OLYMPIC DAM
Annual Radiation Protection Report
July 2011 to June 2012
OLYMPIC DAM

Annual Radiation Protection Report
July 2011 June 2012

DISTRIBUTION

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Senior Radiation Safety Officer – Mine
Senior Radiation Safety Officer – Process
Ventilation Superintendent
Records Centre
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This Report has been reviewed by:

Senior Radiation Safety Officer – Process                              Matthew Allen
Senior Radiation Safety Officer – Mine                                Chuong Pham
Acting Superintendent Radiation & Occupational Hygiene               John Warneke
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1 INTRODUCTION

This document is the annual report on radiation protection for BHP Billiton Olympic Dam Incorporation Pty Ltd.

In fulfilment of clauses 2.10.1, 3.8.1 and 3.10.1 of the Code of Practice and Safety Guide on Radiation Protection and Radioactive Waste Management in Mining and Processing 2005, employee dose assessments, dose calculation methodologies, dose parameters and dose conversion factors for the period 1 July 2011 to 30 June 2012 are presented. Individual personal doses and dose components for the period 1 July 2011 to 30 June 2012 are forwarded with this document on electronic media.
2 EMPLOYEE DOSE ASSESSMENT METHOD

2.1 Exposure Calculation Methodology

2.1.1 Exposure Calculation at the Mine

The main exposure pathways for Mine workers are inhalation of Radon Decay Products (RDP), irradiation by gamma radiation and inhalation of radioactive dust. Assessment of exposure from dust and RDP are based on employee time sheet/card information and measurements from the approved monitoring program.

Employee and contractor time card information is entered into one of the three time tracking databases [IRIS, SAP, Production Tracking Normal Time (Prodtrak_Normtime)] for either daily or monthly work periods. The site security database (CARDAX) is also used to determine the monthly average hours for individuals whose timesheets have not been logged into any of the other databases mentioned above. The information from CARDAX is converted into tables that can be easily imported into the IRIS database for dose calculation. Each database records employee name, employee number, occupation, date, work location and hours in location information.

Locations within the Mine are grouped into areas of ‘like air’ known as airways. The Senior Ventilation Engineer or their nominee, who is familiar with the underground environment, maintains the locations within the airways. Airways are segregated into weekly periods and new locations are mapped into their relevant airway this results in there being 13 weekly groupings each quarter covering the history of ventilation throughout the Mine.

The RDP concentration is then determined for each airway for each week using measurements from the approved monitoring program, which covers monitoring of most active work areas. For work airways not sampled in that week, an average is calculated. This average is calculated from all readings for that particular airway over the quarter.

Employee exposure to radioactive dust is calculated using quarterly occupation-based averages. The averages are obtained from monitoring performed under the approved monitoring program. An occupation-based dust concentration level is then allocated to each occupation.

The occupation-based dust concentration information and location-based RDP concentration information is then combined with the employee time card information to derive individual exposure data. Dust exposure is measured in units of Becquerel-hours per cubic metre (Bq.hr/m$^3$) and RDP concentration is measured in units of micro Joule-hours per cubic metre (µJ.hr/m$^3$). Exposure details are combined to give quarterly personal exposures.

The entire procedure is processed using a software program known as the Integrated Radiation Information System (IRIS). The system is designed such that the Radiation Safety Officer is required to perform checks in each step of the process. This is in addition to a built-in auditing system within the program.

Respiratory protection in the form of airstream helmets are available for all employees and are worn when tasks are identified as requiring them. They are typically worn by some workgroups such as Ore Handling Beltrunners and Services Ventilation Crew. Airstream helmets are also mandatory for identified specific tasks or in certain conditions. Routine and non-routine use of airstream helmets is monitored and logged.
No respiratory protection factors are used in these exposure calculations, and therefore actual individual exposures will be lower than reported.

Exposure to gamma radiation is assessed using Thermo Luminescent Dosimeters (TLD’s) badges from the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) Personal Monitoring Service. TLD badges are worn for a period of three months; non-badge wearers are allocated an occupation-based average exposure.

2.1.2 Exposure calculation in the Metallurgical Plant

The main exposure pathways for Metallurgical Plant workers are inhalation of radioactive dust and fumes, and irradiation by gamma radiation. Assessment of exposure from dust and fumes is based on employee time sheet/card information and measurements from the approved monitoring program. Dust exposure in the Metallurgical Plant may involve exposure to different types of dust. These dusts will differ in particle size and radionuclide composition, which will produce different Dust Dose Conversion Factors (DCF’s). The table of DCF’s is given in Appendix A.

Information from employee and contractor time cards or employee activity sheets is entered into IRIS via one of the three databases [IRIS (Manual), SAP, Prodtrak] containing daily or monthly information, depending on work area and occupation. From these databases a file of unique locations/occupations is obtained. Locations of the same section or similar exposure are grouped into exposure groups. A quarterly mean of dust activity is determined for each of the exposure groups based on the results of the monitoring program.

CARDAX is used to extract time sheet information for all personnel where it is not possible to get this information from the three main databases commonly used at Olympic Dam for timesheet logging (IRIS, Prodtrak and SAP).

Quarterly location/occupation dust averages are combined with time information to produce a dust exposure for each employee and each different dust type.

Exposure to gamma radiation is assessed using TLD badges from the Personal Monitoring Service of ARPANSA. TLD badges are worn for a period of three months. They are issued to all occupation groups with designated employees. The balance of employees receive the average exposure for their occupation group. TLD badges are issued to different employees every monitoring period. Employees from occupation groups which are likely to receive elevated gamma dose are issued a TLD badge each monitoring period (eg. Slag Crushers, Mill Technician, Product Packer, Slag Handling Technician, TRS Technician, Instrumentation Technician working with radiation gauges). Spare TLD badges are also kept on hand to be issued to employees upon request.

Although the exposure to RDP within the Metallurgical Plant is much less than other pathways, it is assessed in the same way as for Mine employees. The same time information used for calculation of dust exposure is used for calculating RDP exposure. All surface locations/occupations are grouped into one surface airway. A weekly average is calculated from all surface RDP measurements and is assigned to this airway. Location-based RDP concentration information is then combined with the employee time card information to derive individual weekly exposure data (µJ.hr/m³).
2.2 Exposure to Dose Calculations

Conversion of dust exposure to committed effective dose is achieved by the use of dose conversion factors, which are derived using the methodologies in International Commission on Radiological Protection (ICRP) 68/72. The parameters physically measured to determine the factors are; particle size and radionuclide content. These measurements are undertaken in a number of areas of the Mine and Metallurgical Plant.

Analysis of the samples used to determine the radionuclide content was carried out by the Olympic Dam Analytical Laboratory. These results were used to determine dose conversion factors, which remain unchanged from last year.

Changes to existing conversion factors will only occur in the event of introduction of new processing techniques, major changes to plant or ore type or new recommendations published by the ICRP. A summary of the dose conversion factors used for 2011/2012 is given in Appendix A. Dose conversion factors have been carried over from the previous reporting year.

To calculate committed dose for airborne dust exposure, the airborne dust exposure is multiplied by the appropriate dose conversion factor. The committed doses for the different dusts are then added to give a total airborne dust dose.

Dose equivalent from RDP are calculated by multiplying the RDP exposure by the default dose conversion factor recommended by ICRP65 of 1.41 mSv.m$^3$/mJ.hr (5mSv/WLM).
3 Employee Doses

3.1 Doses to Mine Employees

3.1.1 Descriptive Statistics

A total of 695 full-time designated Mine worker's doses were calculated for the period 1st July 2011 to 30th June 2012. This included all BHP Billiton Olympic Dam Mine employees and associated contractors. The distribution of doses for these work classifications is given in Figure 1.

![Figure 1 – Annual Dose Distribution 2010/2011 for All Designated Employees - Mine](image)

The selection criteria for determining whether employees are categorised as ‘full-time’ or ‘part-time’ is as follows:

A ‘full-time’ Mine employee is an employee whose dose has been assessed for a total of three or more quarters in the Mine. A ‘part-time’ employee therefore has dose assessment for less than three quarters. This eliminates any unintentional biasing of the analysis of data due to short exposure periods.

The mean dose to all designated mine employees was 2.9mSv in 2011/2012, unchanged from 2010/2011.

The mean dose for full-time designated mine workers was 3.0mSv in 2011/2012, unchanged from 2010/2011.

The mean dose for part-time designated mine workers was 2.1mSv in 2011/2012, unchanged from 2010/2011.

The average exposure to radon decay products (RDP) in the underground mine for 2011/2012 was 61%, slightly greater the 2010/2011 value of 59%.

Table A consolidates the results for the exposures at the mine.
Table A – Statistics for designated employees, mine

<table>
<thead>
<tr>
<th>Statistics</th>
<th>Full-Time Designated Employees</th>
<th>Part-Time Designated Employees</th>
<th>All Designated Employees</th>
</tr>
</thead>
<tbody>
<tr>
<td>Count</td>
<td>695</td>
<td>62</td>
<td>757</td>
</tr>
<tr>
<td>Arithmetic Mean (mSv)</td>
<td>3.0</td>
<td>0.8</td>
<td>2.8</td>
</tr>
<tr>
<td>90th Percentile (mSv)</td>
<td>4.2</td>
<td>1.7</td>
<td>4.0</td>
</tr>
<tr>
<td>Min (mSv)</td>
<td>0.4</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>Max (mSv)</td>
<td>6.6</td>
<td>2.3</td>
<td>6.6</td>
</tr>
<tr>
<td>Mean % Dose from RDP</td>
<td>62%</td>
<td>53%</td>
<td>61%</td>
</tr>
<tr>
<td>Mean % Dose from Dust</td>
<td>4%</td>
<td>5%</td>
<td>4%</td>
</tr>
<tr>
<td>Mean % Dose from Gamma</td>
<td>35%</td>
<td>42%</td>
<td>35%</td>
</tr>
</tbody>
</table>

No Mine worker received an annual dose greater than 10mSv. The highest dose was 6.6mSv, compared to a maximum value in 2009/2010 of 7.1mSv.

3.1.2 Review of doses by work category

Table B shows the breakdown of doses by work category for full-time designated employees.

The total number of all designated employees has decreased to 695 in the 2011/2012 year from 883 in 2010/2011. The primary focus of our monitoring programs has remained on the critical workgroups that are currently working in the underground mine.

Of the three major exposure pathways (gamma irradiation, inhalation of radioactive dust and inhalation of RDP), the gamma irradiation exposure levels for full-time designated workers has decreased from 37% to 35% of the total dose since last year, RDP has increased from 59% in 2009/2010 to 62% of the total dose in 2011/2012 and the dust component remains low at 4% of the total dose.

Average annual doses for all mine work groups have varied and are well within historical variations. The Raise Driller work group received the highest average dose of 3.9mSv. The highest individual annual dose of 6.6mSv was also received by a Raise Driller.

The dose components for all work categories are shown graphically in Figure 2.
Table B – Statistics for Full Time Designated Mine Employees

<table>
<thead>
<tr>
<th>WORK CATEGORY</th>
<th>No. of Emp.</th>
<th>Mean (mSv)</th>
<th>Minimum (mSv)</th>
<th>Maximum (mSv)</th>
<th>90th Percentile (mSv)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Backfill</td>
<td>2</td>
<td>1.1</td>
<td>0.7</td>
<td>1.5</td>
<td>1.4</td>
</tr>
<tr>
<td>Core Processing</td>
<td>4</td>
<td>0.5</td>
<td>0.5</td>
<td>0.6</td>
<td>0.6</td>
</tr>
<tr>
<td>Development</td>
<td>144</td>
<td>3.5</td>
<td>0.6</td>
<td>5.4</td>
<td>4.5</td>
</tr>
<tr>
<td>Diamond Drilling</td>
<td>21</td>
<td>2.5</td>
<td>0.4</td>
<td>3.7</td>
<td>3.6</td>
</tr>
<tr>
<td>Electrician</td>
<td>14</td>
<td>2.4</td>
<td>0.9</td>
<td>3.4</td>
<td>3.3</td>
</tr>
<tr>
<td>Fitter</td>
<td>78</td>
<td>1.9</td>
<td>0.8</td>
<td>4.6</td>
<td>2.7</td>
</tr>
<tr>
<td>Mine Surface</td>
<td>20</td>
<td>2.1</td>
<td>0.7</td>
<td>3.3</td>
<td>3.3</td>
</tr>
<tr>
<td>Ore Handling</td>
<td>156</td>
<td>3.0</td>
<td>0.7</td>
<td>4.8</td>
<td>3.8</td>
</tr>
<tr>
<td>Production Charging</td>
<td>16</td>
<td>3.5</td>
<td>2.0</td>
<td>4.7</td>
<td>4.3</td>
</tr>
<tr>
<td>Production Drilling</td>
<td>45</td>
<td>3.2</td>
<td>1.9</td>
<td>4.2</td>
<td>3.9</td>
</tr>
<tr>
<td>Raise Drilling</td>
<td>14</td>
<td>3.9</td>
<td>1.1</td>
<td>6.6</td>
<td>5.7</td>
</tr>
<tr>
<td>Underground Services</td>
<td>181</td>
<td>3.1</td>
<td>0.5</td>
<td>5.3</td>
<td>4.2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>WORK CATEGORY</th>
<th>RDP. Average (mSv)</th>
<th>RDP. % of Total Dose</th>
<th>Gamma Average (mSv)</th>
<th>Gamma % of Total Dose</th>
<th>Dust Average (mSv)</th>
<th>Dust % of Total Dose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Backfill</td>
<td>0.4</td>
<td>35%</td>
<td>0.6</td>
<td>58%</td>
<td>0.1</td>
<td>6%</td>
</tr>
<tr>
<td>Core Processing</td>
<td>0.1</td>
<td>10%</td>
<td>0.3</td>
<td>47%</td>
<td>0.2</td>
<td>43%</td>
</tr>
<tr>
<td>Development</td>
<td>2.2</td>
<td>63%</td>
<td>1.2</td>
<td>34%</td>
<td>0.1</td>
<td>3%</td>
</tr>
<tr>
<td>Diamond Drilling</td>
<td>1.1</td>
<td>44%</td>
<td>1.3</td>
<td>52%</td>
<td>0.1</td>
<td>4%</td>
</tr>
<tr>
<td>Electrician</td>
<td>1.2</td>
<td>51%</td>
<td>1.0</td>
<td>42%</td>
<td>0.2</td>
<td>7%</td>
</tr>
<tr>
<td>Fitter</td>
<td>1.1</td>
<td>58%</td>
<td>0.7</td>
<td>37%</td>
<td>0.1</td>
<td>6%</td>
</tr>
<tr>
<td>Mine Surface</td>
<td>1.1</td>
<td>55%</td>
<td>0.9</td>
<td>42%</td>
<td>0.1</td>
<td>3%</td>
</tr>
<tr>
<td>Ore Handling</td>
<td>2.0</td>
<td>65%</td>
<td>1.0</td>
<td>32%</td>
<td>0.1</td>
<td>2%</td>
</tr>
<tr>
<td>Production Charging</td>
<td>1.7</td>
<td>47%</td>
<td>1.7</td>
<td>49%</td>
<td>0.2</td>
<td>4%</td>
</tr>
<tr>
<td>Production Drilling</td>
<td>1.8</td>
<td>58%</td>
<td>1.2</td>
<td>39%</td>
<td>0.1</td>
<td>3%</td>
</tr>
<tr>
<td>Raise Drilling</td>
<td>2.3</td>
<td>58%</td>
<td>1.5</td>
<td>39%</td>
<td>0.1</td>
<td>3%</td>
</tr>
<tr>
<td>Underground Services</td>
<td>2.0</td>
<td>65%</td>
<td>0.9</td>
<td>30%</td>
<td>0.1</td>
<td>4%</td>
</tr>
</tbody>
</table>
The average and maximum effective dose for the critical Mine underground workgroups and dose component trends for selected workgroups are given from Figure 3 - Figure 26.
Backfill

The average dose to the Backfill workgroup has increased from 0.7mSv to 1.1mSv and the maximum dose to this workgroup has increased from 1.0mSv to 1.5mSv. This reflects the nature of Backfill employee’s work, mostly on the surface with minimal time underground and the variations are in line with normal fluctuations.

Figure 3 – Annual Dose Distribution for the Backfill Workgroup

Figure 4 – Annual Dose Trends for the Backfill Workgroup
Core Processing

The average and maximum doses to Core Processing employees have remained at low levels under 1mSv per year. The average dose for 2011/2012 was 0.5mSv and the maximum dose was 0.6mSv. Dust exposure to this workgroup has been assessed for occupational hygiene purposes and the installation of a new local exhaust ventilation system has been installed.
Development

The average dose to the Development workgroup has remained at 3.5mSv and the maximum dose has decreased from 5.7mSv to 5.4mSv. These doses are in line with normal variations and do not reflect any significant changes in work practices for this workgroup.

Figure 7 – Annual Dose Distribution for the Development Workgroup

Figure 8 – Annual Dose Trends for the Development Workgroup
Diamond Drilling

The average dose to the Diamond Driller workgroup increased slightly from 2.4mSv to 2.5mSv and maximum dose to the Diamond Drilling workgroup has decreased from 3.8mSv and 3.7mSv. These doses are in line with normal variations and do not reflect any significant changes in work practices for this workgroup.

![Graph showing annual dose distribution for Diamond Drilling workgroup](image)

Figure 9 – Annual Dose Distribution for the Diamond Drilling Workgroup

![Graph showing annual dose trends for Diamond Drilling workgroup](image)

Figure 10 – Annual Dose Trends for the Diamond Drilling Workgroup
**Electrician**

The average dose to electricians remained at 2.4mSv while the maximum dose to this workgroup has decreased from 4.0mSv in 2010/2011 to 3.4mSv. These doses are in line with normal variations and do not reflect any significant changes in work practices for this workgroup.

![Diagram showing dose distribution for Electrician workgroup](image)

**Figure 11 – Annual Dose Distribution for the Electrician Workgroup**

![Graph showing dose trends for Electrician workgroup](image)

**Figure 12 – Annual Dose Trends for the Electrician Workgroup**
Fitter

The average dose to the Fitter workgroup has increased from 1.6mSv to 1.9mSv whilst the maximum dose for Fitters has increased from 2.7mSv to 4.6mSv. These doses are in line with normal variations and do not reflect any significant changes in work practices for this workgroup.

Figure 13 – Annual Dose Distribution for the Fitter Workgroup

Figure 14 – Annual Dose Trends for the Fitter Workgroup
Mine Surface

The average dose has increased from 1.8mSv to 2.1mSv and the maximum dose has decreased from 4.4mSv to 3.3mSv. These doses are in line with normal variations and do not reflect any significant changes in work practices for this workgroup.

Figure 15 – Annual Dose Distribution for the Surface Workers Workgroup

Figure 16 – Annual Dose Trends for the Surface Workers Workgroup
Ore Handling

The average dose has decreased from 3.3mSv to 3.0mSv while the maximum dose has decreased slightly from 4.9mSv to 4.8mSv. These doses are in line with normal variations and do not reflect any significant changes in work practices for this workgroup.

Figure 17 – Annual Dose Distribution for the Ore Handling Workgroup

Figure 18 – Annual Dose Trends for the Ore Handling Workgroup
Production Charging

The average dose for Production Chargers has decreased from 4.7 mSv to 3.5 mSv while the maximum dose also decreased from 5.9 mSv to 4.7 mSv. The exposures are in line with historical exposures recorded for the workgroup.

![Annual Dose Distribution for the Production Charger Workgroup](image1)

![Annual Dose Trends for the Production Charger Workgroup](image2)
Production Drilling

The average dose for the production drillers has decreased from 3.8mSv to 3.2mSv and the maximum dose has also decreased from 5.8mSv to 4.2mSv. The results are in line with historical exposures recorded for the workgroup.

Figure 21 – Annual Dose Distribution for the Production Driller Workgroup

Figure 22 – Annual Dose Trends for the Production Driller Workgroup
Raise Drilling

The average dose has decreased from 4.7 mSv to 3.9 mSv and the maximum dose has decreased from 7.1 mSv to 6.6 mSv. Focus on radon decay product exposure continues to be the main priority for radiation exposure to this workgroup.

Figure 23 – Annual Dose Distribution for the Raise Driller Workgroup

Figure 24 – Annual Dose Trends for the Raise Driller Workgroup
Underground services

The average dose has decreased from 3.2mSv to 3.1mSv and the maximum dose has decreased from 5.6mSv to 5.3mSv. The exposures are in line with historic exposures.

Figure 25 – Annual Dose Distribution for the Underground Services Workgroup

Figure 26 – Annual Dose Trends for the Underground Services Workgroup
3.1.3 **Strategies for Dose Reduction**

There is a continuous focus on reducing dose to employees at the mine and some of these measures include:

- Investigation for monitoring of exposure to employees who work in air-conditioned filtered mining equipment
- Trial of personal radon decay product monitors
- Focused radiation monitoring for the higher exposed work groups
- Reviewing historical results and trending higher exposed work groups

In early FY11 a radon steering committee was established to determine and implement controls for the reduction of exposure to radon decay products underground. A number of the dose reduction strategies are a result of actions from the steering committee.

The mine ventilation department have continued to focus on ensuring that exposure to radon decay products are minimised through continued extensions of the Mine ventilation systems when required.

3.1.4 **Doses to Non-Designated Mine Employees**

A dose distribution for non-designated employees and contractors at the Mine is listed in Figure 27. Non-designated employees are tracked individually on the same dose calculation system as the designated employees. A summary of all non-designated employee doses is given in Table C.
Table C – Non-designated Mine Employee Statistics

<table>
<thead>
<tr>
<th>Statistics</th>
<th>Non Designated Employees</th>
</tr>
</thead>
<tbody>
<tr>
<td>Count</td>
<td>896</td>
</tr>
<tr>
<td>Arithmetic Mean (mSv)</td>
<td>1.3</td>
</tr>
<tr>
<td>90th Percentile (mSv)</td>
<td>2.7</td>
</tr>
<tr>
<td>Min (mSv)</td>
<td>0.3</td>
</tr>
<tr>
<td>Max (mSv)</td>
<td>4.3</td>
</tr>
<tr>
<td>Mean % Dose from RDP</td>
<td>48%</td>
</tr>
<tr>
<td>Mean % Dose from Dust</td>
<td>7%</td>
</tr>
<tr>
<td>Mean % Dose from Gamma</td>
<td>45%</td>
</tr>
</tbody>
</table>

Maximum and average dose trends for all non-designated mine workers are presented in Figure 28.

Figure 28 – Average Dose Trends for Non-Designated Employees

Airborne dust doses and radon decay product doses have been calculated using average airborne dust measurements, average radon decay product measurements, dose conversion factors and either an estimation of the hours worked based on a typical working roster, or actual hours. Gamma doses have been estimated based on direct personal monitoring and averages resulting from this monitoring.
Figure 29 shows maximum and average dose trends for all non-designated Mine workers from 1 July 2011 to 30 June 2012.

The total number of non-designated employees has decreased from 1441 in 2010/2011 to 896 in 2011/2012. The average dose has increased from 1.0mSv to 1.3mSv. 48 non-designated mine employees received a dose above 3mSv, with the highest being 4.2mSv. These employees have not been designated because they were recently engaged workers, have recently changed jobs or previously assessed as not needing to be designated.

3.1.5 Cumulative Five Year Dose

As outlined in ICRP 103, the total dose of any individual radiation worker should not exceed 100mSv in any five year period. To this end, a five year total dose has been determined for all full-time currently designated Mine workers who were employed at Olympic Dam for the previous five years. The calculation of cumulative five year effective dose includes employees who have worked for more than 18 quarters.

There were a total of 466 designated Mine workers who worked continuously at the Mine during the period 1 July 2007 to 30 June 2012. This number has decreased from the 639 workers reported for the period 1 July 2006 to 30 June 2011. The maximum dose for a Mine worker is 31.3mSv for the five year period ending 30 June 2012, as compared with 31.4mSv for the 2005/2006 to 2010/2011 five year dose period. The arithmetic mean for the group was 15.8mSv, an increase from 13.2mSv for the five year dose period 2005/2006 to 2010/2011.

The distribution of doses for the cumulative five year dose is shown in Figure 30.
Figure 30 – Five Year Cumulative Dose Distribution Mine

A summary of the cumulative five year dose is given in Table D.

**Table D – Five Year Stats**

<table>
<thead>
<tr>
<th>Statistics</th>
<th>Cumulative 5 year Doses</th>
<th>Equivalent Average yearly Dose</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>For Continuously Employed</td>
<td>Designated Mine Employees</td>
</tr>
<tr>
<td>Count</td>
<td>466</td>
<td>466</td>
</tr>
<tr>
<td>Arithmetic Mean (mSv)</td>
<td>15.8</td>
<td>3.2</td>
</tr>
<tr>
<td>90th Percentile (mSv)</td>
<td>21.5</td>
<td>4.3</td>
</tr>
<tr>
<td>Min (mSv)</td>
<td>3.0</td>
<td>0.6</td>
</tr>
<tr>
<td>Max (mSv)</td>
<td>31.3</td>
<td>6.3</td>
</tr>
<tr>
<td>Mean % Dose from RDP</td>
<td>59%</td>
<td></td>
</tr>
<tr>
<td>Mean % Dose from Dust</td>
<td>11%</td>
<td></td>
</tr>
<tr>
<td>Mean % Dose from Gamma</td>
<td>36%</td>
<td></td>
</tr>
</tbody>
</table>

### 3.2 Doses to Metallurgical Plant Employees

#### 3.2.1 Descriptive Statistics

A total of 205 full-time designated Metallurgical Plant worker's doses were calculated for the period 1 July 2011 to 30 June 2012. This included most BHP Billiton Olympic Dam Metallurgical Plant employees and associated contractors who work full time in the plant.

The process plant performed well with no major interruptions. Approximately 9.7 million tonnes of material (ore and slag) was milled producing at total of 192,506...
tonnes of copper cathode, 3,885 tonnes uranium oxide concentrate, 117,845 ounces gold bullion and 907,133 ounces silver bullion.

The mean dose to all designated plant employees was 1.9mSv in 2011/2012, a decrease from the 2010/2011 value of 2.0mSv.

The mean dose for full-time designated plant workers was 2.1mSv in 2011/2012, unchanged from 2010/2011.

The mean dose for part-time designated plant workers was 0.4mSv in 2011/2012, unchanged from 2010/2011.

For this period the distribution of doses is shown in Figure 31, and the statistics are given in Table E.

### Table E – Statistics for designated employees, Metallurgical Plant

<table>
<thead>
<tr>
<th>Statistics</th>
<th>Full-Time</th>
<th>Part-Time</th>
<th>All Designated</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Designated</td>
<td>Designated</td>
<td>Employees</td>
</tr>
<tr>
<td>Count</td>
<td>205</td>
<td>11</td>
<td>216</td>
</tr>
<tr>
<td>Arithmetic Mean (mSv)</td>
<td>2.1</td>
<td>0.4</td>
<td>1.9</td>
</tr>
<tr>
<td>90th Percentile (mSv)</td>
<td>6.6</td>
<td>0.8</td>
<td>6.1</td>
</tr>
<tr>
<td>Min (mSv)</td>
<td>0.3</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>Max (mSv)</td>
<td>8.8</td>
<td>1.2</td>
<td>8.8</td>
</tr>
<tr>
<td>Mean % Dose from RDP</td>
<td>6%</td>
<td>9%</td>
<td>7%</td>
</tr>
<tr>
<td>Mean % Dose from Dust</td>
<td>75%</td>
<td>64%</td>
<td>75%</td>
</tr>
<tr>
<td>Mean % Dose from Gamma</td>
<td>18%</td>
<td>27%</td>
<td>19%</td>
</tr>
</tbody>
</table>
3.2.2 Review of Doses by Work Areas

The analysis of doses by work area is presented in Table F. The dose statistics for the 2011/2012 year from the Metallurgical Plant areas show most areas are in line with historical levels. There has been an increase in average and maximum doses at the smelter but maximum doses remain below the site target of 10 mSv.

The number of full-time designated employees in the Metallurgical Plant has decreased from 156 in 2010/2011 to 205 in 2011/2012.

Annual dose components for each work area can be seen in Figure 32.
### Table F – Annual Dose Statistics by Work Areas, Full-Time Designated Metallurgical Plant Employees

<table>
<thead>
<tr>
<th>WORK CATEGORY</th>
<th>No. of Emp.</th>
<th>Mean (mSv)</th>
<th>Minimum (mSv)</th>
<th>Maximum (mSv)</th>
<th>90th Percentile (mSv)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concentrator</td>
<td>9</td>
<td>1.6</td>
<td>1.1</td>
<td>2.2</td>
<td>2.1</td>
</tr>
<tr>
<td>Hydromet</td>
<td>16</td>
<td>1.1</td>
<td>0.7</td>
<td>2.1</td>
<td>1.3</td>
</tr>
<tr>
<td>Smelter</td>
<td>78</td>
<td>3.6</td>
<td>0.7</td>
<td>8.8</td>
<td>7.2</td>
</tr>
<tr>
<td>Refinery</td>
<td>11</td>
<td>0.5</td>
<td>0.4</td>
<td>0.8</td>
<td>0.7</td>
</tr>
<tr>
<td>Services/Maintenance*</td>
<td>91</td>
<td>1.2</td>
<td>0.3</td>
<td>4.6</td>
<td>2.2</td>
</tr>
<tr>
<td>Smelter Slag Handling</td>
<td>7</td>
<td>2.0</td>
<td>1.0</td>
<td>3.4</td>
<td>3.4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>WORK CATEGORY</th>
<th>RDP. Average (mSv)</th>
<th>RDP. % of Total Dose</th>
<th>Gamma Average (mSv)</th>
<th>Gamma % of total Dose</th>
<th>Dust Average (mSv)</th>
<th>Dust % of Total Dose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concentrator</td>
<td>0.05</td>
<td>3%</td>
<td>0.36</td>
<td>23%</td>
<td>1.18</td>
<td>74%</td>
</tr>
<tr>
<td>Hydromet</td>
<td>0.05</td>
<td>5%</td>
<td>0.44</td>
<td>42%</td>
<td>0.56</td>
<td>53%</td>
</tr>
<tr>
<td>Smelter</td>
<td>0.05</td>
<td>1%</td>
<td>0.18</td>
<td>5%</td>
<td>3.37</td>
<td>94%</td>
</tr>
<tr>
<td>Refinery</td>
<td>0.05</td>
<td>10%</td>
<td>0.13</td>
<td>24%</td>
<td>0.36</td>
<td>67%</td>
</tr>
<tr>
<td>Services/Maintenance*</td>
<td>0.24</td>
<td>20%</td>
<td>0.57</td>
<td>47%</td>
<td>0.40</td>
<td>33%</td>
</tr>
<tr>
<td>Smelter Slag Handling</td>
<td>0.08</td>
<td>4%</td>
<td>1.18</td>
<td>60%</td>
<td>0.73</td>
<td>37%</td>
</tr>
</tbody>
</table>

* Services/Maintenance work group also includes Slag handling workers
* Services/maintenance group also includes Slag handling workers

Figure 32 – Annual dose components by workgroup

Annual total dose distributions and dose trends for each work area along with dose component profiles for selected workgroups can be seen in Figure 33 to Figure 42.
Concentrator

Concentrator doses remained consistent with 2010/2011 levels.

Figure 33 – Annual Dose Distribution for the Concentrator Workgroup

Figure 34 – Dose Trends for the Concentrator Workgroup
Hydromet

The average and maximum dose for Hydromet workers in 2011/12 were consistent with 2010/2011 levels.

Figure 35 – Annual Dose Distribution for the Hydromet Workgroup

Figure 36 – Dose Trends for the Hydromet Workgroup
Smelter

Average doses in the smelter increased to 3.6mSv from 3.1mSv. Maximum dose increased from 6.4mSv to 8.8mSv with the 90th percentile dose increasing to 7.2mSv. The smelter has continued to closely monitor Polonium 210 (Po210) activity concentrations in key smelter inputs and outputs during the year to ensure it would not reach activity concentrations that would adversely impact on dust exposures.
Refinery

The Refinery workforce recorded the lowest maximum and annual average of any designated workgroup in the Metallurgical Plant, and remains at less than 1 mSv.

Figure 39 – Annual Dose Distribution for the Refinery Workgroup

Figure 40 – Dose Trends for the Refinery Workgroup
Maintenance/ Services

The variable nature of the maximum dose is due to the fact that some of these personnel are spending time both underground and in the smelter building. The annual average dose increased from 1.1mSv to 1.2mSv.

Figure 41 – Annual Dose Distribution for the Maintenance/Services Workgroup

Figure 42 – Dose Trends for the Maintenance/Services Workgroup
Slag Handling
The average dose to the Slag Handling workgroup has decreased in the 2011/2012 year. The maximum dose increased slightly but remains with historical levels. The main component of the maximum dose was external gamma radiation.

![Annual Dose Distribution for the Smelter Slag Handling Workgroup Dose Histogram](image1)

**Figure 43 – Annual Dose Distribution for the Smelter Slag Handling Workgroup Dose Histogram**

![Dose Trends for the Smelter Slag Handling Workgroup](image2)

**Figure 44 – Dose Trends for the Smelter Slag Handling Workgroup**
3.2.3 Strategies for Dose Reduction

Both the smelter and concentrator team have continued increased assay frequency of key process streams such as Dust Leach, Concentrate Leach and the Smelter Furnace inputs and outputs in order to maintain control of Po210 throughout the system. Most of the Po210 control is achieved at the smelter by varying the amount of waste heat boiler and electrostatic precipitator dust recycled directly to the flash furnace. However the dust that is bled to the concentrator also needs to be monitored to ensure that the dust is sufficiently leached of Po210, otherwise the Po210 will return to the smelter through the feed concentrate.

Smelter monitoring data has been closely reviewed with smelter management on a monthly basis in order to identify process and task contributions to overall exposures.

3.2.4 Doses to Non-Designated Employees

Doses to the most exposed non-designated Metallurgical Plant employees have been assessed. The current time/location system collects information from the majority of BHP Billiton Olympic Dam employees and contractors on site. Only a small fraction of these workers are designated. The rest are classified as non-designated workers, however, their doses are assessed using the same dose calculation system as for designated employees. A summary of dose statistics is given in Table G.

Table G – Non-Designated Employees Metallurgical plant, Dose Statistics

<table>
<thead>
<tr>
<th>Statistics</th>
<th>Non Designated Employees</th>
</tr>
</thead>
<tbody>
<tr>
<td>Count</td>
<td>2812</td>
</tr>
<tr>
<td>Arithmetic Mean (mSv)</td>
<td>0.8</td>
</tr>
<tr>
<td>90th Percentile (mSv)</td>
<td>1.1</td>
</tr>
<tr>
<td>Min (mSv)</td>
<td>0.2</td>
</tr>
<tr>
<td>Max (mSv)</td>
<td>3.6</td>
</tr>
<tr>
<td>Mean % Dose from RDP.</td>
<td>7%</td>
</tr>
<tr>
<td>Mean % Dose from Dust</td>
<td>44%</td>
</tr>
<tr>
<td>Mean % Dose from Gamma</td>
<td>49%</td>
</tr>
</tbody>
</table>

The total number of non-designated employees increased from 2157 in the 2010/2011 year to 2812 in the 2011/2012 year.
The average dose has decreased to 0.8mSv from 1.0mSv in 2010/2011. The 90th percentile has also decreased to 1.1mSv. The highest recorded dose for a non-designated employee was 3.6mSv. This employee is a contractor communications technician who performs some work duties underground.

The distribution of doses for 2011/2012 non-designated Metallurgical Plant employees is given in Figure 46.
Dose statistics for non-designated employees working in the Metallurgical Plant areas are shown in Table H and Figure 47.

Table H – Dose Statistics For Non Designated Plant employees

<table>
<thead>
<tr>
<th>WORK CATEGORY</th>
<th>No. of Emp.</th>
<th>Mean (mSv)</th>
<th>Minimum (mSv)</th>
<th>Maximum (mSv)</th>
<th>Standard Deviation (mSv)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concentrator</td>
<td>61</td>
<td>1.6</td>
<td>0.7</td>
<td>2.4</td>
<td>0.4</td>
</tr>
<tr>
<td>Hydromet</td>
<td>58</td>
<td>1.0</td>
<td>0.3</td>
<td>3.3</td>
<td>0.6</td>
</tr>
<tr>
<td>Smelter</td>
<td>71</td>
<td>1.5</td>
<td>0.4</td>
<td>3.4</td>
<td>0.7</td>
</tr>
<tr>
<td>Refinery</td>
<td>82</td>
<td>0.6</td>
<td>0.3</td>
<td>1.0</td>
<td>0.1</td>
</tr>
<tr>
<td>Services/Maintenance</td>
<td>2540</td>
<td>0.7</td>
<td>0.2</td>
<td>3.6</td>
<td>0.3</td>
</tr>
</tbody>
</table>
Airborne dust doses and radon decay product doses have been calculated using average airborne dust measurements, average positional radon decay product measurements and the relevant dose conversion factors. Gamma doses have been estimated based on direct personal monitoring and averages resulting from this monitoring. Hours are recorded by actual hours as recorded by Prodtrak, SAP, and the Cardax system. The Refinery and services/maintenance workgroups continued to record an average dose below 1 mSv during 2011/2012.

3.2.5 Cumulative Five Year Dose
As outlined in ICRP 103, the total dose of any individual radiation worker should not exceed 100 mSv in any five year period. To this end, a five year total dose has been determined for all Metallurgical Plant employees who were employed at BHP Billiton Olympic Dam for the previous five years. Designated employees who have worked for more than 18 quarters are included in this analysis.

There were a total of 172 currently designated Metallurgical Plant employees who worked continuously at Olympic Dam during the period 1 July 2007 to 30 June 2012.

The maximum dose for the five year period was 35.2 mSv, compared to the value of 32.5 mSv calculated in 2010/2011. The arithmetic mean for the five year dose period for the Metallurgical Plant has increased from 7.6 mSv to 10.9 mSv. The distribution of doses for the cumulative five year dose is shown in Figure 48.
Figure 48 – 5 Year Cumulative Dose Distribution for Process Plant Employees

A summary of the cumulative five year dose is given in Table I below.

**Table I – Five Year Dose Statistics**

<table>
<thead>
<tr>
<th>Statistics</th>
<th>Cumulative 5 year Doses</th>
<th>Equivalent Average yearly Dose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Count</td>
<td>172</td>
<td>172</td>
</tr>
<tr>
<td>Arithmetic Mean (mSv)</td>
<td>10.9</td>
<td>2.2</td>
</tr>
<tr>
<td>90th Percentile (mSv)</td>
<td>20.5</td>
<td>4.1</td>
</tr>
<tr>
<td>Min (mSv)</td>
<td>2.2</td>
<td>0.4</td>
</tr>
<tr>
<td>Max (mSv)</td>
<td>35.2</td>
<td>7.0</td>
</tr>
<tr>
<td>Mean % Dose from RDP</td>
<td>13%</td>
<td></td>
</tr>
<tr>
<td>Mean % Dose from Dust</td>
<td>74%</td>
<td></td>
</tr>
<tr>
<td>Mean % Dose from Gamma</td>
<td>22%</td>
<td></td>
</tr>
</tbody>
</table>

**3.3 Annual Dose Trends**

The average total effective dose to all designated employees at the Mine and Metallurgical Plant since 2007/2008 are shown in Figure 49 and Figure 50 respectively. The annual dose for the last year has been dominated by radon decay product exposure in the Mine and by dust exposure in the Process Plant, in particular, due to polonium-210 in the Smelter.
Figure 49 – Mine Annual dose trend

Figure 50 – Plant Annual Dose Trend
3.4 Doses to Members of the Public

The full assessment of doses to members of the public will be presented separately in the Environmental Management and Monitoring Report.

For all members of the public, the effective dose from the operation, for the period July 2011 to June 2012 was well below the statutory limit of 1 mSv per annum. Estimated maximum operational related doses are shown in Table J.

Table J – Public Doses

<table>
<thead>
<tr>
<th>2010/2011 dose to Members of the Public living at</th>
<th>Dose (mSv)</th>
<th>Dose Limit (mSv)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roxby Downs</td>
<td>0.026</td>
<td>1</td>
</tr>
<tr>
<td>Olympic Dam Village</td>
<td>0.033</td>
<td>1</td>
</tr>
</tbody>
</table>

Figure 51 presents the public dose trends for Olympic Dam Village and Roxby Downs since 1991. The FY11 dose to the members of the public has continued to remain below the minimum detection limit of 0.048 mSv.

Figure 51 – Total Dose Trend for Olympic Dam Village and Roxby Downs
APPENDIX A

Dose Conversion Factors 2011/2012

A summary of the airborne dust dose conversion factors for specific work areas can be viewed in the following table.

Table K – Dust Dose Conversion Factors

<table>
<thead>
<tr>
<th>Location</th>
<th>DCF (µSv.m³/Bq.hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smelter</td>
<td>7.5</td>
</tr>
<tr>
<td>Refinery / STP</td>
<td>5.4</td>
</tr>
<tr>
<td>SX / Precipitation / Calciners</td>
<td>4.5</td>
</tr>
<tr>
<td>Other*</td>
<td>4.1</td>
</tr>
</tbody>
</table>

*All other areas of Mine, Concentrator, Slag Concentrator, Hydromet and Services (Laboratories and Metallurgical Workshop)

The default RDP dose conversion factor used was 1.41 mSv.m³/mJ.hr (5 mSv/WLM).