BASELINE RADIATION PARAMETERS PRIOR TO WAGERUP 3 EXPANSION

ALCOA WORLD ALUMINA AUSTRALIA

Prepared by: Dr Keith W Terry BSc PhD MAIP
RADIATION-WISE PTY LTD
PO BOX 3066
SHELLEY WA 6148
Tel: (08) 9457 1698
Fax: (08) 9354 2711
Mobile: 041 9965 891
Email: radwise@ozemail.com.au
FEBRUARY 2005

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EXECUTIVE SUMMARY

In seeking approval for the Wagerup 3 expansion it is necessary to consider the radiological impact of the additional production on the environment. This is due to the bauxite feed stock containing low levels of uranium and thorium, and the fact that these radionuclides follow the residue streams.

To be in a position to assess the potential future radiological impact the baseline radiological parameters prior to the expansion have been documented. Since the current Wagerup refinery and residue storage area have been operational for more than twenty years the so called baseline data is basically the status quo prior to the expansion.

The bauxite feed stock to the refinery will continue to be sourced from the Willowdale mine site. The bauxite feed stock over the last twelve months contains thorium and uranium at the 0.8 Bq g^{-1} and 0.1 Bq g^{-1} level, respectively. Thorium levels in the sand and mud fractions of the residue are 0.8 Bq g^{-1} and 1.8 Bq g^{-1}, respectively, while the uranium levels are <0.1 Bq g^{-1} and 0.2 Bq g^{-1}, respectively. None of these materials are classed as radioactive material under the current WA Radiation Safety (General) Regulations. Also the materials would be exempt from the provisions of the Radiation Safety (Transport of Radioactive Substances) Regulations.

It has not been possible to establish a baseline gamma radiation level on the Wagerup site due to the previous twenty years use of the site. The mean value of 0.16 μGy h^{-1} obtained around the site boundaries should be used for future rehabilitation of the site.

The gamma radiation levels at the site boundaries which are approximately 2 km from the operations are not expected to change as a result of the Wagerup 3 expansion. Several millimeters, if not centimeters, thickness of wind swept dust would be necessary before an increase in gamma radiation levels would be detected at the site boundaries.

The dust concentrations vary from day to day, and from season to season. Extensive data is available from historical daily high volume air samples taken from six locations around the residue storage area. During the last twelve months the summer levels have been around 42 μg m^{-3} compared to 14 μg m^{-3} in the winter. This is attributed to dry summers and wet winters typical for the region. The mean values are typical environment levels despite the current production levels so that the Wagerup 3 expansion can be expected to have minimal impact on these levels.

Limited radon concentrations in air data are available for the Wagerup region. A measured mean value of 18 Bq m^{-3} is higher than the mean value of 16 Bq m^{-3} reported for WA homes and the world-wide mean value of 10 Bq m^{-3}. The higher value is attributed to the uranium and thorium content of the local soils. The Wagerup 3 expansion is not expected to cause any increase in the radon and thoron concentrations in air at the site boundaries of the Alcoa's land holdings. The site boundaries are at least 2 km from the operations and the half-life of radon (^{222}Rn) and thoron (^{220}Rn) are 3.82 days and 55.6 s, respectively.

The measured activity concentrations of three radionuclides in the ^{238}U decay series and two radionuclides in the ^{232}Th decay series do not support the measured gross alpha and gross beta activity concentrations when assuming secular equilibrium. The higher gross alpha and gross beta activity concentrations are attributed to levels of ^{226}Ra and ^{228}Ra above those predicted from secular equilibrium. Recent measurements have given a mean activity concentration of 65 mBq L^{-1} and 280 mBq L^{-1} for ^{226}Ra and ^{228}Ra, respectively. This data should be regarded as the baseline data for the Wagerup 3 expansion.

Currently the integrity of the residue storage area to retain radionuclides, and other species, is being monitored using pH, electrical conductivity, sodium/chloride ratio, and alkalinity. Consideration should be given to extending the on-going measurements on bore waters to ^{226}Ra and ^{228}Ra.

The Wagerup 3 expansion can be expected to maintain the status quo of the radiological parameters as per the current operational conditions. Just more of the same material is to be processed in a similar fashion as the current production.

1.0 INTRODUCTION

Alcoa World Alumina Australia (Alcoa) intends to expand its existing Wagerup refinery through completing the construction of a third production unit. This would increase the total alumina production of the refinery to approximately 4.7 million tonnes per annum.

In seeking approval for the expansion it is necessary to address the associated radiological impact on the environment since the bauxite feed stock to the refinery contains low levels of thorium and uranium. As such, the bauxite feed stock may be regarded as a naturally occurring radioactive material, or NORM. It is well established that when using the Bayer Process to produce alumina from bauxite the naturally occurring radionuclides follow the residue stream.

The radiological aspects of bauxite processing at Wagerup, and at its other two refineries in Western Australia, have been progressively assessed and documented by Alcoa and subsequently reported to the relevant government regulators. A review of the series of studies conducted over the last 25 years has recently been made by O'Connor (2004). One of O'Connor's recommendations was that a baseline radiological study be conducted in advance of any new operations or major expansion.

This report documents the available baseline radiological data for the Wagerup 3 expansion. After a review of the relevant radiation legislation, the following five specific topics are covered:

(i) radionuclide content in the feed stock and wastes;
(ii) gamma radiation levels;
(iii) dust and gross alpha activity concentrations in air;
(iv) radon concentrations in air; and
(v) radionuclides in ground-waters.

2.0 RELEVANT LEGISLATION

Currently in Western Australia the primary legislation controlling radiation is the Radiation Safety Act 1975 and it associated Radiation Safety (General) Regulations 1983 – 1997. Under these Regulations a material is classed as a radioactive material if its total activity concentration exceeds 30 Bq g^{-1}. In the case of NORM this would be the total activity of the parent and progeny of both the ^{232}Th and the ^{238}U decay series. Neither the bauxite feed stock nor the process residues would be classed as radioactive materials under these Regulations. However, the Regulations are applicable to materials of lower total activity concentration if, in the opinion of the Radiological Council, there is a risk that their use could result in an individual receiving a dose exceeding the appropriate dose limits for that individual.

The current dose limits are those in the Recommendations for Limiting Exposure to Ionizing Radiation (printed 1995, republished 2002) and National Standards for Limiting Occupational Exposure to Ionizing Radiation (printed 1995, republished 2002). These dose limits are listed in Table 2.1 and in summary are a maximum occupational dose of 50 mSv in any year with a mean of 20 mSv over any five years, and a public limit of 1 mSv in any one year. These doses are over and above the natural background radiation exposures.

Mining activities in Western Australia are regulated by the Mines Safety and Inspection Act 1994 and the Mines Safety and Inspection Regulations 1995 (MS&IR). Part 16 of these

TABLE 2.1

DOSE LIMITS FOR IONIZING RADIATION

	Dose limits[a]
Occupational	20 mSv per year, averaged over a period of 5 consecutive calendar years[b]
Public	1 mSv in a year[c]

[a] The limits shall apply to the sum of the relevant doses from external exposure in the specified period and the 50 year committed dose from intakes in the same period.

[b] With the further provision that the effective dose shall not exceed 50 mSv in any single year.

[c] In special circumstances, a higher value of effective dose could be allowed in a single year, provided that the average over 5 years does not exceed 1 mSv per year.

Regulations covers radiation and take precedence over the Radiation Safety (General) Regulations. Division 2 of Part 16 deals with the mining and processing of radioactive materials.

The MS&IR does not define a radioactive material but these Regulations are applicable if the annual dose to workers and members of the public are likely to exceed 1 mSv and 0.5 mSv, respectively. Under Part 16.3 of the MS&IR the SME may exempt a mine from all or part of Division 2 if the effective dose is less than 1 mSv per year for each employee. Previous radiological assessment of the Wagerup operations (O'Connor, 2004) has indicated that all employees receive an annual effective dose of less than 1 mSv, so satisfying the criteria for exemption from Division 2 of Part 16 of the MS&IR.

Current mining practice in Western Australia is to dispose of radioactive material in a similar condition as Category A waste specified in the Code of Practice for the Near-Surface Disposal of Radioactive Waste in Australia 1992. This requires a minimum cover of 2 m of clean (non-radioactive) material.

Any transport of radioactive material off-site from Alcoa's operations is regulated by the Radiation Safety (Transport of Radioactive Substances) Regulations 1991. These Regulations adopt the Code of Practice for the Safe Transport of Radioactive Material 2001 which exempts natural materials and ores containing naturally occurring radionuclides, which have been processed, where the physical or chemical processing was not for the purpose of extracting radionuclides, provided the aggregate activity concentration of ^{232}Th and ^{238}U in the material does not exceed 10 Bq g^{-1}. The bauxite feed stock to, and the mud and sand fractions of the residues from, the Wagerup refinery would therefore be exempt from this Transport Code.

3.0 RADIOLOGICAL BASELINE PARAMETERS

3.1 RADIONUCLIDE CONTENT OF FEED STOCK AND WASTE

The radionuclide content of the bauxite feed stock, and the sand and mud fractions of the residue are routinely sampled on at least a daily basis. The bauxite sample is taken from the refinery stock-pile; the sand fraction of the residue is sampled as it goes to the residue storage area; the mud fraction of the residue is the mud from the last stage washer which feeds into the super thickener. Daily shift samples of each material are analysed on-site using X-ray fluorescence spectrometry. A mean monthly composite analysis is obtained by weighting each result by the appropriate shift tonnages. The means and standard deviations from the means for the uranium and thorium analyses are given in Table 3.1 and plotted in Figure 3.1.

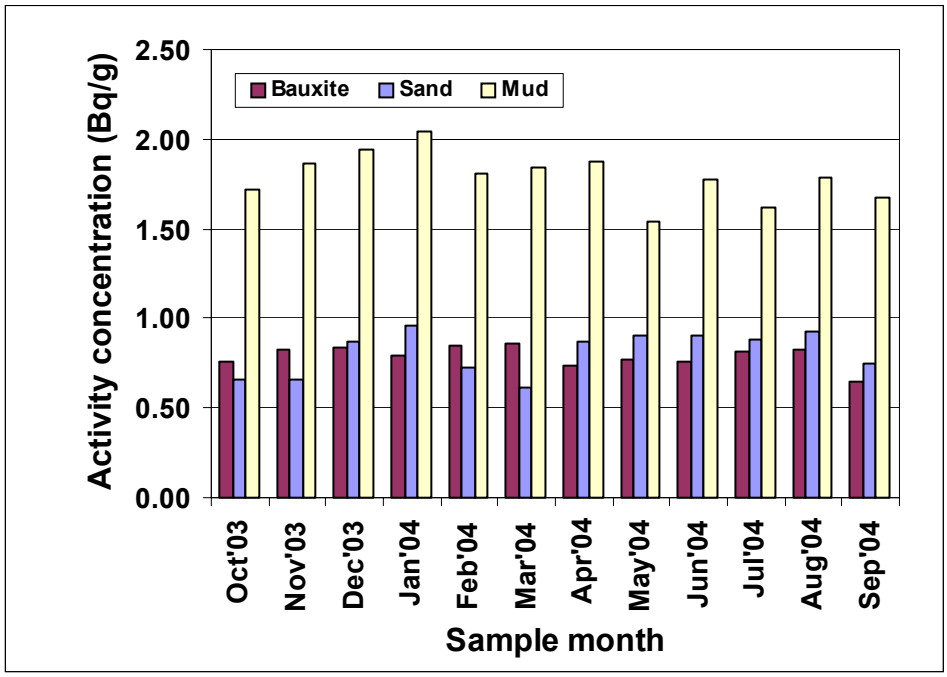
There is quite a variation in the radionuclide content in the three materials during the year. This variation is attributed to the mining schedule. The aggregate activity concentration of ^{232}Th and ^{238}U exceeds 1 Bq g^{-1} occasionally for the bauxite feed stock and the sand fraction of the residue, but the annual means are less than 1 Bq g^{-1}. In contrast, the aggregate activity concentration in the mud fraction of the residue is consistently above 1 Bq g^{-1} throughout the year. From this data none of the three materials are classed as a radioactive material under the current State legislation. In addition all three materials would be exempt from the Transport Code under section 2.4.

TABLE 3.1

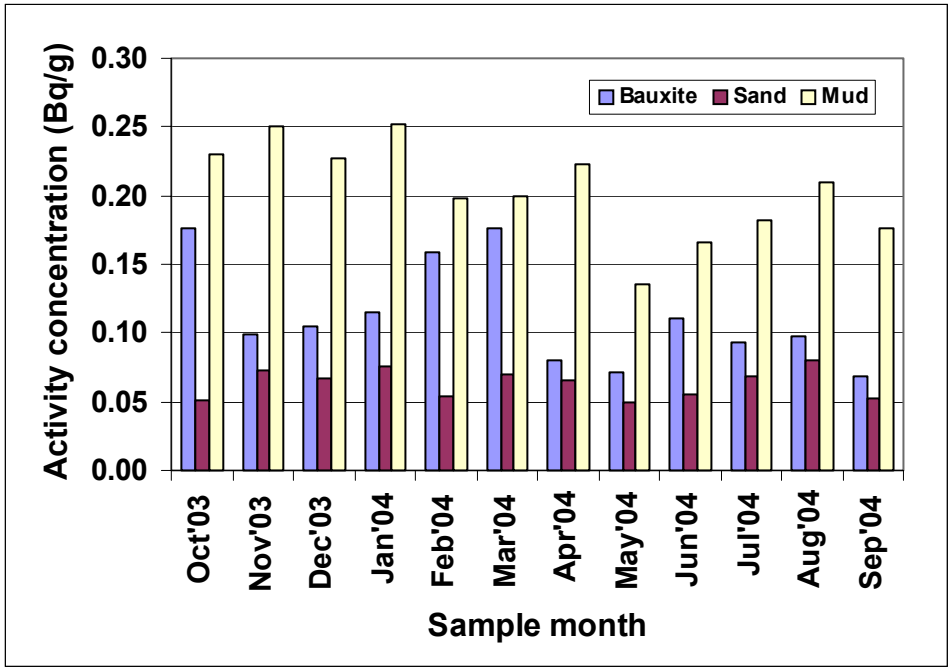
RADIONUCLIDE CONTENT OF BAUXITE FEED STOCK AND THE RESIDUE FRACTIONS

Sample	Thorium (Bq g^{-1})			Uranium (Bq g^{-1})		
	Bauxite	**Sand**	**Mud**	**Bauxite**	**Sand**	**Mud**
Oct'03	0.76	0.66	1.72	0.18	0.05	0.23
Nov'03	0.83	0.66	1.86	0.10	0.07	0.25
Dec'03	0.83	0.88	1.94	0.10	0.07	0.23
Jan'04	0.80	0.95	2.04	0.12	0.08	0.25
Feb'04	0.85	0.73	1.81	0.16	0.05	0.20
Mar'04	0.86	0.61	1.84	0.18	0.07	0.20
Apr'04	0.74	0.87	1.87	0.08	0.07	0.22
May'04	0.77	0.90	1.54	0.07	0.05	0.13
Jun'04	0.76	0.90	1.77	0.11	0.06	0.17
Jul'04	0.82	0.88	1.62	0.09	0.07	0.18
Aug'04	0.82	0.93	1.78	0.10	0.08	0.21
Sep'04[a]	0.65	0.75	1.68	0.07	0.05	0.18
Mean	**0.79**	**0.81**	**1.79**	**0.11**	**0.06**	**0.20**
Std. Dev.	**0.06**	**0.12**	**0.14**	**0.04**	**0.01**	**0.04**

[a] The Oct'04 data has been used for Bauxite since the Sep'04 data is not available.



(a) Thorium



(b) Uranium

Note: The Oct'04 data has been used for Bauxite instead of the Sep'04 data.

FIGURE 3.1: RADIONUCLIDE CONTENT OF BAUXITE FEED STOCK AND THE RESIDUE FRACTIONS (a) THORIUM and (b) URANIUM.

The historical radionuclide contents of the bauxite feed stock and the residue fractions are summarized in Table 3.2. The previous data was fairly consistent considering the time span over which the data applies and indicated that both the bauxite and the mud fraction of the residue exceeded an aggregate activity concentration of ^{232}Th and ^{238}U of 1 Bq g^{-1}. In contrast the recent monthly composite data indicates lower thorium in the bauxite and lower uranium in the three materials. This appears to be a true decrease since the current analytical technique is the same as that used for the Terry 2001 data.

The expectation is that similar variations will occur in the radionuclide content of future bauxite feed stock so that a similar range as at present will occur in future residue fractions. The consequence of the Wagerup 3 upgrade is that more of the same type of material will be processed.

TABLE 3.2

HISTORICAL RADIONUCLIDE CONTENT OF BAUXITE FEED STOCK AND RESIDUE FRACTIONS

Radionuclide[a]	Radionuclide content (Bq g^{-1})			
	O'Connor 1989	Terry 2001	ANSTO 2004	Monthly composites 2003-2004
Bauxite				
Thorium	0.77	1.05	1.03	0.79
Uranium	0.22	0.35	0.35	0.11
Sand fraction				
Thorium	0.77	0.62	0.74	0.81
Uranium	0.14	0.16	0.17	0.06
Mud fraction				
Thorium	1.80	1.90	2.14	1.79
Uranium	0.63	0.60	0.71	0.20

[a] Thorium and uranium refer to ^{232}Th and ^{238}U, respectively.

3.2 GAMMA RADIATION SURVEY

Gamma radiation levels were measured using Mini Instrument Environmental Meter, type 6-80, serial number 2250, which had been calibrated against ^{137}Cs at the Radiation Health Branch of the Western Australian Department of Health on 3/6/04. A copy of the calibration certificate is included as Appendix A.

Readings were made holding the detector horizontally one metre above ground level and recording the aggregate counts in 60 s at each location. All measurements were made on 3/11/04.

3.2.1 Site boundaries

Measurements were made at approximately 1 km intervals at the side of the public roads towards the perimeter of the Alcoa land holdings around the refinery and residue storage area. In particular, the perimeter roads were the Access Road, South West Highway, Cornucopia Road, Burney Road, Roberts Road, McClure Road, Somers Road and Bancel Road. These roads are shown in Figure 3.2.

The measured gamma radiation levels are detailed in Table 3.3 together with the eastings and northings of each location. A plot of the eastings and the northings is shown in Figure 3.3. The values ranged from 0.11 $\mu Gy\ h^{-1}$ to 0.28 $\mu Gy\ h^{-1}$ with a mean and standard deviation from the mean of $0.17 \pm 0.04\ \mu Gy\ h^{-1}$. The single high value of 0.28 $\mu Gy\ h^{-1}$ was from the constructed wall between the two ponds on the Access Road. Omitting this value from calculations results in a range from 0.11 $\mu Gy\ h^{-1}$ to 0.21 $\mu Gy\ h^{-1}$ and a mean and standard deviation from the mean of $0.16 \pm 0.03\ \mu Gy\ h^{-1}$. The standard deviation from the mean is higher than expected from the counting statistics associated with the measurements and is attributed to the varying soil types at the measuring locations. However, the value of $0.16 \pm 0.03\ \mu Gy\ h^{-1}$ may be regarded as the background level in the vicinity of the Wagerup refinery.

The increase of the refinery's capacity following the Wagerup 3 expansion is unlikely to result in an increase in the gamma radiation levels around the site boundaries. Several millimeters, if not centimeters, thickness of wind swept dust would be necessary before an increase in gamma radiation levels would be detected.

3.2.2 Footprint of Wagerup 3 Expansion

The facilities to be constructed in the Wagerup 3 expansion will be duplicates of existing plant and as such will occupy various sites around the refinery. The proposed locations for these extra facilities are shown in green in Figure 3.4.

Gamma radiation surveys were conducted over five of these locations, namely, Digestion, Precipitation, Filtration, Evaporation and Sand Separation. Measurements were made on a nominal 10 m x 10 m grid at each location. The measured gamma radiation levels are listed in Table 3.4. A summary of the data is given in Table 3.5.

The means and standard deviations from the means for the five locations are quite different to each other. This is attributed to the variety of material types currently used to cover each location as none of the areas is undisturbed land. This is not unexpected due to the on-going production at Wagerup over the last twenty years. All but one of the five areas have a mean

390000 392000 394000 396000 398000 400000 402000 404000

6364000 6362000 6360000 6358000 6356000 6354000

Road

Roberts Rd.

HAMEL

Burney Rd.

Cornucopia Rd.

South Western Highway

McClure

Road

North

RNW

Somers

RN

South Samson

Diversion Drain

155SGW

25GW

153SGW

Access Road

RDA7

RDA6 (Stage2)

RDA5

RDA6 (Stage1)

RDCP2

Detention Pond

SP1

Willowdale Mine Road

78G

West

SP12

Oxalate

Storage

72SG

RDA4

RDA3

56SG

RDA1

RDA2

Cooling Pond

RE

WAGERUP

REFINERY

RW

1GW

26GW

East

79G

146SGW

100SIG

RDCP1

RDA8

ROWS Pond

18G

Rail Corridor

BRmet

Bancell Rd

2GW

South

Bancell

Rd

28GW

BRW

Kaus Rd

NL3

BR001

Boundary Rd

Aitken St

YARLOOP

Perth

Booragoon

Kwinana

Huntly

Dwellingup

Wagerup

Willowdale

Bunbury

Locality Map

Legend

Premises Bdy

Dust Monitors

Licenced Site

Other Monitoring

Stacks

Water Monitoring

Licenced Bore

Water Monitoring

Surface Point

Landfill

Weather Stations

BRmet

Noise Monitor

Noise Monitor

Roads

Sealed >6m

Unsealed >6m

Sealed <6m

Unsealed <6m

Track

Conveyor

Railway

Cutting

Transmission

Haul Road

Landholdings - Alcoa

Landholdings - Other

Note: Landholding detail current as at January 2005

N

1 0 1 2 Kilometers

Scale 1:50000

Date: 28/2/2005

Fig. 3.2 MONITORING POINTS USED IN THE BASELINE STUDY OF THE RADIOLOGICAL PARAMETERS

TABLE 3.3

GAMMA RADIATION LEVELS AROUND PERIMETER OF WAGERUP OPERATIONS

Point	Easting (m)	Northing (m)	Gamma radiation level ($\mu Gy\ h^{-1}$)
1	398794	6357101	0.21
2	398870	6358096	0.28
3	398815	6359056	0.11
4	397879	6359314	0.11
5	397922	6359904	0.11
6	398691	6360588	0.19
7	399236	6361361	0.18
8	399348	6362067	0.16
9	398487	6361902	0.20
10	397094	6361848	0.19
11	396112	6361842	0.14
12	395117	6361831	0.16
13	394103	6361826	0.20
14	393087	6361814	0.14
15	392542	6361407	0.15
16	392556	6360384	0.18
17	392525	6359366	0.17
18	392335	6358397	0.12
19	392347	6357403	0.13
20	392901	6356636	0.17
21	393786	6356144	0.15
22	394767	6356053	0.14
23	395773	6356054	0.18
24	396762	6356068	0.18
25	397695	6356149	0.18
26	398707	6356144	0.20
Mean[a]			**0.16**
Std. dev.			**0.03**

[a] Omitting the data for location 2.

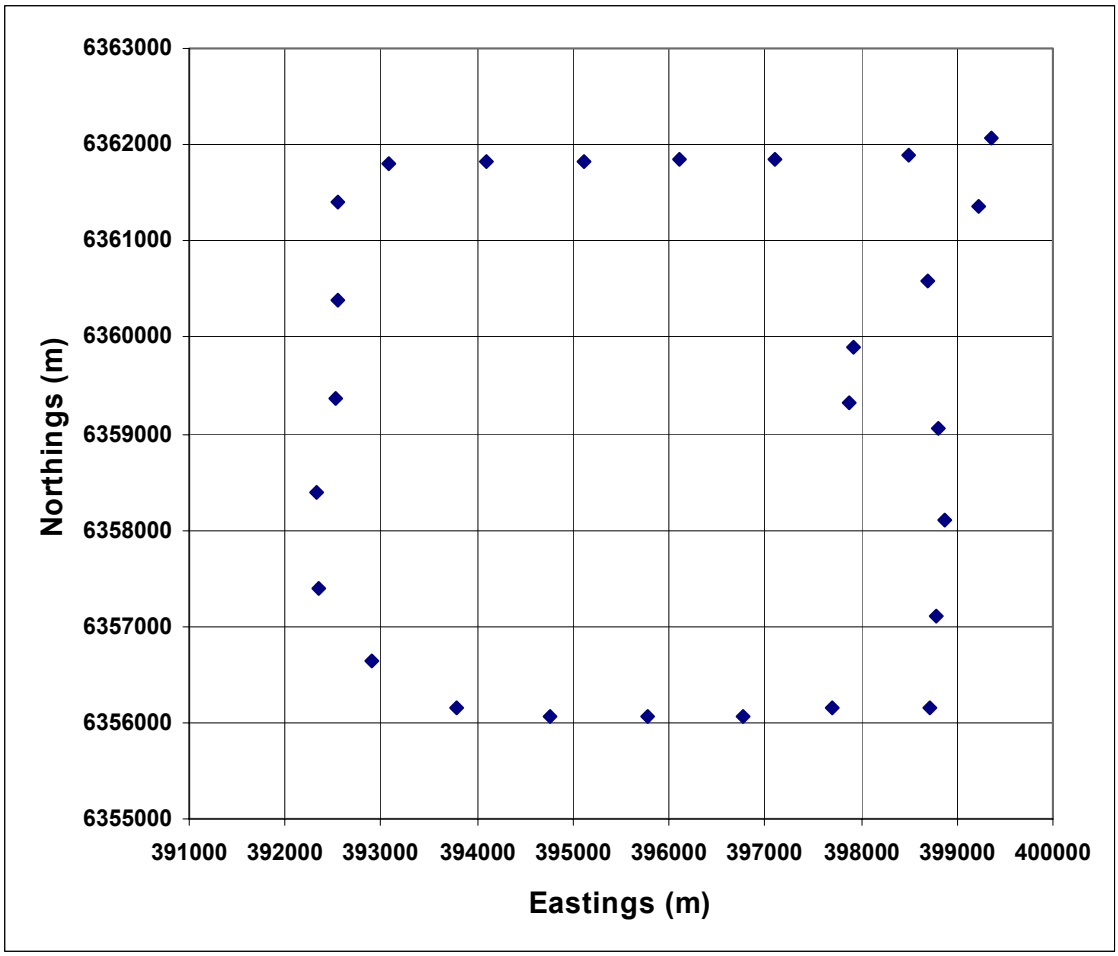


FIGURE 3.3: PLAN OF THE EASTINGS AND NORTHINGS OF MEASURING POINTS USED IN THE GAMMA RADIATION SURVEY AROUND THE PERIMETER OF THE WAGERUP OPERATIONS.

FIGURE 3.4: LOCATIONS FOR THE NEW FACILITIES TO BE CONSTRUCTED DURING WAGERUP 3 EXPANSION.

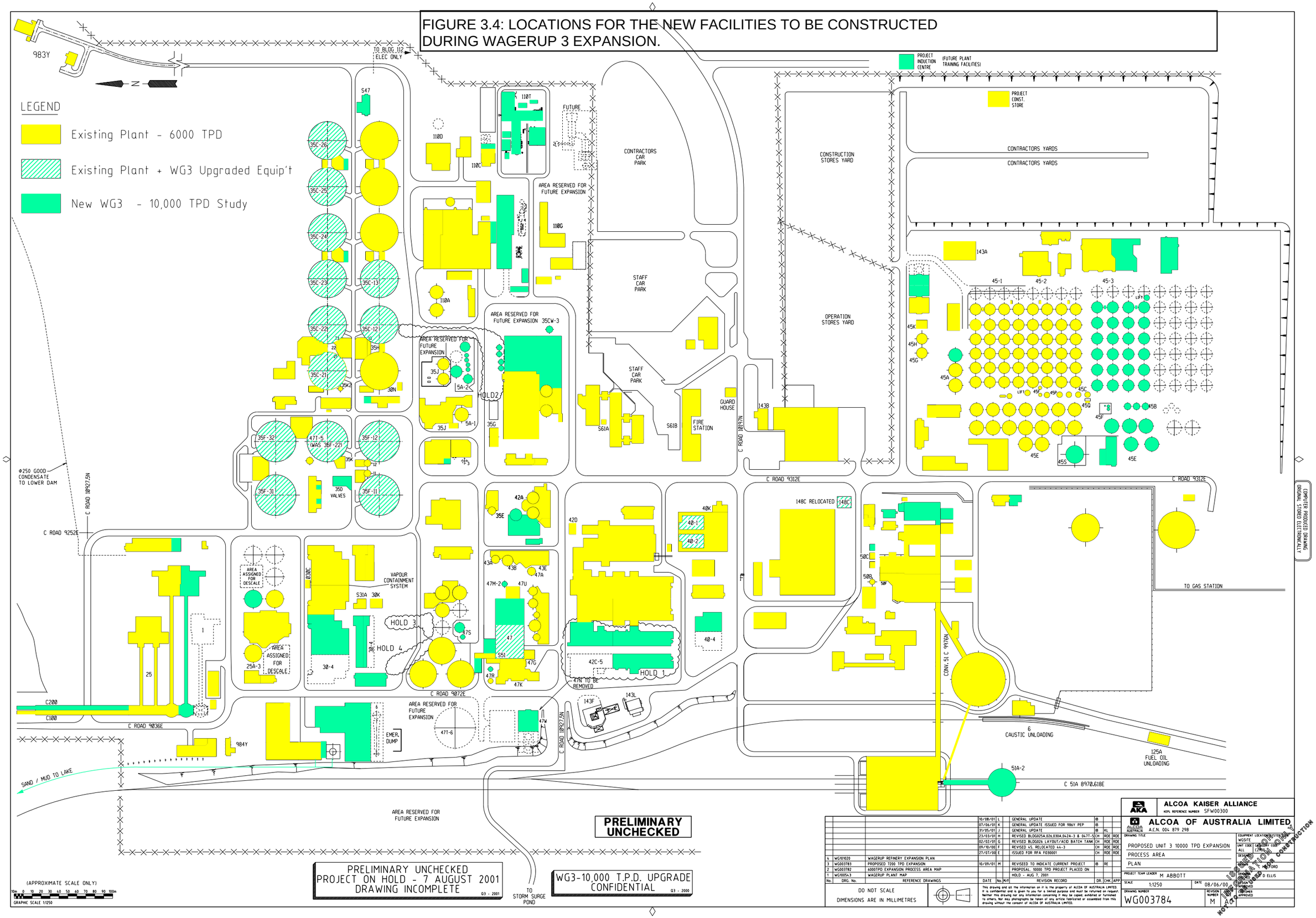
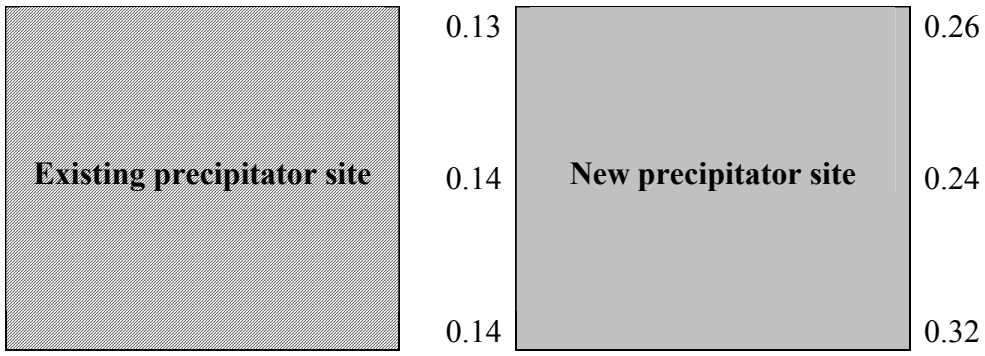


TABLE 3.4

GAMMA RADIATION LEVELS ON WAGERUP 3 FOOTPRINT

A. Precipitation



B. Digestion, Building 30

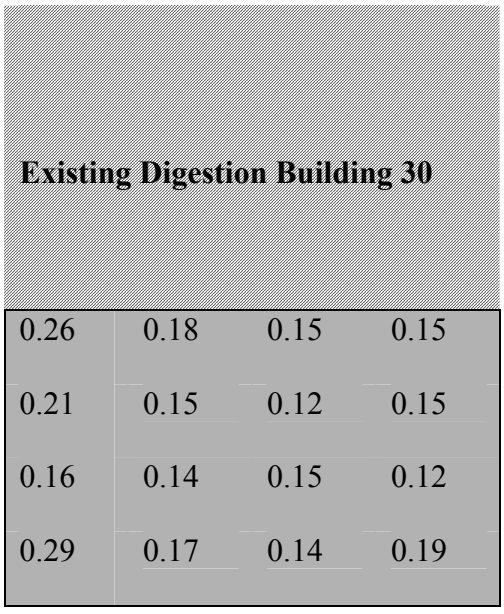


TABLE 3.4 (Cont.)

GAMMA RADIATION LEVELS ON WAGERUP 3 FOOTPRINT

C Filtration, Building 35X

0.13	0.14	0.16	0.14	0.16	0.39
0.16	0.12	0.14	0.17	0.15	0.28
0.21	0.16	0.18	0.13	0.16	0.19
0.27	0.22	0.18	0.14	0.20	0.24
0.41	0.49	0.36	0.44	0.27	0.30
				0.21	0.23

Existing Digestion, Building 35

D. Sand Separation, Building 26

	0.24	0.29	0.29	0.25
	0.17	0.37	0.24	0.22
Sand Separation, Building 26	0.27	0.29	0.27	0.27
			0.19	0.27
			0.13	0.17

TABLE 3.4 (Cont.)

GAMMA RADIATION LEVELS ON WAGERUP 3 FOOTPRINT

E. Evaporation, Building 42

Existing Evaporation, Building 42							
0.11	0.13	0.12	0.12	0.13	0.12	0.16	0.14
0.12	0.11	0.12	0.12	0.13	0.15	0.16	0.16

TABLE 3.5

SUMMARY OF GAMMA RADIATION LEVELS ON WAGERUP 3 FOOTPRINT

Location	No. of points	Gamma radiation levels (μGy h^{-1})			
		Min	Max	Mean	Std Dev
Digestion, Building 30	16	0.12	0.29	0.17	0.05
Precipitation	6	0.13	0.32	0.21	0.08
Filtration, Building 35X	32	0.12	0.49	0.22	0.10
Evaporation, building 42	16	0.11	0.16	0.13	0.02
Sand separation, building 26	16	0.13	0.29	0.25	0.06
Site boundaries	**25**[a]	**0.11**	**0.21**	**0.16**	**0.03**

[a] Omitting the data for location #2.

gamma level in excess of the mean value of 0.16 μGy h^{-1} determined in section 3.2.1 for the site boundaries.

Due to the difficulty of establishing a baseline value for the current footprint of the Wagerup operations these values should be used as indicative values only. It is recommended that the mean site boundary value of 0.16 μGy h^{-1} be adopted for future rehabilitation purposes.

It is likely that the gamma radiation levels on the Wagerup 3 footprint will change as a result of the construction and subsequent operations of the facilities. These changes will be attributed to the choice of construction materials brought to site. In the long-term, there will be no lasting impact on the environment since, in the eventual decommissioning and rehabilitation of the site, the gamma radiation levels will be restored to the local background levels, i.e., 0.16 ± 0.03 μGy h^{-1}.

3.3 DUST AND GROSS ALPHA ACTIVITY CONCENTRATIONS

Twenty-four hour samples are obtained daily from six high-volume air samplers at locations surrounding the residue area. The sampling locations are shown in Figure 3.2.

The high volume samplers are fitted with 10" x 8" glass fibre filters and run at 70 $m^3 h^{-1}$. The daily dust concentrations from five of these samplers for the period 1 October 2003 to 30 September 2004 are shown in Figure 3.5. There are large differences in the dust concentrations from samplers on some days.

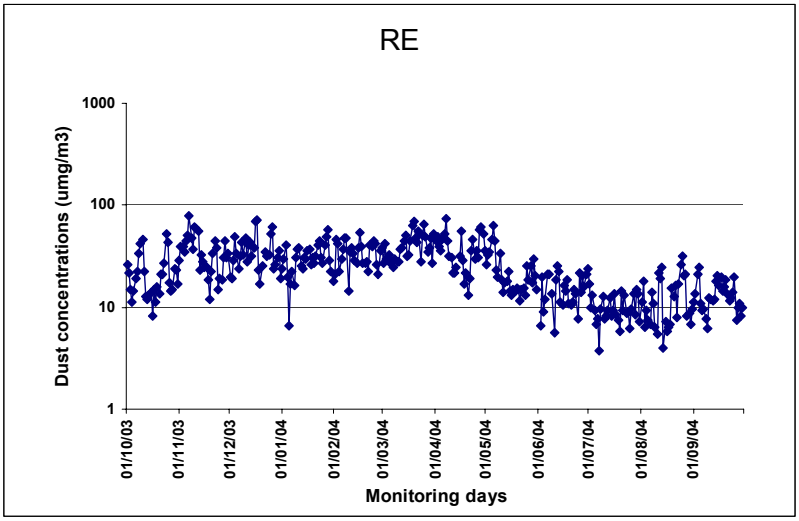
The summary data in Table 3.6 shows mean dust concentrations of 42 $\mu g\ m^{-3}$ in the summer (Oct to Apr) and 14 $\mu g\ m^{-3}$ in the winter (May to Sep). This is attributed to the dry summer and wet winter weather conditions. There are occasional excursions to both high and low levels outside of the broad band of the daily variations within each season. The 20 samples in excess of 100 $\mu g\ m^{-3}$ were all associated with locations RW and RN.

The five 24-hour samples from filters used on 15 January 2004, 15 April 2004 and 15 October 2004 were selected for gross alpha counting. A 44 mm diameter disk was cut out of each filter and its gross alpha count in 50,000 s measured in a Canberra Alpha Spectrometer, type 7401. The gross alpha activity concentration was calculated using the calibration factor from a 47 mm diameter standard ^{241}Am source which itself is calibrated annually by the RHB. The latest letter of calibration from the RHB dated 18/6/04 is attached as Appendix B.

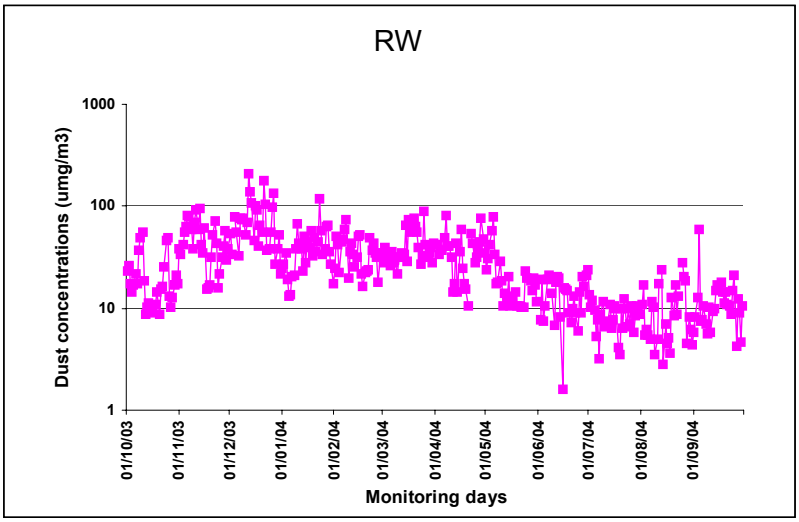
The measured dust and gross alpha activity concentrations are shown in Table 3.7. The data demonstrates not only variations between locations on a particular day, but significant variations in the four seasons. The specific activity of the dust is also listed in Table 3.7. The data from the January 2004 samples (of the order of 2 – 4 Bq g^{-1}) are typical of environmental dusts. The values above 4 Bq g^{-1} in April 2004 and October 2004 can probably be attributed to bauxite or residue dusts. It is most likely that the high specific activity of the dust in the July 2004 samples is due to "radioactive wash-down" rather than from operational dusts. "Radioactive wash-down" is a phenomenon previously observed by the author. The specific activity of dust samples is higher in winter than expected from environmental or operational dusts. The increase is attributed to airborne radioactivity being precipitated by rain. However, alpha spectrometry of the dusts would be necessary to verify the fact that the excess activity concentration is not associated with uranium or thorium radionuclides, or their progenies.

The potential annual internal radiation dose to a member of the public from inhaling the dust at each location is also listed in Table 3.7. The calculation assumes full-time occupancy, a breathing rate of 1.2 $m^3 h^{-1}$, and a dose conversion factor of 9.7 $\mu Sv\ \alpha dps^{-1}$ (This is the dose conversion factor for thorium ore dusts with an activity median aerodynamic diameter of 5 μm). The mean annual dose would be a total of 0.02 mSv. This is one fiftieth of the public limit of 1 mSv and is a conservative estimate since the breathing rate is an occupational rate rather than a passive rate and no background has been subtracted.

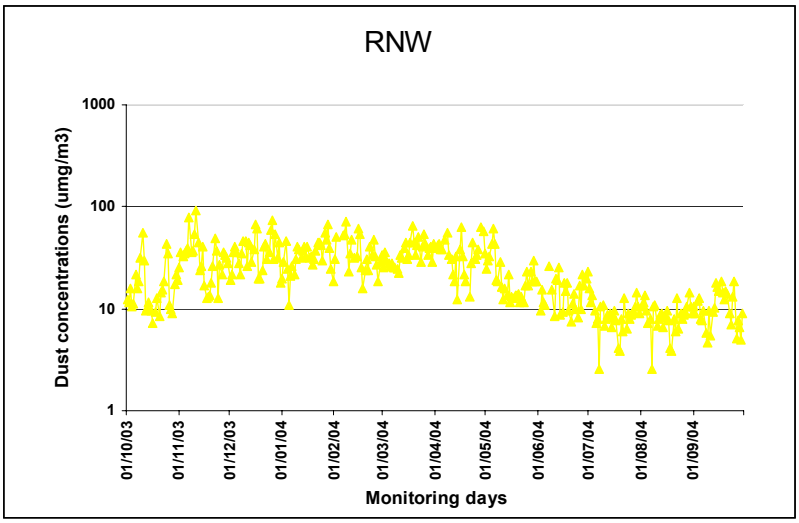
It is seen that despite wide variations in the dust and gross alpha activity concentrations during the year, the annual internal radiation dose from the current operations is negligible.



(a) **RE**

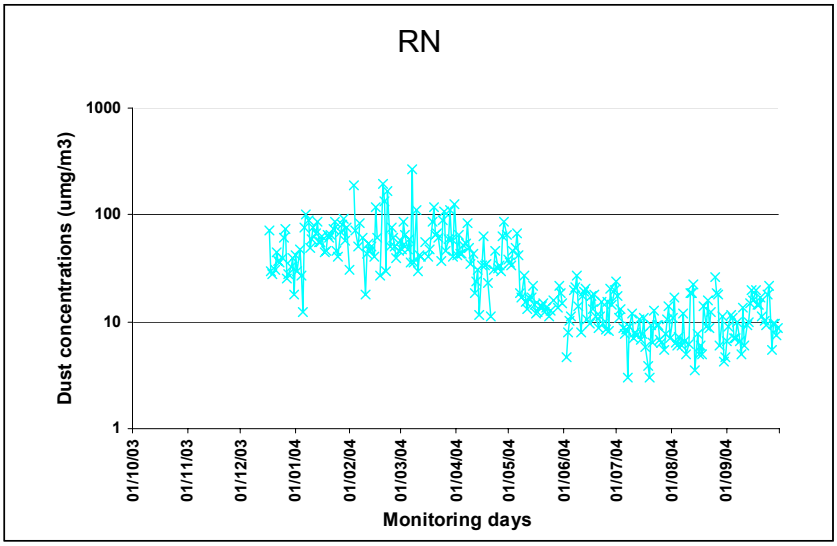


(b) RW

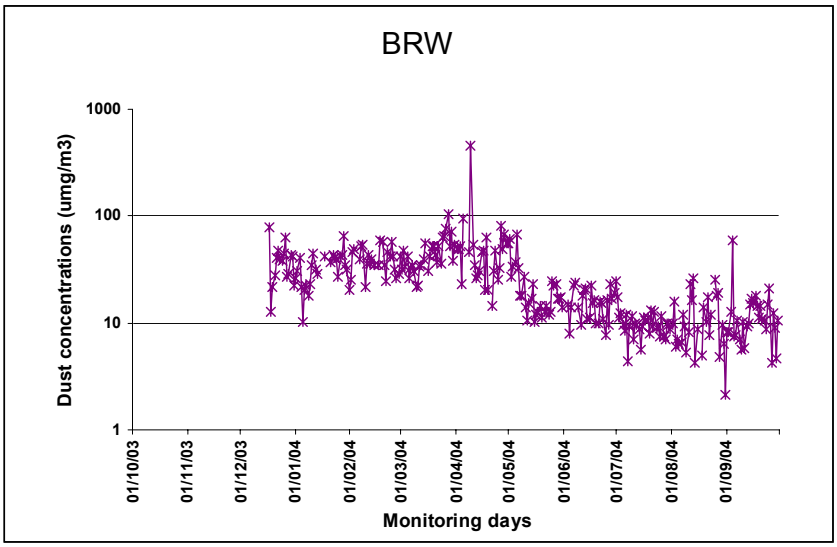


(c) RNW

FIGURE 3.5: DAILY DUST CONCENTRATIONS AROUND THE WAGERUP REFINERY FOR THE YEAR OCT'03 – SEP'04.



(d) RN



(e) BRW

FIGURE 3.5 (cont.): DAILY DUST CONCENTRATIONS AROUND THE WAGERUP REFINERY FOR THE YEAR OCT'03 – SEP'04.

TABLE 3.6

SUMMARY OF DUST CONCENTRATIONS

Location	No. of samples	Dust concentrations (μg m^{-3}) Min	Max	Mean	Std dev
Oct'03 - Apr'04					
RE	211	6.6	78.3	33.5	13.7
RW	210	8.7	207.6	42.5	27.7
RNW	205	7.2	90.7	33.1	14.7
RN	129	11.1	268.6	58.9	36.6
BRW	122	10.3	459.4	43.9	41.2
Mean				**42.4**	
May'04 – Sep'04					
RE	151	3.7	63.5	14.9	8.3
RW	147	1.6	79.4	13.1	10.0
RNW	150	2.6	61.1	12.8	7.9
RN	149	3.0	67.1	13.3	8.8
BRW	146	2.1	67.1	14.1	9.4
Mean				**13.6**	

TABLE 3.7

DUST AND GROSS ALPHA ACTIVITY CONCENTRATIONS

Location	Dust concentration ($\mu g\ m^{-3}$)	Gross alpha activity concentration ($\mu Bq\ m^{-3}$)	Specific activity ($Bq\ g^{-1}$)	Annual internal dose[a] (mSv)
15 Jan'04				
RNW	33	112	3.4	0.01
RN	56	142	2.5	0.01
RE	29	125	4.3	0.01
BRW		-	-	-
RW	28	107	3.8	0.01
Mean	**37**	**121**	**3.5**	**0.01**
15 Apr'04				
RNW	38	361	9.5	0.04
RN	34	374	11.1	0.03
RE	32	351	11.0	0.03
BRW	46	363	7.9	0.04
RW	36	301	8.4	0.04
Mean	**30**	**350**	**9.6**	**0.04**
15 Jul'04				
RNW	7	204	29.1	0.01
RN	7	197	28.1	0.01
RE	9	156	17.3	0.01
BRW	6	200	33.3	0.01
RW	7	193	27.6	0.01
Mean	**7**	**192**	**27.1**	**0.01**
15 Oct'04				
RNW	15	89	5.9	0.02
RN	22	85	3.9	0.02
RE	16	119	7.4	0.02
BRW	19	101	5.3	0.02
RW	15	62	3.3	0.02
Mean	**17**	**91**	**5.2**	**0.02**
MDL		**40**		

[a] Assumes full time occupancy, a breathing rate of 1.2 m^3h^{-1}, and a dose conversion factor of 9.7 $\mu Sv\ \alpha dps^{-1}$.

3.4 RADON CONCENTRATIONS IN AIR

Limited data on the radon concentrations in air was obtained from a three-month monitoring programme over the period 27/4/97 to 22/7/97. No thoron monitoring was undertaken. Passive radon monitors (track etch type), type DRNM, from Landauer Inc were set out approximately 2 km in each cardinal direction from the Wagerup residue storage area. The locations are shown in Figure 3.2. Each radon monitor was placed under an open-bottom plastic weatherproof cover attached approximately 1 m above ground to a wooden stake.

A summary of the data is given in Table 3.8.

The mean value of 18 Bq m^{-3} is marginally higher than the mean radon concentration of 16 Bq m^{-3} in Western Australian homes (Toussaint 1994), and the mean world-wide value of 10 Bq m^{-3} (UNSCEAR, 1993). The higher values at Wagerup are attributed to the higher uranium and thorium content of local soils.

The current and future operations at Wagerup are not expected to cause any increases in the radon and thoron concentrations in air at the site boundaries of the Alcoa land holdings. The site boundaries are at least 2 km from the operations and the half-life of radon (^{222}Rn) and thoron (^{220}Rn) are 3.82 days and 55.6 seconds, respectively.

It is recommended that consideration be given to include a twelve-month monitoring of radon and thoron concentrations in the vicinity of the Wagerup operations in any future on-going radiation monitoring. The above baseline data is only for a single three month period whilst radon concentrations are subject to seasonal changes.

TABLE 3.8

RADON CONCENTRATIONS IN AIR IN THE VICINITY OF WAGERUP OPERATIONS

Monitor	Location	Radon dose[a] (pCi L^{-1})	Radon concentration[b] (Bq m^{-3})
4215 101	South	43.3	18.0
4215 120	East	<30	<12
4215 122	North	55.0	22.9
4215 123	West	49.1	20.4
	Mean		**18.3**

[a] Values from Landauer dose report.
[b] Calculated by dividing the radon dose by the number of days in the monitoring period, i.e., 89 days, and using a factor of 1 pCi L^{-1} equals 37 Bq m^{-3}.

3.5 RADIONUCLIDES IN GROUND WATERS

Samples of ground-waters at Wagerup for radiometric analyses were collected during 1996/97 and in 2004. The schedule of the water sampling and the radiometric parameters measured are detailed in Table 3.9. The monitoring bore locations are shown in Figure 3.2. The analytical reports on these samples are attached as Appendix C. An assessment of the activity concentrations in the samples is shown in Tables 3.10, 3.11, 3.12, 3.13, 3.14, 3.15 and 3.16.

The data from the first two series provides the activity concentration of three radionuclides in the ^{238}U decay series and two radionuclides in the ^{232}Th decay series. The predicted alpha and beta activity concentrations have been calculated assuming secular equilibrium of the two decay series. A comparison of the measured and the predicted gross alpha and gross beta activity concentrations in the Series 1 samples are shown in Table 3.11. The fact that the measured values are higher than the predicted values indicates that the decay series are not in secular equilibrium. The most likely cause of the discrepancy is a higher ^{226}Ra and ^{228}Ra content than expected from the parents of the decay series and assuming secular equilibrium.

The data from the second series gives predicted gross alpha and gross beta activity concentrations half of those from the first series. Unfortunately no measured values are available.

The data from the third series show a mean ^{226}Ra concentration of 65 mBq L^{-1} which is much lower than the mean measured and predicted gross alpha activity concentrations in the first series, and similar to the mean predicted gross alpha activity concentration in the second series. The mean ^{228}Ra concentration of 277 mBq L^{-1} is lower than the measured mean gross alpha activity concentration in the first series, and much higher than the predicted mean values from both the first and second series.

Greater confidence should be given to the 2004 data and these means should be accepted as the current baseline data for the Wagerup 3 expansion.

The potential leaching of radionuclides into the ground-waters is the most important feature when considering the long-term radiological impact of the Wagerup operations on the environment. The eventual 2 m cover of the residue will adequately reduce the gamma radiation levels to background, avoid wind-swept residue, and attenuate radon and thoron emanations into the atmosphere. Hence the integrity of the residue storage area to retain water-borne radionuclides is the major concern.

Currently no on-going radiometric data are being measured on bore samples. Indication of leaching and leakages from the residue is being obtained from other ground-water data. Full details are available in a report by Nield Consulting and Parsons Brinkerhoff (2004). They report the use of pH, electrical conductivity, sodium/chloride ratio and alkalinity as indicators of contamination from residue leachate and process liquor.

Following recommendations in O'Connor (2004) it is likely that Alcoa will implement a more systematic radiological monitoring programme for its operations. Such a programme can expect to include radiometric analyses on bore waters. Based upon previous studies within Alcoa, and other WA mineral processors, the most appropriate analyses would be for ^{226}Ra and ^{228}Ra.

TABLE 3.9

SCHEDULE OF WATER SAMPLING AT WAGERUP AND ANALYSES

Series	Sampling date	Bores sampled	Analyst[a]	Report date	Radiometric parameters measured
Series 1	Early 1996	18G, 25G, 25W, 28W, 26W, 72G, 78G, 100G	ANSTO	27/5/96	U-238, U-234, Th-230, Th-232, Th-228, gross alpha, gross beta
Series 2	18/12/96	18G, 25G, 26G, 72G, 78G, 79G, 100G, 72S, 25W	ANSTO	8/4/97	U-238, U-234, Th-230, Th-232, Th-228
Series 3	1/12/04	SP001, SP012, 22G, 155W, 155GG, 155S, 153S, 153G, 153W, 001G, 001W, 146W, 146G, 146S	WRS	26/1/05	Ra-226, Ra-228

[a] ANSTO - Australian Nuclear Science and Technology Organisation.
WRS – Western Radiation Services.

TABLE 3.10

ASSESSMENT OF ACTIVITIES FROM THE U-238 DECAY SERIES IN FIRST SERIES OF WAGERUP BORE WATERS

Bore	Activity concentration					
	U-238 (Bq L^{-1})	U-234 (Bq L^{-1})	Th-230 (Bq L^{-1})	Sum (Bq L^{-1})	Alpha[a] (Bq L^{-1})	Beta[b] (Bq L^{-1})
deionised	0.005	0.003	0.003	0.011	0.029	0.022
deionised	0.004	0.004	0.006	0.014	0.037	0.028
25G	0.009	0.011	0.024	0.044	0.117	0.088
25W	0.004	0.006	0.002	0.012	0.032	0.024
26W	0.010	0.019	0.003	0.032	0.085	0.064
26W	0.014	0.026	0.003	0.043	0.115	0.086
18G	0.002	0.004	0.021	0.027	0.072	0.054
100G	0.003	0.003	0.006	0.012	0.032	0.024
78G	0.002	0.004	0.006	0.012	0.032	0.024
72S	0.014	0.011	0.003	0.031	0.083	0.062
72S	0.003	0.004	0.005	0.012	0.032	0.024
72G	0.001	0.002	0.004	0.007	0.019	0.014
Mean[c]	**0.006**	**0.009**	**0.008**	**0.023**	**0.062**	**0.046**

[a] Calculated from the sum assuming 8 alpha decays, i.e., 8/3 x sum.
[b] Calculated from the sum assuming 6 beta decays, i.e., 6/3 x sum.
[c] Not including data from deionised water.

TABLE 3.11

ASSESSMENT OF ACTIVITIES FROM THE TH-232 DECAY SERIES IN FIRST SERIES OF WAGERUP BORE WATERS

Bore	Activity concentration				
	Th-232 (Bq L^{-1})	Th-228 (Bq L^{-1})	Sum (Bq L^{-1})	Alpha[a] (Bq L^{-1})	Beta[b] (Bq L^{-1})
deionised	0.011	0.010	0.021	0.063	0.042
deionised	0.014	0.024	0.038	0.114	0.076
25G	0.009	0.033	0.042	0.126	0.084
25W	0.007	0.012	0.019	0.057	0.038
26W	0.007	0.016	0.023	0.069	0.046
26W	0.007	0.013	0.020	0.060	0.040
18G	0.008	0.005	0.013	0.039	0.026
100G	0.007	0.008	0.015	0.045	0.030
78G	0.008	0.013	0.021	0.063	0.042
72S	0.007	0.056	0.064	0.192	0.128
72S	0.011	0.010	0.021	0.063	0.042
72G	0.006	0.013	0.019	0.057	0.038
Mean[c]	**0.008**	**0.018**	**0.026**	**0.077**	**0.051**

[a] Calculated from the sum assuming 6 alpha decays, i.e., 6/2 x sum.
[b] Calculated from the sum assuming 4 beta decays, i.e., 4/2 x sum.
[c] Not including data from deionised water.

TABLE 3.12

MEASURED AND PREDICTED VALUES FOR THE GROSS ALPHA AND GROSS BETA ACTIVITY CONCENTRATIONS IN THE FIRST SERIES OF WAGERUP BORE WATERS

Bore	Measured gross alpha activity conc (Bq L^{-1})	Predicted gross alpha activity conc[a] (Bq L^{-1})	Measured gross beta activity conc (Bq L^{-1})	Predicted gross beta activity conc[b] (Bq L^{-1})
deionised	<0.06	0.09	<0.11	0.06
deionised	<0.07	0.15	<0.11	0.10
18G	<0.09	0.24	0.13	0.17
25G	0.55	0.09	1.30	0.06
25W	0.16	0.15	0.32	0.11
28G	0.38	0.17	0.62	0.13
26W	<0.31	0.11	0.68	0.08
72G(1)	0.18	0.08	0.32	0.05
72G	<0.81	0.10	3.44	0.07
78G	<0.41	0.27	<0.93	0.19
100G	<0.12	0.10	0.25	0.07
72G(11)	<0.24	0.08	0.17	0.05
Mean[c]	**0.32**	**0.14**	**0.82**	**0.10**

[a] The sum of the calculated alpha activity concentration from the U and Th Series (Tables 7 & 8).
[b] The sum of the calculated beta activity concentrations from the U and Th series (Table 7 & 8).
[c] Not including data from deionised water.

TABLE 3.13

ASSESSMENT OF ACTIVITIES FROM THE U-238 DECAY SERIES IN SECOND SERIES OF WAGERUP BORE WATERS

Bore	Activity concentrations					
	U-238 (Bq L^{-1})	U-234 (Bq L^{-1})	Th-230 (Bq L^{-1})	Sum (Bq L^{-1})	Alpha[a] (Bq L^{-1})	Beta[b] (Bq L^{-1})
deionised	<0.001	<0.001	0.002	0.003	0.008	0.006
deionised	0.002	0.002	<0.001	0.005	0.013	0.010
18G	0.008	0.004	0.002	0.014	0.037	0.028
25G	0.009	0.010	0.003	0.022	0.059	0.044
26G	0.005	0.002	0.003	0.010	0.027	0.020
72G	<0.001	<0.001	0.003	0.003	0.008	0.006
78G	0.004	0.006	0.002	0.012	0.032	0.024
79G	0.006	0.004	0.003	0.013	0.035	0.026
100G	0.003	0.003	0.001	0.007	0.019	0.014
72S	0.013	0.006	<0.001	0.019	0.051	0.038
25W	0.003	0.005	0.001	0.009	0.024	0.018
26W	0.006	0.006	<0.001	0.012	0.032	0.024
Mean[c]	**0.006**	**0.005**	**0.002**	**0.012**	**0.032**	**0.024**

[a] Calculated from the sum assuming 8 alpha decays, i.e., 8/3 x sum.
[b] Calculated from the sum assuming 6 beta decays, i.e., 6/3 x sum.
[c] Excluding data from deionised water.

TABLE 3.14

ASSESSMENT OF ACTIVITIES FROM THE TH-232 DECAY SERIES IN SECOND SERIES OF WAGERUP BORE WATERS

Bore	Activity concentration				
	Th-232 (Bq L^{-1})	Th-228 (Bq L^{-1})	Sum (Bq L^{-1})	Alpha[a] (Bq L^{-1})	Beta[b] (Bq L^{-1})
deionised	<0.001	0.003	0.003	0.009	0.006
deionised	<0.001	0.002	0.003	0.009	0.006
18G	0.001	0.004	0.006	0.018	0.012
25G	0.001	0.017	0.018	0.054	0.036
26G	0.001	<0.001	0.001	0.003	0.002
72G	<0.001	0.004	0.004	0.012	0.008
78G	0.001	0.010	0.011	0.033	0.022
79G	0.002	0.008	0.010	0.030	0.020
100G	0.001	0.002	0.002	0.006	0.004
72S	0.001	0.045	0.046	0.138	0.092
25W	<0.001	0.010	0.010	0.030	0.020
26W	<0.001	0.004	0.004	0.012	0.008
Mean[c]	**0.001**	**0.011**	**0.011**	**0.034**	**0.023**

[a] Calculated from the sum assuming 6 alpha decays, i.e., 6/2 x sum.
[b] Calculated from the sum assuming 4 beta decays, i.e., 4/2 x sum.
[c] Excluding data from deionised water.

TABLE 3.15

PREDICTED VALUES FOR THE GROSS ALPHA AND GROSS BETA ACTIVITY CONCENTRATIONS IN SECOND SERIES OF WAGERUP BORE WATERS

Bore	Predicted gross alpha activity conc ($Bq\ L^{-1}$)	Predicted gross beta activity conc ($Bq\ L^{-1}$)
Deionised	0.02	0.01
Deionised	0.02	0.02
18G	0.05	0.04
25G	0.11	0.08
26G	0.03	0.02
72G	0.02	0.01
78G	0.07	0.05
79G	0.07	0.05
100G	0.03	0.02
72S	0.19	0.13
25W	0.05	0.04
26W	0.04	0.03
Mean	**0.07**	**0.05**

TABLE 3.16

RADIUM-226 AND RADIUM-228 ACTIVITY CONCENTRATIONS IN THIRD SERIES OF WAGERUP BORE WATERS

Bore	Radium-226 (mBq L^{-1})	Radium-228 (mBq L^{-1})
SP001	<MDL	112
SP012	13	<MDL
155W	63	<MDL
155G	69	<MDL
155S	235	<MDL
022G	15	<MDL
153S	122	279
153G	95	282
153W	59	1220
001G	32	607
001W	40	348
146W	39	<MDL
146G	15	<MDL
146S	60	272
Mean	**65**	**277**
MDL	**3**	**100**

4.0 CONCLUSIONS

Alcoa has been operating its alumina refinery and associated residue storage areas at Wagerup for in excess of twenty years. It is now proposing to proceed with a further upgrade of its on-site facilities, namely, the Wagerup 3 expansion.

As part of the approval process, Alcoa has undertaken to conduct a baseline study of the radiological parameters associated with the expansion. In practice, the data in the baseline study is more of a status quo of the parameters after twenty years of operations.

A review of the radionuclide content of the bauxite feed stock and the residue fractions during the last twelve months indicates variations throughout the year. The data also indicates lower levels of thorium in the bauxite, and lower levels of uranium in the bauxite and residues than in previous years. None of these materials are classed as radioactive materials under the Radiation Safety (General) Regulations applicable within WA and would be exempt from the associated Transport Code.

It was not possible to obtain baseline gamma radiation levels on the various sites for the Wagerup 3 expansion due to Alcoa's operations on this site for twenty years. The mean of 0.16 $\mu Gy\ h^{-1}$ obtained around the perimeter of Alcoa's land holdings around the refinery and residue storage area may be taken as the local background gamma radiation level.

The dust concentrations around the site not only have variations between locations on a particular day, but significant variations in the four seasons. A mean value of 42 $\mu g\ m^{-3}$ was measured for the dry summer months (October to April) compared to a mean value of 14 $\mu g\ m^{-3}$ for the winter months (May to September). Gross alpha activity concentrations of the dust reveal large variations in the specific activity of the dust between seasons. The high mean value of 27 $Bq\ g^{-1}$ in July 2004 is attributed to "radioactive wash-down", whilst environmental levels (2 – 4 $Bq\ g^{-1}$) were recorded in January 2004. An assessment of the annual internal radiation dose from the measurements gave a conservative value of 0.02 mSv, compared with the annual limit of 1 mSv for a member of the public. It can be concluded that the annual internal radiation dose from the current operations is negligible.

The radon concentrations in air are approximate twice the world-wide mean value and higher than the reported mean value in WA homes. The higher values at Wagerup are attributed to the higher uranium and thorium content of soils types in the Wagerup area compared to the world-wide mean values, rather than to the current Wagerup operations. It is recommended that measurements of the radon and thoron concentrations in air be included in any future on-going radiation monitoring programme associated with the Wagerup operations.

Limited radiometric data is available for the ground-waters in the vicinity of the Wagerup operations. Indications are that the ^{232}Th and ^{238}U decay series are not in equilibrium within the ground-waters, and that the ^{226}Ra and ^{228}Ra contents are higher than their ^{238}U and ^{232}Th parents, respectively. Leaching or leakages of materials from the residue storage area is currently monitored using other indicators, such as pH, electrical conductivity, sodium/chloride ratio and alkalinity. It is recommended that ^{226}Ra and ^{228}Ra analyses be conducted on bore samples in the future on-going water monitoring programme.

5.0 REFERENCES

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APPENDIX A

LETTER OF CALIBRATION FOR THE RADIATION MONITOR

Department of Health
Government of Western Australia

Your ref
Our ref 030604b1 5362
Enquiries Mr I Bucklow Ph:(08) 9346 2260

Dr K W Terry
Radiation-Wise
PO Box 3066
SHELLEY WA 6148

Dear Dr Terry

LABORATORY CHECK FOR MINI-MONITOR 6-80 (SERIAL No. 2250) FITTED WITH A G-M TUBE MC-71 (SERIAL No. 1196)

A calibration factor of 1.15×10^{-3} micrograys per hour per 60 second count has been derived at this laboratory for this instrument on 2nd June 2004 for response to the Radiation Health Section's standard ^{137}Cs gamma radiation.

The above calibration factor is approved for a period of 12 months to 3rd June 2005 to convert the aggregate counts in 60 seconds to micrograys per hour.

Yours sincerely

Mr L Dahlskog
Senior Health Physicist

3rd June, 2004

RADIATION HEALTH BRANCH
ENVIRONMENTAL HEALTH DIRECTORATE
Address all correspondence to the Managing Health Physicist
Letters Locked Bag 2006 Nedlands WA 6009
18 Verdun Street Nedlands WA 6009
Telephone: (08) 9346 2260 Facsimile: (08) 9381 1423
Email: radiation.health@health.wa.gov.au

APPENDIX B

LETTER OF CALIBRATION FOR THE ALPHA SOURCE

RADIOLOGICAL COUNCIL
Government of Western Australia

Address all correspondence to
The Secretary

Your ref 272
Our ref 040618sc5362 g040502
Enquiries Mr Steve Crossley 9346 2260

Radiation Wise
Attn: Keith Terry
16 Beryl Avenue
SHELLY WA 6155

Dear Mr Terry

CALIBRATION OF AMERICIUM-241 SOURCES

The following sources have been calibrated against the Radiation Health Section's ^{241}Am standards. The 2-pi alpha emission rate was measured using an internal gas flow proportional chamber.

MEASUREMENT RESULTS

The following are the observed number of alpha particles emerging **per minute** from the front surface:

SERIAL NO	NUMBER OF ALPHA PARTICLES PER MINUTE (overall uncertainty 5%)
2139-96	109732
1452/93	118843
1458/93	98422

The measurement result assumes 1.5% backscatter of alpha particles from the surface of the disc. The uncertainty of 5% is the sum of random counting error and the estimated upper limits of systematic error in the measurement.

Yours faithfully

H. Upton

Ms H Upton
Managing Health Physicist

18 June 2004

Letters: Locked Bag 2006 P O Nedlands W A 6009
16 Verdun Street Nedlands W A 6009
Telephone (61 8) 9346 2260 Facsimile (61 8) 9381 1423

APPENDIX C

ANALYST REPORTS ON RADIONUCLIDES IN BORE WATERS

AUSTRALIAN NUCLEAR SCIENCE
& TECHNOLOGY ORGANISATION

LUCAS HEIGHTS RESEARCH LABORATORIES NEW ILLAWARRA ROAD, LUCAS HEIGHTS, NSW

PRIVATE MAIL BAG 1
MENAI NSW 2234

Environmental Radiochemistry Group,
Environment Division
Ph: (02) 717 3903 Fax: (02)717 9270

Certificate Number	98EM0006

CERTIFICATE OF ANALYSIS

Client: Melanie Hume

Company / Organisation: ALCOA Wagerup refinery

Order number: WG 1257809-JR

Sample Identification: 12 WATERS

Date of Analysis: 7/5/98 to 20/5/98

Analyst: Y.Farrar & T.Loosz

GROSS ALPHA AND GROSS BETA ACTIVITIES
(Gross beta activity includes the contribution from natural potassium-40)

Client Sample Description	ANSTO Sample Number	Sample Volume mL	Sample Solids mg	Gross Alpha Bq/L	Alpha Error +/-	Gross Beta Bq/L	Beta Error +/-
dalon 1	6240	85	24	< 0.06		< 0.11	
dalon 2	6241	85	22	< 0.07		< 0.11	
15G	6242	60	98	< 0.09		0.18	0.09
25G	6243	50	63	0.55	0.07	1.69	0.12
25W	6244	60	89	0.16	0.05	0.48	0.09
28G	6245	40	96	0.38	0.08	0.83	0.14
28W	6246	50	69	< 0.31		0.94	0.16
72G(I)	6247	60	117	0.18	0.08	0.43	0.13
72S	6248	15	60	< 0.61		3.48	0.53
78G	6249	30	61	< 0.41		< 0.93	
100G	6250	70	87	< 0.12		0.40	0.11
72G(II)	6251	60	95	< 0.24		0.34	0.13

Certificate Number	96EM0008

CERTIFICATE OF ANALYSIS

TABLE 2

GROSS BETA ACTIVITY WITH POTASSIUM-40 CONTRIBUTION REMOVED.
CALCULATED USING THE RATIO OF 27.8 Bq OF POTASSIUM-40
PER 1 GRAM OF STABLE POTASSIUM.

Client Sample Description	ANSTO Sample Number	Sample Volume mL	Gross Beta Bq/L	+/- Beta Error	K mg/L	^{40}K Act. in sample Bq/L	Corrected Gross Beta Bq/L
deion 1	6240	85	<0.11		0.0	0.00	<0.11
deion 2	6241	85	<0.11		0.0	0.00	<0.11
16G	6242	60	0.18	0.09	2.0	0.06	0.13
25G	6243	50	1.69	0.12	14.2	0.39	1.30
25W	6244	60	0.46	0.09	6.1	0.17	0.32
26G	6245	40	0.83	0.14	7.7	0.21	0.62
26W	6246	50	0.94	0.16	9.4	0.26	0.68
72G(I)	6247	60	0.43	0.13	4.1	0.11	0.32
72S	6248	15	3.48	0.53	1.7	0.05	3.44
78S	6249	30	<0.93		4.8	0.13	<0.93
100G	6250	70	0.40	0.11	5.4	0.15	0.25
72G(II)	6251	60	0.34	0.13	6.2	0.17	0.17

Results Checked By: [signature] Date: 29/5/96

[signature] 27/5/96

Page 2 of 2

Certificate Number: 96RC0027

PRIVATE MAIL ...
MENAI NSW 2234

CERTIFICATE OF ANALYSIS

Client: Melanie Hume
Company / Organisation: Alcoa of Australia Limited
Project/Purchase Order:
Sample Identification: Wagerup Refinery water samples
Date of Analysis: 2/7/96 to 13/8/96
Name of Analyst(s): Susan Orsini

ANSTO Number	Sample ID	234U (Bq/L)	234U error (Bq/L)	238U (Bq/L)	238U error (Bq/L)	
5015	25 G	0.011	0.001	0.008	0.001	
5016	25 W	0.006	0.001	0.004	0.001	
5017	26 W	0.019	0.002	0.010	0.001	
5018	26 W	0.026	0.002	0.014	0.002	
5019	18 G	0.004	0.001	0.002	0.001	
5020	100 G	0.003	0.001	0.003	0.001	
5021	78 G	0.004	0.001	0.002	0.001	
5022	72 S	0.011	0.001	0.017	0.001	
5023	72 G (H) (S)	0.004	0.001	0.003	0.001	
5024	72 G (O)	0.002	0.001	0.001	0.001	
5025	Deionised 1	0.003	0.001	0.005	0.001	
5026	Deionised 2	0.004	0.001	0.004	0.001	

ANSTO Number	232Th (Bq/L)	232Th error (Bq/L)	230Th (Bq/L)	230Th error (Bq/L)	228Th (Bq/L)	228Th error (Bq/L)
5015	0.009	0.001	0.024	0.002	0.033	0.003
5016	0.007	0.001	0.002	0.001	0.012	0.002
5017	0.007	0.001	0.003	0.001	0.016	0.002
5018	0.007	0.001	0.003	0.001	0.013	0.002
5019	0.008	0.001	0.021	0.002	0.005	0.001
5020	0.007	0.001	0.006	0.001	0.008	0.002
5021	0.008	0.001	0.006	0.001	0.013	0.002
5022	0.007	0.001	0.003	0.001	0.056	0.003
5023	0.011	0.001	0.005	0.001	0.010	0.001
5024	0.005	0.001	0.004	0.001	0.013	0.001
5025	0.011	0.001	0.003	0.001	0.010	0.002
5026	0.014	0.002	0.005	0.002	0.024	0.003

Results checked by: [signature] Date: 14/8/1996

Certificate Issued by: Robert Chiron Date: 14/8/96

ansto
Telephone (02) 717 3111 • Telegram Ansto Sydney • Facsimile (02) 543 5097 • Telex AA 24562

Kevin,
Lucas

AUSTRALIAN NUCLEAR SCIENCE & TECHNOLOGY ORGANISATION

ansto

LUCAS HEIGHTS SCIENCE & TECHNOLOGY CENTRE, NEW ILLAWARRA RD, LUCAS HEIGHTS, NSW

PRIVATE MAIL BAG 1 MENAI, NSW 2234
General telephone (61 2) 9717 3111
General facsimile (61 2) 9543 5097

CERTIFICATE OF ANALYSIS

Client:	Melanie Hume
Company / Organisation:	ALCOA of Australia Limited
Project:	Purchase Order WG 1350634 JH
Sample Identification:	12 Bore water samples
Name of Analyst(s):	Robert Chisari

ANSTO Number	Client's Reference Number	234U Activity (Bq/L)	234U error (Bq/L)	238U Activity (Bq/L)	238U error (Bq/L)	
6090	Deionized water A	0.0006	0.0002	0.0003	0.0002	
6091	Deionized water B	0.0022	0.0005	0.0022	0.0005	
6092	18G	0.004	0.001	0.008	0.001	
6093	25G	0.010	0.001	0.009	0.001	
6094	26G	0.0015	0.0005	0.0053	0.0009	
6905	72G	0.0004	0.0004	< 0.0001		
6096	78G	0.006	0.002	0.004	0.002	
6907	79G	0.004	0.002	0.006	0.002	
6098	100G	0.0033	0.0007	0.0025	0.0006	
6099	72S	0.006	0.001	0.013	0.002	
6100	25W	0.0050	0.0008	0.0027	0.0006	
6101	26W - nitric preserved	0.006	0.001	0.006	0.001	

ANSTO Number	232Th Activity (Bq/L)	232Th error (Bq/L)	230Th Activity (Bq/L)	230Th error (Bq/L)	228Th Activity (Bq/L)	228Th error (Bq/L)
6090	0.0004	0.0002	0.0020	0.0005	0.0029	0.0006
6091	0.0006	0.0003	0.0006	0.0005	0.0020	0.0007
6092	0.0011	0.0004	0.0018	0.0007	0.0044	0.0009
6093	0.0009	0.0004	0.003	0.001	0.017	0.002
6094	0.0009	0.0004	0.0027	0.0009	< 0.0001	
6095	0.0004	0.0002	0.0025	0.0006	0.0039	0.0008
6096	0.0011	0.0004	0.0022	0.0007	0.010	0.001
6097	0.0017	0.0007	0.003	0.001	0.008	0.002
6098	0.0006	0.0003	0.0014	0.0007	0.0017	0.0007
6099	0.0012	0.0006	< 0.0001		0.045	0.004
6100	< 0.0001		0.0014	0.0008	0.010	0.001
6101	0.0004	0.0003	< 0.0001		0.004	0.001

Results checked by: Robert Chisari Date: 8-4-97

Certificate Issued: Vanessa Chaseee Date: 8/4/97

WESTERN RADIATION SERVICES

ABN 17 053 332 602

26th January 2005

Ref: WRS-J3971
Order No: 34514

Parsons Brinckerhoff
PO Box 172
PINJARRA WA 6208

Attn: Diane How

ANALYTICAL REPORT

The results (to 95%, 2σ, confidence level) of Radium-226 and Radium-228 analyses of fourteen (14) water samples as received at our laboratory on the 9th of December 2004, are detailed on page 2 of this report.

MDL: Radium-226 3 mBq/l Radium-228 - 100 mBq/l

Method: LTP3 Radium-226 – by De-emanation.
LTP4(a) Radium-228 – by High Resolution Gamma Spectrometry.

W.P.Chandler
Authorised signatory

NATA Accreditation
Number 14174

26th January 2005

WRS-J3971
Page 2 of 2

WRS ID	Sample ID	Ra-226 (mBq/l)	Ra-228 (mBq/l)
14099	SP001	<MDL	112 ± 40
14100	SP012	13 ± 6	<MDL
14101	RG 155W	63 ± 17	<MDL
14102	RG 155G	69 ± 18	<MDL
14103	RG 155S	235 ± 41	<MDL
14104	RG 022G	15 ± 6	<MDL
14105	RG 153S	122 ± 27	279 ± 102
14106	RG 153G	95 ± 22	282 ± 108
14106D	RG 153G Duplicate	109 ± 25	329 ± 178
14107	RG 153W	59 ± 17	1220 ± 362
14108	RG 001G	32 ± 12	607 ± 188
14109	RG 001W	40 ± 13	348 ± 110
14110	RS 146W	39 ± 13	<MDL
14111	RS 146G	15 ± 7	<MDL
14112	RS 146S	60 ± 17	272 ± 81

W.P.Chandler
Authorised signatory