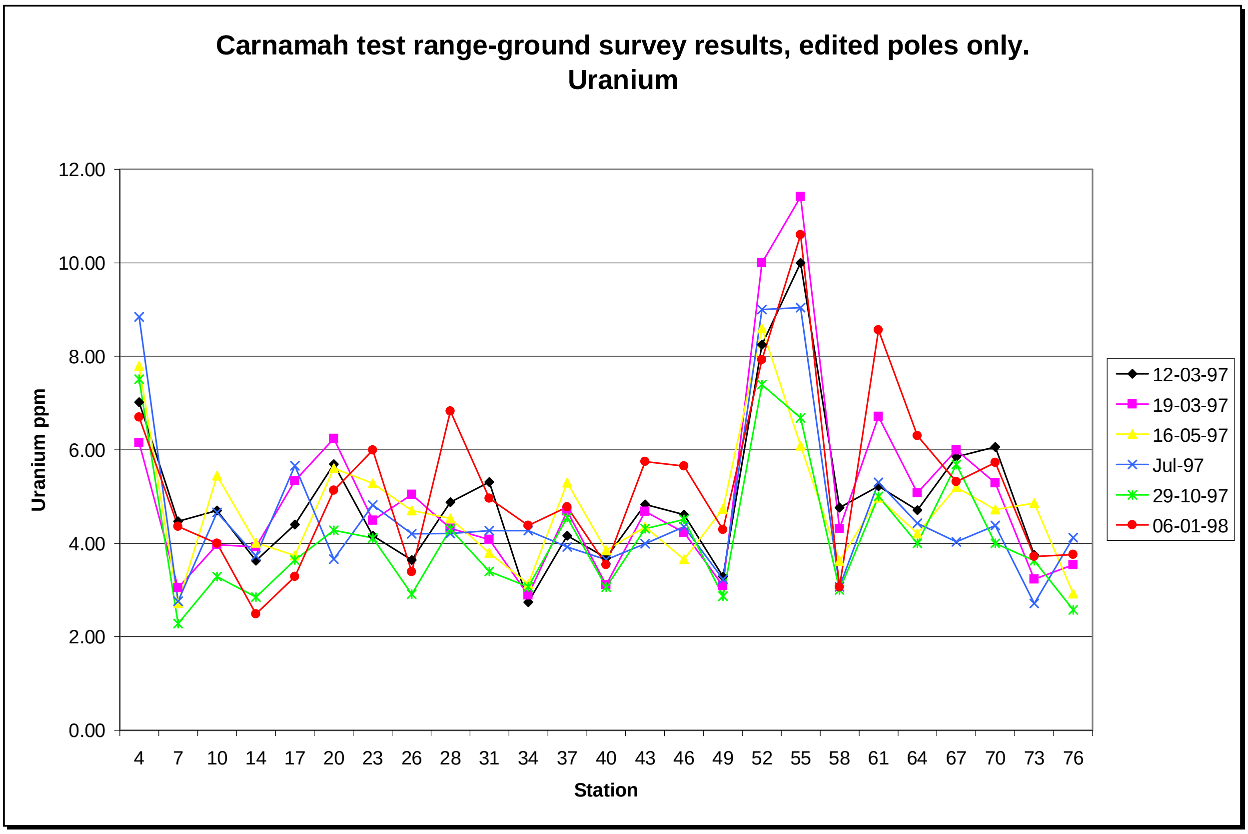
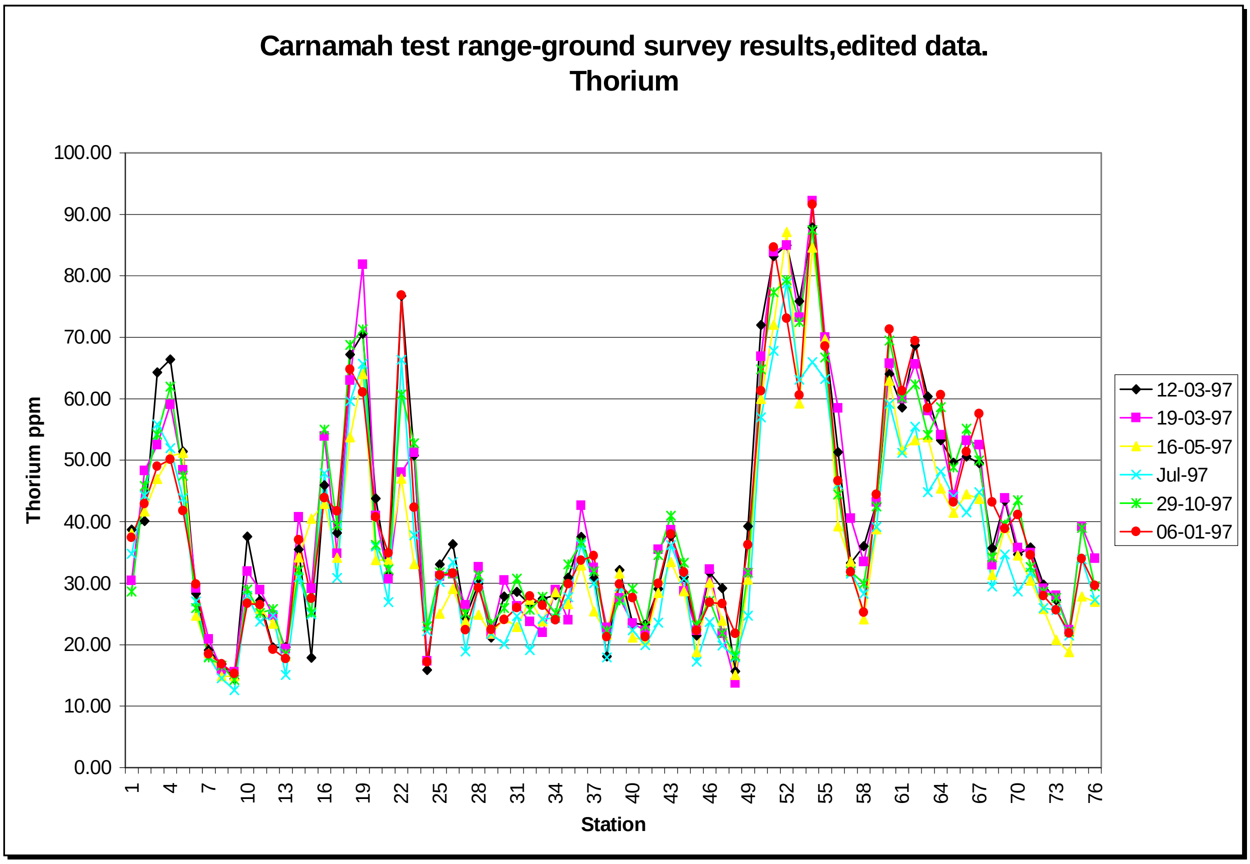


Figure. 6. Edited Uranium data



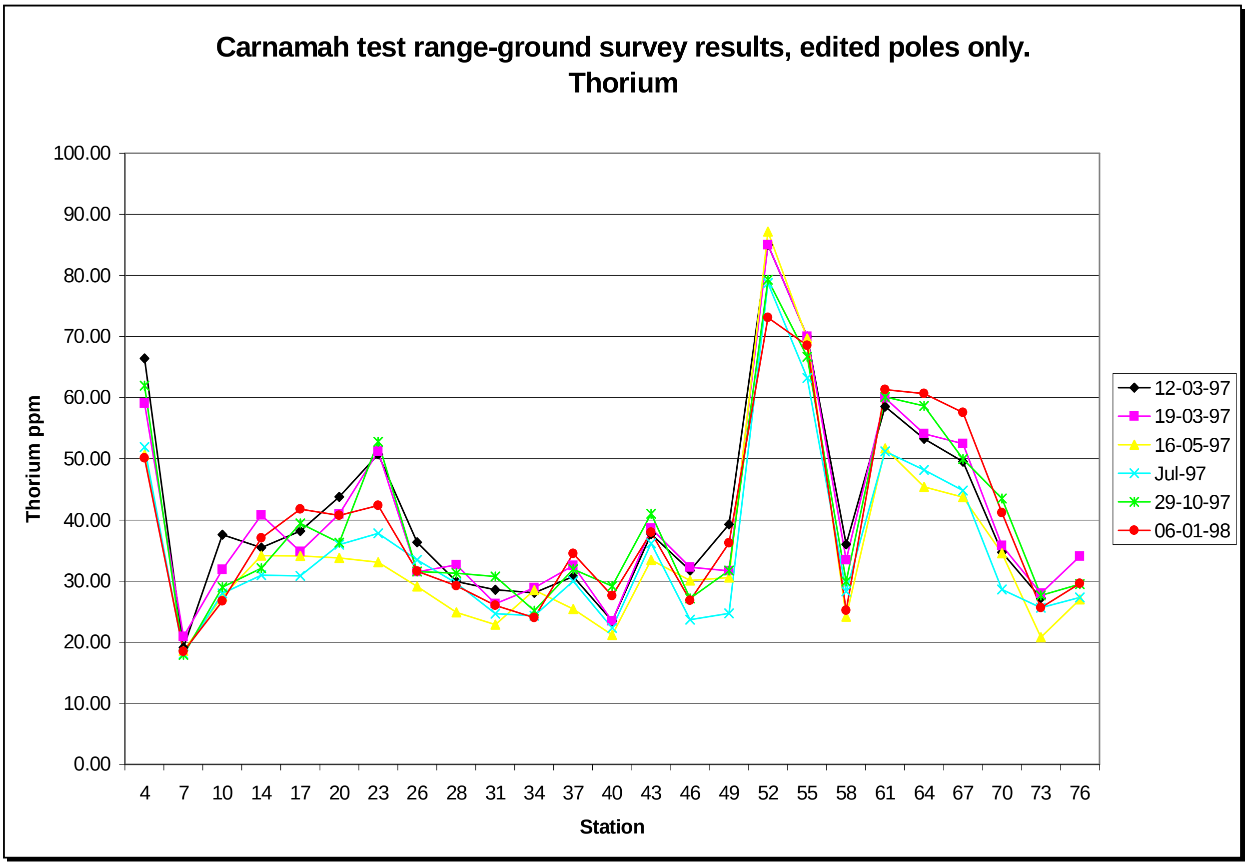
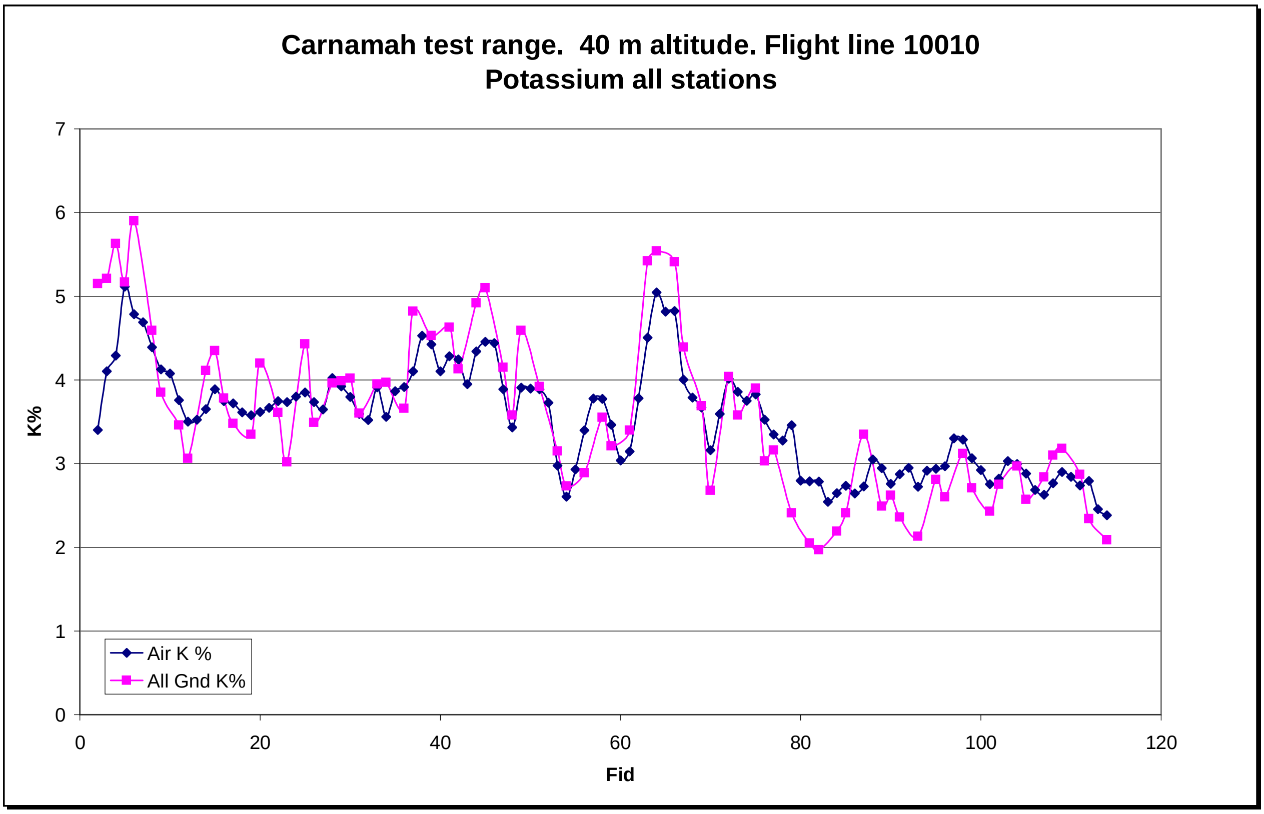


Figure. 7. Edited Thorium data.



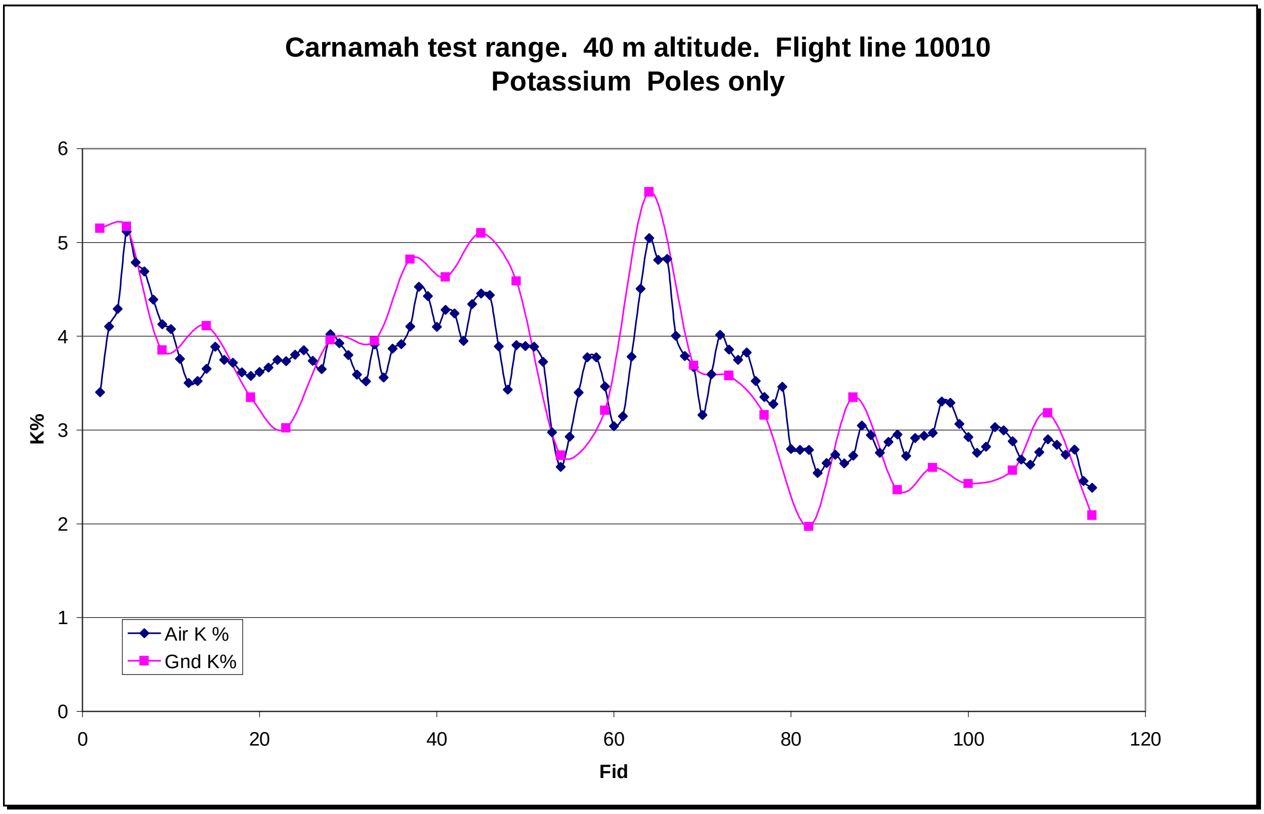
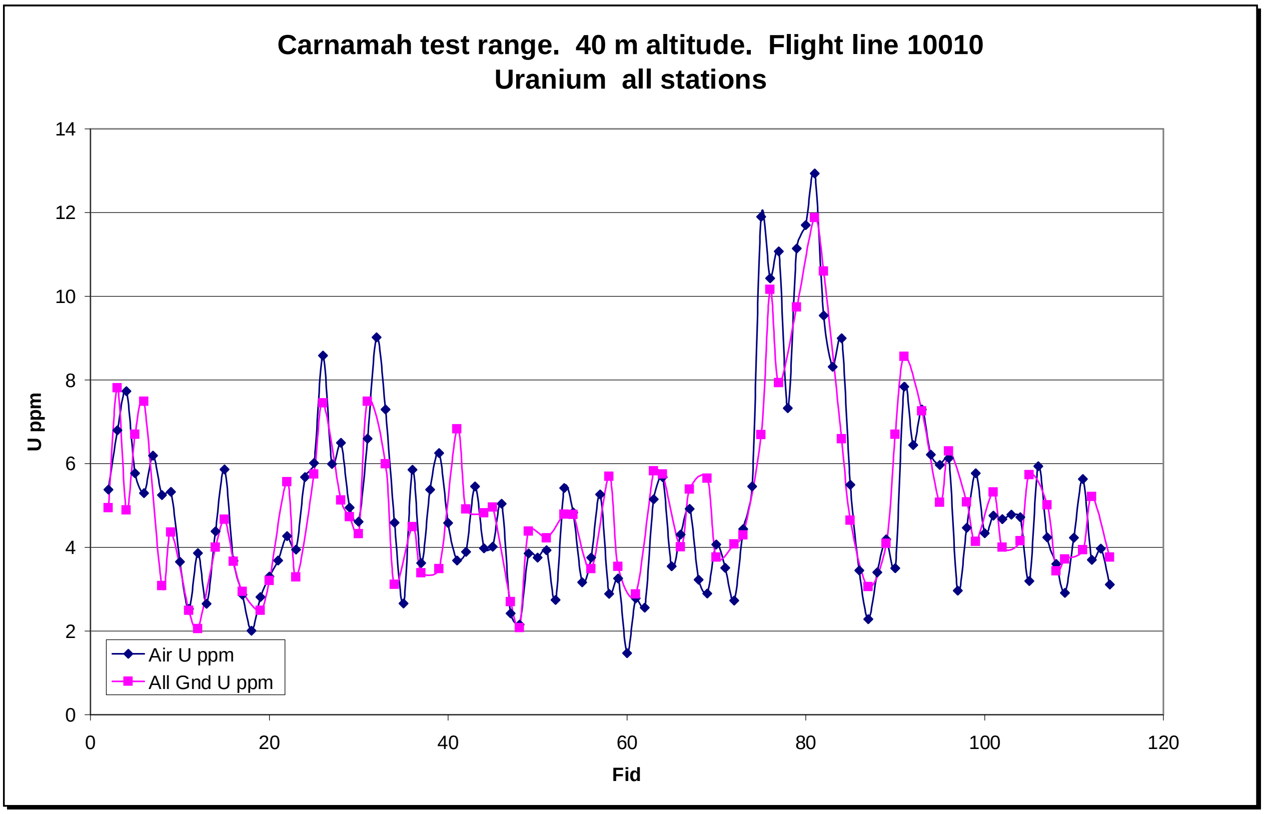
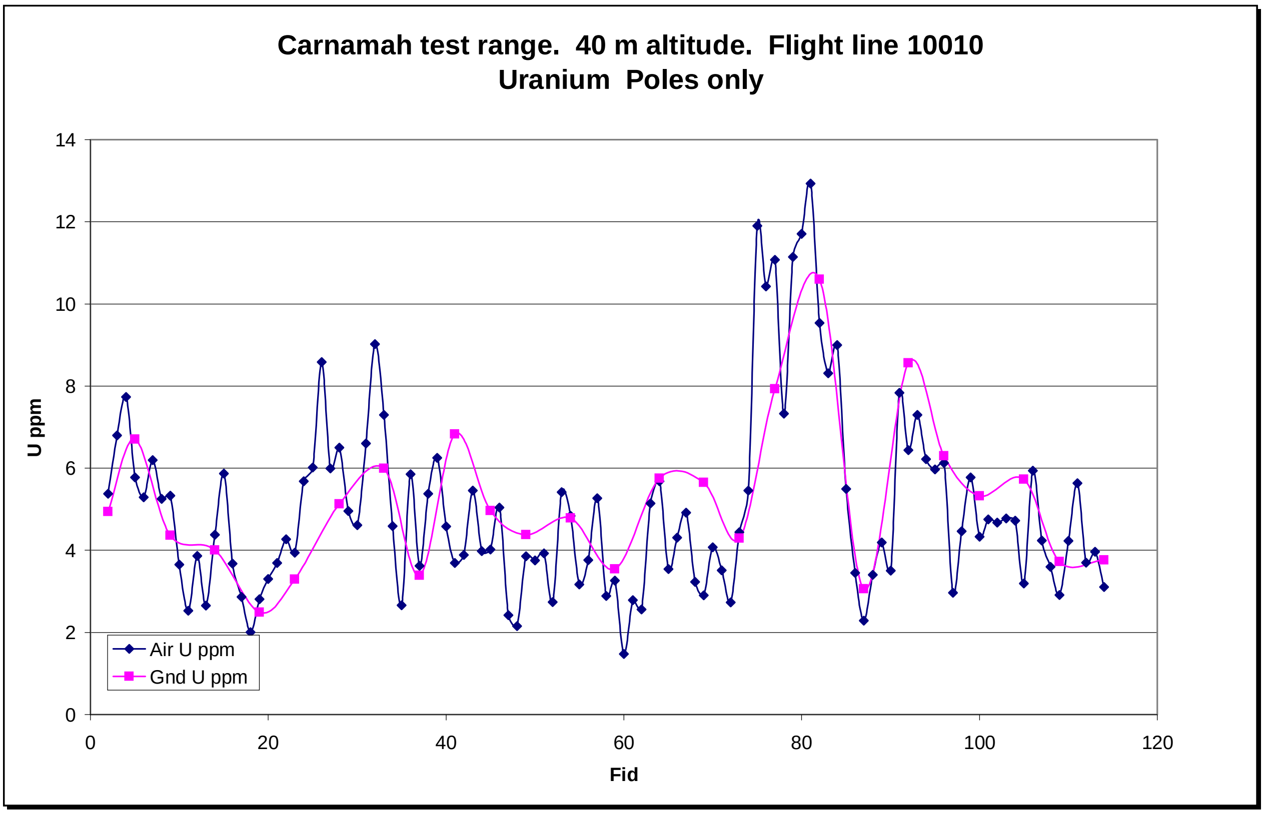
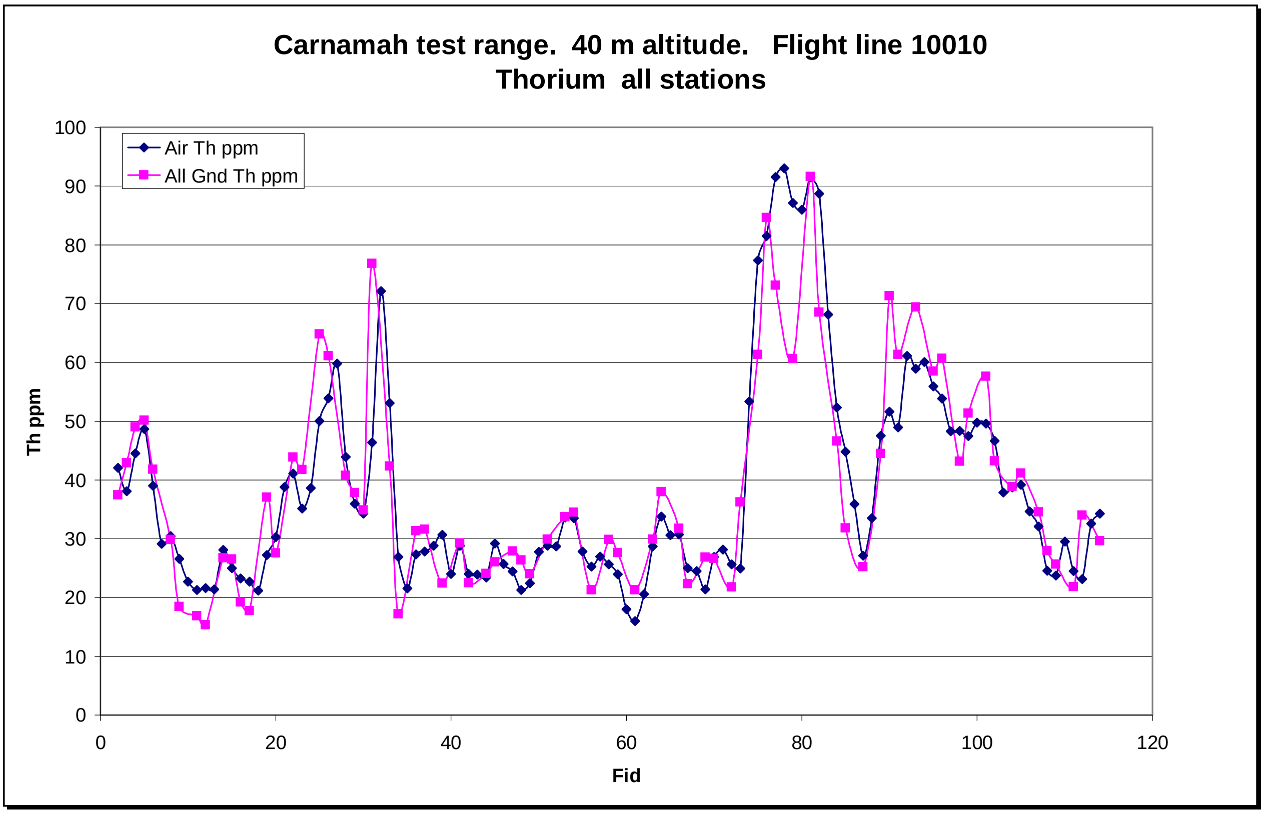


Figure. 8. Potassium - flight profiles vs ground profiles.





<u>Figure. 9. Uranium - flight profiles vs ground profiles.</u>



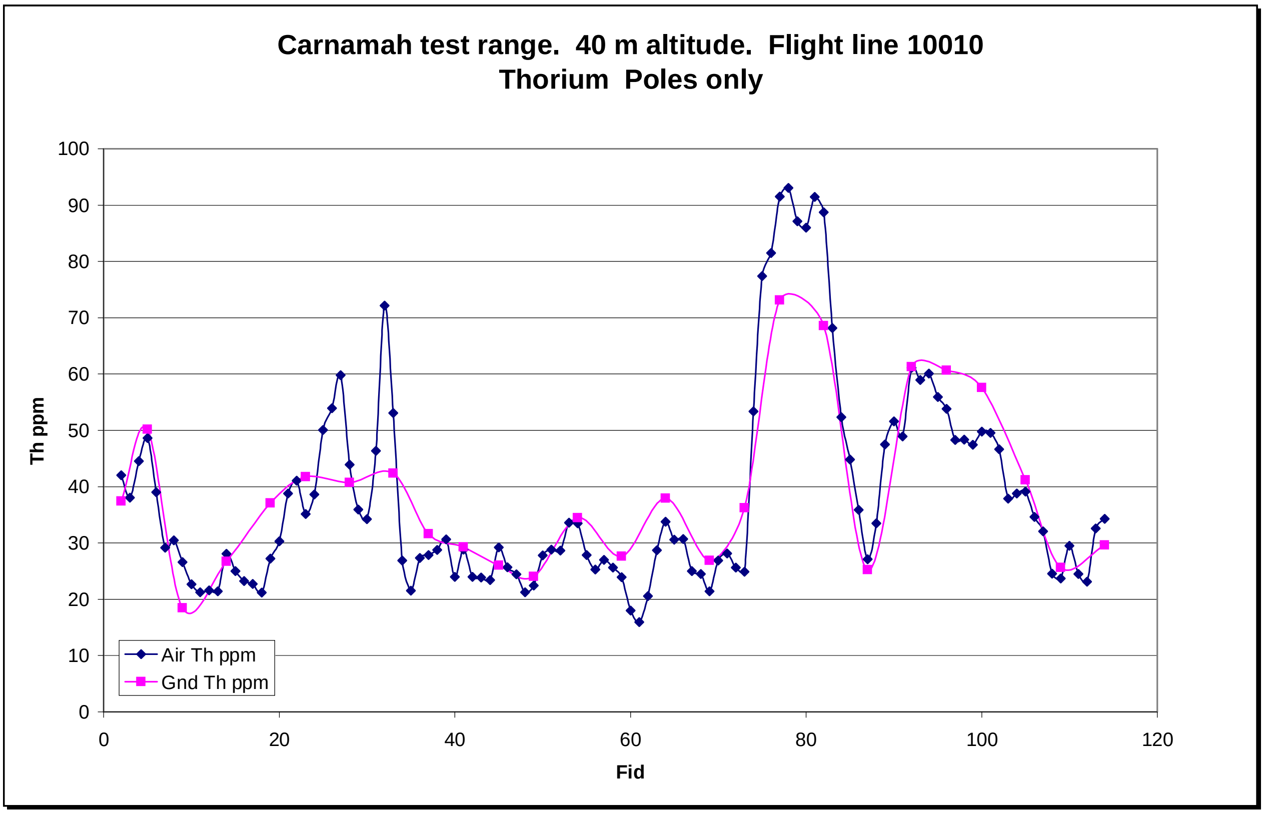


Figure. 10. Thorium - flight profiles vs ground profiles.

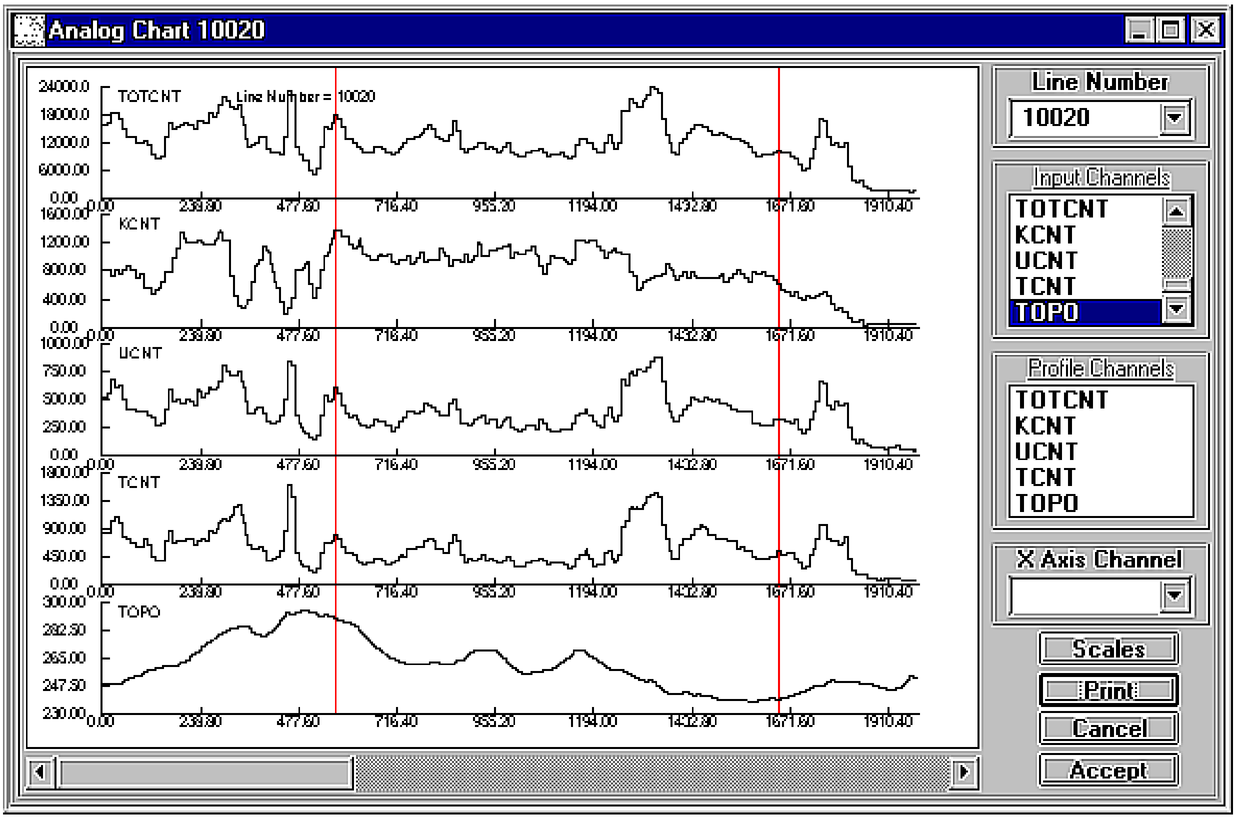


Figure. 11. Profiles along test range and past ends. (North end to Left).

The profiles shown above are from a single pass at approximately 40 metres altitude using an Exploranium GR820 with 67 litres of crystal volume. The Test Range is delineated by the RED cursors. The radiometric data is stripped and normalised.

As can be seen from Fig. 11 there is some 48 metres of ***Topo***graphical relief along the Test Line, however, the highest point is ***past*** the Northern end of the line. There is a creek at the lowest point, just prior to the Southern end.

The large variation in the K, U and Th profiles occurring in the vicinity of the line ends makes it imperative that the airborne data set be trimmed back to the published end co-ordinates for the range. Note the remarkable drop off in readings past the Southern end of the range.

CARNAMAH TEST RANGE USE TO MARCH 2003

There are now ground data for thirty-nine (39) calibration passes of Carnamah available for comparison. These cover the period March 1997 to March 2003 and are available from the author as a progressive EXCEL spreadsheet file (carnamah progressive.xls). These results show remarkable repeatability with seasonal variations. The Uranium response is relatively 'prevailing wind' direction dependent as would be expected of a range relatively close to a large ocean.