Radiation Consultancy and Training Services

Radiation Consultancy & Training Services

Health Physics Report on

Radiological Risk Assessment for transportation of UOC

For Cameco Australia

21st October 2011

By Robert Blackley
Radiation Consultancy & Training Services
Australian Nuclear Science & Technology Organisation

21st October 2011

Table of Contents

1. Introduction

Cameco Australia is proposing to start mining uranium at Kintyre in the East Pilbara region located approximately 1,200 km north northeast of Perth in the Shire of East Pilbara of Western Australia (WA). These operations are expected to commence after 2016.

The Project will consist of an open-cut uranium mine, process plant and associated infrastructure. The Project will produce between 2.7 and 3.6 kilotonnes (kT) (six and eight million pounds) per year uranium oxide concentrate (UOC) as U3O8 equivalent, and is anticipated to operate for approximately 15 years.

The final product of the mine, uranium concentrate, is to be transported via truck in sealed drums inside shipping containers. It is proposed that approximately 2500 to 3500 tonnes per year will be transported. There are a few transport route options available to Cameco Australia; namely from Kintyre via road to a hub at Kalgoorlie and (depending on the availability of the hub) then by road or rail to Port Adelaide, and possibly by rail from Adelaide to Darwin, or by road from Kintyre to Darwin.

Cameco has approached the Australian Nuclear Science and Technology Organisation (ANSTO) to provide assistance in meeting their transportation requirements. This includes the preparation of a risk assessment of the various transportation routes and conditions for transportation of the uranium concentrate in Western Australia and South Australia.

2. Purpose

This radiological risk assessment is being provided as an appendix to the Environmental Review and Management Program, and underpins the overarching framework Cameco intends to implement in order to ensure the safe transport of UOC in accordance with Australian and International requirements.

3. Scope

This radiological risk assessment applies to UOC that will be sealed in 205L drums and loaded into 20ft General Purpose containers for transport via road or road/rail (depending on the availably of a Transport Hub near Kalgoorlie), to the nominated ports of Darwin or Adelaide, for export from Australia.

There are expected to be up to 70 transport movements per year, and transport will occur within three States and Territories of Australia.

UOC is classed as a dangerous good and would be transported as UN2912, Class 7 – Radioactive Substances, LSA-1

There are a number of options available to Cameco for transporting the UOC product to its destination. The preferred route is by road from the Kintyre project site by sealed road to Parkeston near Kalgoorlie via Telfer, Marble Bar, Port Hedland, Newman, Mount Magnet, Sandstone, Leinster and Leonora.

From Parkeston the preferred route is by rail or road to Port Adelaide or Darwin.

Alternative routes exist either using secondary roads to detour Port Hedland, via Nullagine, and Mount Magnet, or using road transport from Kintyre to Darwin.

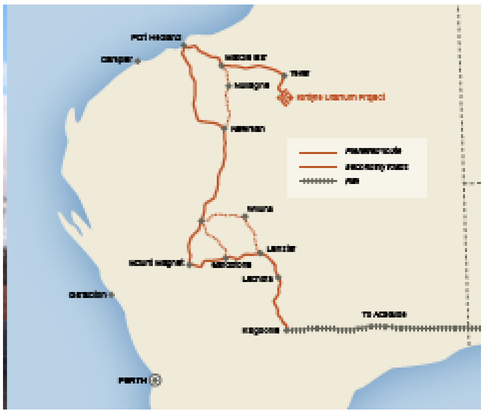

Figure 1 – Proposed transport routes and alternative routes from Kintyre to Parkston

Cameco is currently proposing to use the proposed Parkeston Transport Hub northeast of Kalgoorlie for transfer of the UOC product from road to rail, for transport interstate to the export port. The Parkeston Transport Hub has been proposed by the WA Government to allow offloading and transfer of bulk freight between road and rail transport networks. In the event the facility is not established by the time Kintyre has commenced production, Cameco would use road transport to the Port of Adelaide or Darwin.

The scope of this risk assessment covers the transportation of UOC in road trains and rail car along each of the proposed routes to the port of exit. The assessment does not include activities prior to loading of the material onto the road train nor does it include activities once the material arrives at the port of exit. The scope is limited to the radiological risks during the transportation and only considers other non-radiological risks where there is potential radiological impact.

4. Basic Radiological Issues

Most elements consist of a number of different isotopes. Some of these isotopes are stable; however, some isotopes are not and transform into a more stable nuclear state by losing energy in the form of ionising radiation. In some cases, the newly formed nuclides are also unstable and decay into other isotopes. This process continues until the final decay product is stable. Various types of ionising radiation can be emitted in the transformation of the nucleus of an atom. Predominately the emissions are in the form of gamma radiation or beta or alpha particles. This transformation is called radioactivity.

The rate at which a radionuclide decays is different for each isotope and is expressed as its 'half-life'. In a decay chain, each isotope will have a different half-life.

Alpha radiation is a particle and is identical to the positively charged nucleus of a helium atom, consisting of two protons and two neutrons. This alpha particle is a relatively large particle which only has a short range in air and poses more of an internal radiation hazard than an external radiation hazard.

Beta radiation is a particle in the form of an electron, whose range in air is dependent upon its energy. It is a smaller particle than an alpha particle. It can pose an external skin dose hazard and an internal hazard.

Gamma radiation is in the form of electromagnetic radiation whose range in air, although dependent upon its energy, is longer than alpha or beta radiation. Gamma radiation poses an external radiation hazard.

There are other types of ionising radiation, such as X-rays and neutrons; however, these types of radiation are usually emitted by radiation apparatus or sources used in industrial or medical applications. They are not relevant to this assessment.

5. Potential Exposure Pathways

Human tissue can be exposed to radiation via four main pathways.

- Exposure from external radiation is from radiation sources external to our bodies which penetrates our skin and deposits energy in our organs and tissues.
- Another exposure pathway is via inhalation of gases such as radon or airborne particulates into the lungs, which may remain in the lungs or be absorbed into the bloodstream, depending upon its particular physical and chemical properties.
- Radioactive material can also be ingested via the mouth, where it will either be absorbed into the bloodstream and distributed around the body, or passed through the gut and be excreted if insoluble.
- The fourth main exposure pathway is the entry of radionuclides into the bloodstream through cuts and abrasions in the skin or in some cases through absorption through the skin.

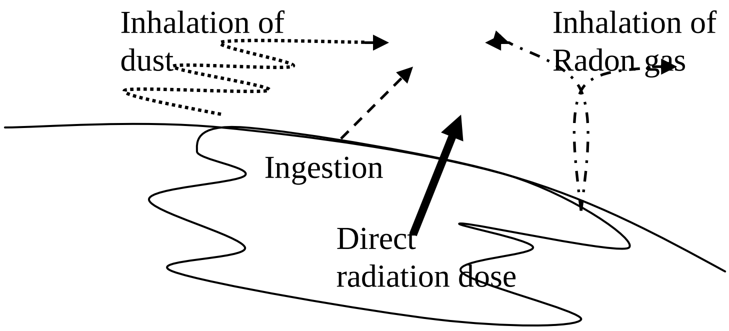

Figure 2 - Simple conceptual model of potential exposure pathways in the immediate vicinity of radioactivity material.

The exposure from external radiation when transporting low level UOC is dependent upon the time spent working around the material and the intensity of the radiation emitted by the material. The total time spent handling or transporting the low level UOC containers combined with the low levels of radiation emitted by the UOC therefore significantly reduces the probability of receiving significant exposure from the material during routine operations.

The main consideration when transporting UOC is preventing or minimising the inhalation or ingestion of the material, due to both its radiological and chemical properties. This is achieved through the packaging of the material in sealed drums inside sealed shipping containers, the stowage methods used, the density of the material and monitoring of the drums prior to stowage.

6. Natural Background Radiation

Everybody is exposed to ionising radiation everyday, from a variety of natural radiation sources. These include cosmic radiation from outer space, potassium-40 inside our bodies, the presence of uranium, thorium and potassium-40 in the earth's crust and subsequent incorporation into food and water and radon gas released during the decay of uranium and thorium.

The average total dose to an individual is approximately 2.4mSv per year. However, this varies considerably depending upon factors such as local geology, altitude, the material that houses are built out of and the food consumed.

Uranium, Thorium and isotopes from their associated decay chains are present in low concentrations in rocks and soils. Typically they average about 3 parts per million (ppm) Uranium and Thorium may be present at up to 10 ppm in ordinary soil, and up to 30 ppm or more in some granites. Uranium ores range from 0.03% (300 ppm) up to a few percent (> 10,000 ppm) in the richest international uranium ore deposits. A number of radionuclides in the natural decay chains for Uranium and Thorium emit gamma radiation, which can be an external radiation hazard to people. Potassium-40 also exists naturally alongside stable potassium isotopes and contributes to external radiation exposure. In addition, potassium-40 exists within our bodies and naturally is a source of internal exposure.

Some radionuclides from the Uranium and Thorium decay series may be incorporated into food and drinking water, which results in internal exposures to radiation.

Radon (^{222}Rn) gas and Thoron (^{220}Rn) gas can be a significant source of exposure through inhalation, and may contribute to more than half of the exposure to individuals from natural sources. The exposure from Radon and Thoron will vary significantly dependent upon the ventilation of the dwelling, the local geology and the weather.

Activities such as the mining of resources containing naturally occurring radiological materials (NORM) or indeed mining the minerals themselves, can lead to additional exposure.

7. Process Description

The following forms a brief description of the various stages or components that are included in the transportation risk assessment.

7.1. Packaging of material at the Mine Site

The objective of packaging requirements is to ensure that there is no loss of containment during transport of consignments of UOC.

In accordance with the guidance material *Managing naturally occurring radioactive material (NORM) in mining and mineral processing – guideline. NORM-4.3 – Transport of NORM* by the Department of Mines and Petroleum, Western Australia, the UOC product from the Cameco operations in Kintyre will be sealed in Industrial Packaging Type 1 (IP –1) 205 litre steel drums in the processing plant at the mine site. Each drum has a lid secured in place by means of a steel locking ring that is clamped by a locking ring bolt. Drums filled with UOC are then loaded into General Purpose (GP) containers conforming to ISO 1496. The drums will be strapped with Corex strapping (Cordlash CC105) approved by the Australian Maritime Safety Authority (AMSA).

The doors of the containers containing the UOC will be sealed with bolt type seals, which are consecutively numbered. The bolt security seals would comply with Customs-Trade Partnership Against Terrorism (C-TPAT) and ISO 17712 standards which meet ASNO standards as part of the Security Plan for the movement of UOC from the Project.

Prior to leaving the Project, and in accordance with the Code, a Radiation Safety Officer or delegate will monitor both the GP container, and the exterior of the 205L drums for surface contamination. Non-fixed surface contamination (i.e. dust particles or similar than can be wiped or washed off) on the external surfaces of either the bulk rail wagon or the 20 ft container shall not exceed the following:

- 4 Bq/cm^2 for beta and gamma emitters and low toxicity alpha emitters
- 0.4 Bq/cm^2 for all other alpha emitters.

The exterior of the GP containers will be measured for gamma radiation to confirm the Transport Index. The Transport Index (TI) is an indicative measure of the potential gamma radiation level at 1 metre for each 20ft GP container and recorded on the Yellow III trefoil label. All radiation measurements will be recorded and retained.

The containers remain sealed throughout the journey from the mine site at Kintyre to the overseas point of delivery. The containers are inspected for integrity at all transhipment and discharge points.

7.2. Road Transportation

Cameco recognises that real-time, accurate communications are necessary to the successful transport of UOC and will implement the following requirements:

All road vehicles used to transport UOC from the Project site to Adelaide, would:

- Normally travel in combinations of at least two trucks which would remain in close proximity throughout the journey;
- Either use two trained drivers per truck with all necessary licenses to complete the direct service stopping only to refuel and for driver meal breaks at designated locations along the approved transport route, or travel with one trained driver per truck, allowing for suitable breaks as per general transportation requirements;
- As a minimum, be outfitted with equipment to communicate quickly, efficiently and reliably with an operational base. This could include two-way radios and satellite phones; and
- a global positioning system (GPS) would be fitted to each prime mover.

A GPS fitted to each truck would provide three main security functions that are outlined below:

- A duress pendant or similar device would be provided to each driver so that if he/she was involved in an en route incident, the pendant may be pressed within 50 m of the vehicle and a duress message would be triggered.
- Out-of-zone requirements (also known as a geo-fence) around the approved road or rail transport routes would be defined, and if a vehicle moved outside these zones or traveled in an alternative direction, a back to base alarm would be generated.
- En route checking (with automatic updates, duress alarms etc through to an authorised user website) would display the location of vehicles during their journey at both the Project main security gate and Transport operational centre.

The total distance of the preferred route from Kintyre to Parkeston is approximately 2300kms. This involves travel along sealed roads through remote areas and some towns. The sealed roads carry road trains and other vehicles from a number of different industries.

7.3. Rail Transport

If rail transport were used to transport UOC from the Project site to Adelaide, it would:

- Be transported on a designated railway carriage designed to securely stow such transport containers.
- Have suitable communications to communicate quickly, efficiently and reliably with an operational base. This includes an effective notification procedure to the Transport operational centre.
- Have a suitable inventory tracking system of material being loaded, transported and unloaded on each railway convoy.
- Transport containers would undergo an inspection of the bolt type seals, which are consecutively numbered to ensure that material has not been tampered with.

7.4. Storage During Transport

UOC will be stored in designated secure areas that have been approved and licensed by ASNO and/or the relevant state or territory regulator.

These designated secure areas are:

- Dubai Ports, Port Adelaide Terminal
- Tolls Terminal, Berrimah Industrial Estate, Darwin

Depending on operational requirements, additional secure transit areas may be needed to support the planned transport process which would be subject to ASNO and/or the relevant State or Territory regulatory approvals and permits at that time.

Stringent security protocols are in place in ASNO approved secure areas and some of the controls are listed below:

- Access to the Ports controlled by maritime security legislation
- Inductions for all staff and visitors accessing the Site
- Security passes issued to staff
- Visitors escorted at all times
- Training for all staff in emergency response procedures and security controls
- CCTV in place
- Physical barriers to restrict access to containers
- Appropriate lighting

7.5. Transfer of Material from Road Train to Rail Car

If required, the material being shipped will be transferred from road train to a rail car at Parkeston near Kalgoorlie.

The shipping container will be lifted off the road train by means of a crane or forklift and transferred onto a rail car for transportation to a sea port. The UOC material will remain inside its sealed drums strapped into the shipping container. The shipping container will remain sealed during this process, with the container inspected for integrity of its individually numbered seal during this stage.

During the transfer of the loaded shipping container from the road train to the rail car, the loaded shipping container may be stored temporarily in a designated storage area at the transfer facility.

7.6. Transfer of Material from Rail Car to the Port

The shipping container will be lifted off the rail car by means of a crane or forklift and transferred onto a designated storage area prior to loading onto a sea vessel. The shipping container will remain sealed during this process, with the container inspected for integrity of its individually numbered seal during this stage.

During the transfer of the loaded shipping container from the rail car to the sea vessel, the loaded shipping container may be stored temporarily in a designated storage area at the transfer facility.

8. Radiological Risk Assessment Method

Potential hazardous scenarios were identified for each of the different stages of the transportation. These were then reviewed to include scenarios related to a potential radiological risk or scenarios that may have a potential impact, either negatively or positively, on the potential radiological risks associated with the transportation. Other scenarios that did not meet this criteria were excluded from the risk assessment.

After the identification of the hazards, a risk assessment was carried out to assess the risk of the various hazardous scenarios.

Five categories of likelihood and five categories of consequence are used to enable the hazardous scenarios to be plotted onto the risk evaluation tables. The likelihood and consequence of the hazardous scenarios were also assessed as per the Frequency Evaluation Table and the Risk Matrix.

9. Tolerability of Risk Criteria

The tolerability of risk criteria is summarised below.

- Risk is determined by the combination of likelihood and severity of consequence
- Risks assessed as Very High or High level are generally not acceptable unless there is an overwhelming societal benefit and the risks are as low as reasonably achievable (ALARA). The activities may be stopped or the risks controlled by using the hierarchy of controls.
- Risks assessed as Medium level are not normally acceptable but may be argued as tolerable if significant national or societal benefit accrues and good safety practice is followed. Further control measures should be adopted to reduce the risks and the radiation exposure is considered ALARA.
- Risks assessed as Low level are generally tolerable if it can be shown that radiation exposure is ALARA and the risks as low as reasonably practicable. Further control measures may be adopted to reduce the risks further if practicable and to maintain good safety practice.
- Risks assessed as Very Low level are tolerable generally without any further control measures. It is necessary to confirm that good safety practice is maintained and the radiation exposure is ALARA.

10. Risk Management and Hazard Control

The risk assessment process identifies measures for reducing the risk of radiological consequences. These are implemented predominately by implementing safe work practice, the inherent safety of the containment vessels, and development and implementation of instructions and management plans.

11. Radiological Risk

There are four main pathways that human tissue can be exposed to radiation, as identified above. Each of these pathways is assessed in the risk assessment for each stage of the transportation, and techniques to mitigate or minimise the potential exposure investigated.

The exposure from external radiation when transporting low level UOC is dependent upon the time spent working around the material and the intensity of the radiation emitted by the material. The total time spent handling or transporting the low level UOC containers combined with the low levels of radiation emitted by the UOC therefore significantly reduces the probability of receiving significant exposure from the material during routine operations.

The main consideration when transporting UOC is preventing or minimising the inhalation or ingestion of the material, due to both its radiological and chemical properties. Other consideration is given to the potential impact on the environment if there existed the possibility of contaminating either the immediate or extended area. Minimising the inhalation or ingestion of material or the impact on the environment is achieved through the packaging of the material in sealed drums inside sealed shipping containers, the stowage methods used, the density of the material and monitoring of the drums prior to stowage.

12. ALARA

For continuing and proposed activities involving potential exposure to ionising radiation, the system of radiation protection requires exposure to be controlled through **justification**, **optimisation** and dose or risk **limitation**.

Optimisation is employed to make the best use of resources in reducing radiation risks, once a practice has been justified. The aim is to ensure that the magnitude of individual doses, the number of people exposed and the likelihood that the potential exposures will actually occur should all be kept **A**s **L**ow **A**s **R**easonably **A**chievable, economic and social actors being taken into account (**ALARA**). It involves the examination and ranking of a suite of possible strategies that reduce detriment. Optimisation is reached when any further step to reduce the detriment would involve a deployment of resources that is out of proportion to the consequent reduction.

Optimisation and the ALARA principle is considered in the risk management strategies in this assessment.

13. Safety Analysis for Normal Operations

Under normal operating conditions, the radiological exposure to personnel and members of the public are assessed to be relatively low during the transportation of UOC by both road and rail.

A number of scenarios potentially resulting in exposure to either personnel or members of the public under routine operations are described and assessed below.

The dose estimates are based upon recorded dose rates from shipments of UOC in a dry goods containers from Cameco operations in Canada, and from similar operations from different mines within Australia. The actual dose rates on the outside of the shipping container transporting material from the Kintyre Project is expected to be lower, however the higher measured results were used in these assessments.

Distance	Gamma (uSv/h)	Estimate of Error +/-
Contact*	12	2
1 meter	2.8	0.5
5 meter	0.7	0.3
10 meter	0.1	0.1

*Contact = gamma meter on the outside surface of the trailer.

Further modelling was completed on the anticipated dose rates within the cabin of the truck, taking into account the distance between the truck cabin and the container (400cm), a minimal amount of shielding offered by the steel from container, drums and truck cabin (1 cm steel), and the in-growth of decay products in the UOC.

Age of UOC (days)	Gamma Dose rate in Cabin (uSv/h)
30	0.15
60	0.21
90	0.24
120	0.25
150	0.26
180	0.26

These results are consistent with literature available on dose rates within cabins for similar other operations within uranium mines Australia. These measurements were used in the assessment of potential doses to drivers of the trucks whilst inside the cabin of the truck.

Driver of road train: The preferred route from Kintyre to Kalgoorlie is approximately 2300km. Based upon an average speed of 75km/h this equates to 30 hours of driving. Transportation conditions restrict a driver from driving for more than 12 hours out of every 24 hours. Therefore if a single driver were to drive the entire route from Kintyre to Kalgoorlie this would equate to a total travel time of approximately 60 hours, including breaks.

Based upon the results above, the distance from the shipping container to the driver's compartment, additional shielding from the driver's compartment and comparison with other similar operations within Australia, a maximum exposure rate of 0.3uSv/h is estimated inside the driver's compartment. The highest exposure scenario, assuming that the driver also slept inside the cabin during all breaks would result in the driver receiving a dose of 0.018 mSv for each journey. If the same driver completed all proposed 70 trips per year this would result in an annual dose of 1.26 mSv. The actual dose received is likely to be lower than this as the driver would probably spend at least some of the time during breaks outside of and away from the driver's cabin.

Members of public on or adjacent to the roadways: As the material is transported along the roadways members of the public travelling in a vehicle behind the road train may be exposed to ionising radiation. However the distance to the road train and the very short duration of exposure time is estimated to result in a minimal dose rate. Based upon the assumption that somebody may travel 5 metres behind a road train for a period of 4 hours, this would result in a maximum dose to a member of the public of less than 0.005 mSv per trip.

Based upon the scenario that a person may be adjacent to the roadway on which the road train is travelling, the distance to the road train and the very short duration of exposure time is estimated to result in a dose of less than 0.001 mSv per trip.

Members of public adjacent to the railway line: As the material is transported along the railway line, members of the public beside the railway may be exposed to ionising radiation. However the distance to the shipping container and the very short duration of exposure time is estimated to result in a dose of less than 0.001 mSv per trip.

Members of public whilst road train stationary: As discussed above, road transportation conditions restrict a single driver from driving more than 12 hours out of every 24 hours. As a result there exists the potential for members of the public to be exposed to ionising radiation from a stationary road train during a scheduled break. These breaks will be at different locations along the route and so it is assumed that the maximum exposure time to an individual from a stationary road train during the transport would be 10 hours (maximum 12 hours minus minimum mandatory routine breaks). Although unlikely it is possible that a member of the public may spend the entire 10 hours during a break at a distance of 1 metre from the container, resulting in a maximum dose of 0.028 mSv/h per trip. However security requirements may include the use of a secure facility or proximity security sensors. Although not required from a safety perspective, the use of these for security would also reduce the potential dose of this individual due to an increase in distance to the container or reduced time spent near the container. However the use of these security measures have not been included in the risk assessment summarised below.

Members of the public during a breakdown: In the non-routine but potential event of a breakdown, the road train may remain stationary in a public area. Access by the general public would be restricted to distances of at least 10 metres by the driver of the vehicle in such an event. Based upon the assumption that mechanical assistance from a town could be provided to the vehicle within 6 hours, the potential exposure to members of the public would be less than 0.001 mSv.

Other potential exposure scenarios exist during routine operations, however all were considered to result in negligible potential exposures.

The following table summarises the risk assessment of all of the above scenarios taking into account some of the management controls discussed (see Section 15).

Likelihood Score	Consequence Score	Risk
Likely	Insignificant	Low

Damage to road infrastructure due to increased traffic: Proposed routes already carry significant frequency of heavy vehicles[1]. The proposed increase in frequency of trucks would

[1] Pilbara Traffic Digest 2003/04 – 2008/09 Mainroads Western Australia, Western Australia Government

only result in a negligible increase in percentage of heavy vehicles on the road and hence only marginally increase the damage to existing road infrastructure.

Likelihood Score	Consequence Score	Risk
Unlikely	Insignificant	Very Low

14. Safety Analysis for Accident Conditions

In the following sections, abnormal scenarios that may have significant safety affects are discussed:

14.1. Loading and Unloading Containers

During the loading or unloading of transport containers at the Processing Plant, at the road/rail interchange or at the port facilities there exists the possibility that loading equipment may fail or operator error may occur. This may result in a crush type injury to personnel if present in the immediate area. The following table summarises the risk assessment of the above scenario. The full assessment can be seen in Section 16.

Likelihood Score	Consequence Score	Risk
Possible	Moderate (injury)	Medium

By adoption of suitable mitigations personnel can be kept away from the immediate area, which will reduce the likelihood of occurrence and hence the risk. The above scenario is not based upon radiological risk.

During the above scenario there does exist the potential for the integrity of the container and drums to be breached, resulting in the release of UOC. Spill kits are available at each location where loading and unloading may occur and staff should be suitably trained in emergency response, which would significantly reduce any radiological exposure. The following table summarises the radiological risk assessment if the integrity is breached.

Likelihood Score	Consequence Score	Risk
Unlikely	Insignificant	Very Low

14.2. Incorrect Dose Rate measurements taken

Prior to release, the exterior of the drums containing the UOC will be monitored for external dose rates and contamination, in accordance with transportation requirements. There does exist the possibility that operator error may result in the incorrect radiological measurement being taken or recorded. The use of competency based training, accredited personnel and calibrated instrumentation will reduce the likelihood of this occurrence. If loose contamination is present on the exterior of the drums, the secondary containment of the container will decrease any consequences. Due to the specific activity of the UOC, the increase in dose rates on the exterior of the container will only increase by a limited factor, limiting the consequences. The following table summarises the radiological risk assessment if the radiological measurements taken are incorrect.

Likelihood Score	Consequence Score	Risk
Possible	Insignificant	Low

14.3. Road accident involving collision with an Object

During the transportation of UOC by road train, there does exist the possibility of the road train being involved in a serious accident involving collision with an object. The causes of this could be a result of driver fatigue, the environmental conditions of the road, traffic congestion, non-compliance with road rules (including speeding) and failure of the vehicle. Various databases on the causes of heavy truck accidents exist, including the National Transport Insurance (NTI) heavy truck database and the Australian Truck crash database (ATCD), both developed by the Australian Transport Safety Bureau. Other serious accident databases also exist including those developed by State and Territory Police.

The introduction of mitigation measures that address the causes of the majority of accidents as described in these databases will significantly reduce the likelihood of an accident occurring.

By the use of a preferred transport supplier, regular preventative maintenance, regular inspection of vehicles and routes travelled, by selecting routes based upon current condition of the road and weather and suitable management of work hours the likelihood of an accident decreases. Regular auditing of compliance with transport regulations, ensuring drivers have adequate competency based training, a transport management plan being developed and implemented, and contingency plans for adverse environmental conditions that can occur along these routes are in place, will further reduce the likelihood and consequence of an accident involving a collision with an object, as indicated in the table below. This assessment is based upon radiological risk only.

Likelihood Score	Consequence Score	Risk
Possible	Insignificant	Low

The drums and the containers containing the UOC are made to meet national and international standards and are designed to be robust. During the above scenario involving collision with an object, however there does exist the low possibility that the integrity of the drums containing the UOC and the container would be breached. With the inclusion of mitigation measures such as an Emergency Response Plan, suitable spill kits on the truck, procedural control and a Security Plan, the radiological consequences of the breach of integrity are reduced, as shown in the table below.

Likelihood Score	Consequence Score	Risk
Possible	Minor	Low

During the above scenario there does exist the possibility that a truck may be involved in an accident resulting in both the loss of containment of the UOC and a significant fire/explosion. The likelihood of such an occurrence is lower than the above scenarios, however the release of particulate UOC from a fire would potentially increase both the radiological exposure via inhalation and environmental consequences due to the potential extended distribution of UOC as a result of increased thermal air movements. By restricting recovery personnel and members of the public to an upwind location of the site as part of the Emergency Response Plan, the exposure consequences are significantly reduced. Personnel Protective Equipment (PPE) worn by fire fighting personnel or recovery personnel, including breathing protection of a

P2 dust mask or greater, will reduce the exposure if working downwind of the collision/fire is required. The changes in consequence and likelihood are reflected in the table below.

Likelihood Score	Consequence Score	Risk
Unlikely	Moderate	Low

During a collision with an object there does exist the possibility that a truck may be involved in an accident resulting in the loss of containment of the UOC during heavy rain. This would reduce the potential exposure of personnel via inhalation, however there would be a slight increase in potential environmental consequences. Management of the spill using a spill kit in accordance with a emergency response plan would minimise this consequence. If very significant volumes of water are present, although containment using a spill kit becomes more difficult, the significant dilution of the material will decrease the environmental consequences.

Likelihood Score	Consequence Score	Risk
Possible	Minor	Low

14.4. Single vehicle road accident

During the transportation of UOC there does exist the potential for a single vehicle road accident. The causes of this could be a result of driver fatigue, the environmental conditions of the road, traffic congestion, non-compliance with road rules (including speeding) and failure of the vehicle.

Various databases on the causes of heavy truck accidents exist, including the National Transport Insurance (NTI) heavy truck database and the Australian Truck crash database (ATCD), both developed by the Australian Transport Safety Bureau. Other serious accident databases also exist including those developed by State and Territory Police.

The introduction of mitigation measures that address the causes of the majority of accidents will significantly reduce the likelihood of an accident occurring.

By the use of a preferred transport supplier, regular preventative maintenance, regular inspection of vehicles and routes travelled, by selecting routes based upon current condition of the road and weather and suitable management of work hours the likelihood of an accident decreases. Regular auditing of compliance with transport regulations, ensuring drivers have adequate competency based training, a transport management plan is developed and implemented and contingency plans for adverse environmental conditions that can occur along these routes are in place, will further reduce the likelihood and consequence of a single vehicle accident occurring.

This assessment is based upon radiological risk only.

Likelihood Score	Consequence Score	Risk
Possible	Insignificant	Low

14.5. Road accident involving collision into a waterway

During the transportation of UOC there does exist the potential for an accident where there is a loss of containment of the UOC and the truck collides with a waterway.

The causes of this could be a result of driver fatigue, the environmental conditions of the road, flooding, traffic congestion, non-compliance with road rules (including speeding) and failure of the vehicle.

This unlikely incident could result in an increased impact on the environment. Exposure to personnel via inhalation would be minimal as the released material would be suspended in water. UOC is soluble in HCl, H_2SO_4, HNO_3 and H_3PO_4 but is insoluble in water. Exposure via ingestion is possible resulting in uranium metal poisoning causing potential damage to the kidney. This is a toxicology hazard more than a radiological hazard.

Mitigation measures such as an emergency response plan covering such scenarios, dilution in high flow waterways and containment in low flow waterways and the insolubility in water of the UOC would reduce the consequence of the incident.

By the use of a preferred transport supplier, regular preventative maintenance, regular inspection of vehicles and routes travelled, by selecting routes based upon current condition of the road and weather and suitable management of work hours the likelihood of an accident decreases. Regular auditing of compliance with transport regulations, ensuring drivers have adequate competency based training, a transport management plan is developed and implemented and contingency plans for adverse environmental conditions that can occur along these routes are in place, will further reduce the likelihood and consequence of an accident involving collision with a waterway.

Likelihood Score	Consequence Score	Risk
Unlikely	Moderate	Low

14.6. Road accident involving fatality of the driver

In the above mentioned scenarios, some of the reduction in consequences is obtained by the driver of the vehicle implementing measures to minimise the time spent by personnel and members of the public in close proximity to the container and to initiate spill management.

In some scenarios it is possible that the accident results in the fatality of the driver.

By the use of a preferred transport supplier, regular preventative maintenance, regular inspection of vehicles and routes travelled, by selecting routes based upon current condition of the road and weather and suitable management of work hours the likelihood of an accident occurring in the first place decreases. Regular auditing of compliance with transport regulations, and contingency plans for adverse environmental conditions that can occur along these routes are in place, will further reduce the likelihood and consequence of an accident.

The low dose rates around the container will only result in insignificant radiation doses to people in the immediate area, even for longer periods of time and without the actions normally implemented by the driver, as reflected in the table below. This assessment is based upon radiological risk only.

Likelihood Score	Consequence Score	Risk
Possible	Insignificant	Low

In the event that an accident resulted in the loss of containment of the UOC and a fatality of the driver, there would be an increase in the potential consequences, both in terms of radiological exposure and environmental damage. However the implementation of an Emergency Response Plan, back-to-base monitoring of the truck, duress alarms and suitable training of emergency response personnel along the route would result in only minor environmental and radiation exposure consequences, as indicated in the table below. This assessment is based upon radiological risk only.

Likelihood Score	Consequence Score	Risk
Possible	Minor	Low

14.7. Loss of containment due to incorrectly sealed drums

During preparation of the UOC for transportation there does exist the possibility that drums could be incorrectly sealed resulting in potential loss of containment of the drums either during loading or during transportation. This could be a result of failure to follow drum packing instructions or the use of incorrect components.

The final dose rate checks on each drum as mandatory in transportation requirements and the installation of bolt security seals would increase the likelihood of detection of such an error. Mitigation measures including the secondary containment of the container, a controlled inventory of drum components, competency based training, accurate record keeping and spill kits being available would reduce the likelihood and consequence of such an error.

Likelihood Score	Consequence Score	Risk
Possible	Minor	Low

14.8. Rail incident involving collision with an object

During the transportation of UOC by rail, there does exist the possibility of the train being involved in a serious accident involving collision with an object. The causes of this could be a result of train driver fatigue, the environmental conditions, non-compliance with rail rules and failure of the train or rail. Studies[2] into train accidents also identify collisions with vehicles at level railway crossings as a significant cause of accidents. The introduction of mitigation measures that address the causes of the majority of accidents will significantly reduce the likelihood of an accident occurring.

By the use of a preferred transport supplier, regular preventative maintenance, regular inspection of trains and railway infrastructure, by selecting routes based upon current condition of the railway line and weather and suitable management of work hours the likelihood of an

[2] For example: Serious injury due to transport accidents involving a railway train, Australia, 2002-03 to 2006-07, Henley G. and Harrison JE

accident decreases. Regular auditing of compliance with transport regulations, ensuring drivers have adequate competency based training, a transport management plan is developed and implemented and contingency plans for adverse environmental conditions that can occur along these routes are in place, will further reduce the likelihood and consequence of a rail accident involving a collision with an object, as indicated in the table below. This assessment is based upon radiological risk only.

Likelihood Score	**Consequence Score**	**Risk**
Possible	Insignificant	Low

14.9. Rail incident involving train leaving the track

During the transportation of UOC by rail, there does exist the possibility of the train being involved in a serious accident involving the train leaving the track. The causes of this could be a result of train driver fatigue, the environmental conditions, non-compliance with rail rules such as speeding and failure of the train or rail. Studies indicate that the likelihood of such a scenario is relatively unlikely. The consequences would be similar to those described in Section 14.8.

Likelihood Score	**Consequence Score**	**Risk**
Unlikely	Insignificant	Very Low

14.10. Security breach of UOC

During the transportation of UOC there does exist the possibility that a person or persons may gain unauthorised access to the UOC material. This may be a result of theft for the purposes of financial gain or an intention to use the UOC for malicious purposes. It may also occur in the instance of a protest or a blockade along the route.

General mitigation measures such as a Transport Management Plan, appropriate training of transport personnel and Emergency Response Plans will decrease the consequence and likelihood of such an event.

Specific measures such as physical protection measures (eg locks), checks of bolt security seals, monitoring of NGO activities, security measures at storage facilities and a specific Security Plan will reduce the likelihood of unauthorised access to the UOC. General ASNO security requirements and measures are indicated on ASNO permits. These measures could include the use of a secure compound for overnight storage. However other compensatory security measures could be utilised instead of a secure compound, including the use of proximity detectors, temporary camera surveillance, etc. The security measures employed would be assessed for their suitability by ASNO.

Measures such as having a GPS system attached to the truck, out-of-zone monitoring of the truck and local Police or government intervention will reduce the consequences if unauthorised access was gained.

If unauthorised access is gained there will be regulatory reporting required, there may be loss of an asset and some public concern about the project, however the radiological risk to personnel and the environment would remain very low.

Likelihood Score	Consequence Score	Risk
Unlikely	Minor	Low

15. Risk Evaluation Table (Risk Matrix)

RISK MATRIX (Risk Evaluation Table)

<table>
<tr><td colspan="3">What is the most serious potential outcome for each hazard?</td><td colspan="5">How likely is the potential outcome to be that serious?</td></tr>
<tr><th colspan="3">Consequence</th><th colspan="5">Likelihood</th></tr>
<tr><td rowspan="7">Injury or Disease
Radiation
Plant Damage
Environmental damage
Business and Operations
Enterprise
Project</td><td colspan="2" rowspan="2">Ranking</td><td>L1</td><td>L2</td><td>L3</td><td>L4</td><td>L5</td></tr>
<tr><td>Rare</td><td>Unlikely</td><td>Possible</td><td>Likely</td><td>Almost Certain</td></tr>
<tr><td>C5</td><td>Severe</td><td>Medium</td><td>High</td><td>High</td><td>Very High</td><td>Very High</td></tr>
<tr><td>C4</td><td>Major</td><td>Low</td><td>Medium</td><td>High</td><td>High</td><td>Very High</td></tr>
<tr><td>C3</td><td>Moderate</td><td>Low</td><td>Low</td><td>Medium</td><td>High</td><td>High</td></tr>
<tr><td>C2</td><td>Minor</td><td>Very Low</td><td>Low</td><td>Low</td><td>Medium</td><td>High</td></tr>
<tr><td>C1</td><td>Insignificant</td><td>Very Low</td><td>Very Low</td><td>Low</td><td>Low</td><td>Low</td></tr>
</table>

Matrix Descriptors

Indicative Scale of LIKELIHOOD How likely is the potential outcome?			
Rating	**Description**	**On a frequency basis (ie for activities, processes, plant, etc intended to operate for several years or more.**	**On a probability basis (ie for projects, activities, processes, plant, etc intended to run/operate for one to two years only**
L5	**Almost certain**	• The risk event will occur on an annual basis • Historical records of greater than one occurrence per year in a similar situation • Well publicised occurrences in other similar facilities	• Almost certain to occur in the life of the project, during the planned life of the activity, or in any one case
L4	**Likely**	• The risk will probably occur at some time • The risk has occurred several times or more in your career • Has occurred a couple of times • Known hazard	• Likely to occur in the life of the project, during the planned life of the activity, or in any one case
L3	**Possible**	• The risk could occur • The risk event might occur once in your career • Has occurred in the past • Known hazard in similar facilities and industrial situations	• Possible to occur in the life of the project, during the planned life of the activity, or in any one case
L2	**Unlikely**	• The risk event does occur somewhere from time to time • Occurrence is conceivable • Has not occurred • Known to have happened in the industry	• Unlikely to occur in the life of the project, during the planned life of the activity, or in any one case
L1	**Rare**	• Heard of something like this risk event occurring elsewhere • Could occur at some time • Known to have happened but has not happened in similar industries	• Extremely unlikely to occur in the life of the project, during the planned life of the activity, or in any one case

Risk Treatment

Risk Rating	Hazard Control Decisions	Application
VERY HIGH	• Immediately ensure a system is in place to prevent exposure to this hazard. The activity should not commence or continue with this level of risk. • Advise Risk Management committee. • Executive to ensure a comprehensive risk assessment and management strategy is in place	• Risks of this magnitude are not acceptable. • The activity should not commence or continue with this level of risk.
HIGH	• Ensure staff are aware of this danger and arrange prompt temporary protective action while remedial action proceeds. • Report the situation to the responsible person. • Imperative that responsible person ensures risk is monitored and managed with significant management effort to mitigate risk to lower	• Risks of this magnitude are not acceptable. • The activity should not commence or continue with this level of risk.
MEDIUM	• A remedial plan must be prepared as soon as possible. Action should be prompt if a quick and effective remedy is available at reasonable cost. • Report the situation to the responsible person.	• Agreement to go ahead would be needed
LOW	• Mitigating controls are not likely to be needed. • Further controls may be implemented if considered cost effective to reduce the risk further • Risk and existing controls to be monitored	• Risk and existing controls to be monitored
VERY LOW	• Risk is acceptable	• Acceptable risks

Hierarchy of Controls

Eliminate ⇨ Substitution/Modification ⇨ Isolation ⇨ Engineering ⇨ Administrative ⇨ PPE

CONSEQUENCES		OHS			Environmental Damage
Rating	**Description**	**Injury or Disease**	**Radiation Dose**	**Plant Damage**	
C5	**Severe**	• Death, permanent disability or illness	• Greater than or equal to 100 mSv	• Major Damage	• Long-term damage (> 10 yrs) with effects beyond the controlled area
C4	**Major**	• Long term illness or serious injury. Recovery possible	• 20 – 100 mSv	• Statutory breach	• Medium-term damage (> 1 yr) but confined to the controlled area
C3	**Moderate**	• Medical attention and or several days off work	• 1 – 20 mSv	• Near statutory Breach • (Near Hit)	• Short to medium-term effects (< 1 yr) confined to site, but breaching statutory requirements
C2	**Minor**	• First Aid Only	• 100 – 1000 μSv	• Minor plant damage	• Environmental effect confined to work area but is anomalous and/or exceeds guidelines
C1	**Insignificant**	• Minimal Effects • No injuries	• Less than 100 μSv	• No plant damage	• Within routine operational conditions but may be an environmental aspect with potential for improvement
Specific Hazard Category					
		• Chemical/Hazardous Substance • Electrical • Manual Handling • Confined Space • Nuclear • Psychological • Excavation • Heights	• Exposure • Contamination	• Lifting equipment • Pressure equipment	• Land use management • Waste management • Resource use - reuse/recycling • Airborne risk to public

CONSEQUENCES		Project	Enterprise	Quality/ Management Systems
Rating	**Description**			
C5	**Severe**	• Significant asset destruction or financial loss is likely to be substantial$ • Total cessation of operations for > 2 weeks(extended) period	• Government or public pressure to curtail operations	• Loss of accreditation
C4	**Major**	• Loss of asset of other financial loss$ • Total cessation of operation for < 2 weeks(short) period	• Regulator or court fine. Major media concern, Parliamentary interest	• Major non conformance
C3	**Moderate**	• Moderate loss of asset or other financial loss$ • Total cessation of operations for less than 2 days	• Media & regulator attention. Lowered public image	• Minor non conformance
C2	**Minor**	• Loss of asset or other financial loss$ • Minor disruption to services	• Report to regulator required. Minor public concern	• Opportunity for improvements identified/ observations
C1	**Insignificant**	• Minor loss of asset or other financial loss$ • No disruption to services	• Unlikely to enter public arena	• Within compliance of required measure
Specific Hazard Category				
		• Financial • Technical • Project management • Resource • Research	• Political • Regulatory • Community • Media • Corporate governance • Reputation • HR	• Management responsibility • Resource management • Product realisation • Measurement, analyses & improvement • Document control

CONSEQUENCES		IT	Business & Finance (Operations)
Rating	**Description**		
C5	**Severe**	• Core services unavailable for an extended period	• Financial loss causing an individual or business to be declared bankrupt or cease trading. • Product, service or process failure results in: a general community health problem attracting public interest and requiring significant medical treatment or hospitalisation for those affected.
C4	**Major**	• Core Services unavailable for 2 working days	• Financial loss that threatens the financial status of individuals or business. • Product, service or process failure results in a customer/community health problem requiring hospitalisation or prolonged medical treatment.
C3	**Moderate**	• Core Services unavailable for less than 2 days	• Significant financial loss. • Product, service or process failure results in a customer/community health problem requiring medical treatment.
C2	**Minor**	• Core Services unavailable for a short period	• Minimal financial loss. • Product, service or process failure results in a customer/community health complaint.
C1	**Insignificant**	• No disruption to services	• Product, service or process does not cause any financial or personal risk or loss.
Specific Hazard Category			

16. Assessment Results

Hazard	Scenario	Cause	Mitigations	Consequence	Consequence Score	Likelihood Score	Risk	Acceptability
Injury to personnel during loading and unloading	Injury to personnel during loading or unloading of containers from the Processing Plant, at the road/rail interchange or at the Port	Vehicle/ human interaction Equipment failure Operator error Inadequate training	Implementation of engineering and administrative controls Preventative maintenance Regular inspection of vehicle suitability Appropriate management of work hours Competency based training Inspection of integrity if significant incident occurred Spill and decontamination kit available	Crush injuries to personnel	Moderate (Injury)	Possible	Medium	Adoption of best practice and mitigations required to reduce likelihood of occurrence. Note: This is not a radiological risk
				Potential damage to integrity of transport container and drums resulting in spillage of UOC Potential contamination of immediate area	Insignificant (Radiation dose) (Environment)	Unlikely	Very Low	Acceptable
Ionising radiation	External dose rates	Incorrect dose rate measurements taken	Competency based training Accredited personnel Calibrated instruments Record keeping	Minor increase in dose rates associated with each external exposure scenario	Insignificant (Radiation dose)	Possible	Low	Tolerable
Road Safety	Road accident involving collision with	Fatigue/fitness for work Environmental	Preferred supplier selection Transport Management	External radiation exposure to	Insignificant (radiation dose)	Possible (Data from comparison of	Low	Tolerable

	an object	conditions Vehicle failure Traffic congestion Non-compliance with road rules	Plan Preventative maintenance Competency based training Appropriate management of work hours Regular inspection of vehicles and route safety Contingency plans for adverse environmental conditions Route selection and timing of transports Auditing of compliance with transport regulations	response personnel and members of the public Injury to driver		number of heavy vehicles on road in Pilbara region* to number and type of heavy vehicle crashes in WA Ŧ╬)		
	Road accident involving single vehicle accident			External radiation exposure to response personnel and members of the public	Insignificant (radiation dose)	Possible (Data from comparison of number of heavy vehicles on road in Pilbara region* to number and type of heavy vehicle crashes in WA Ŧ╬)	Low	Tolerable
	Road accident involving fatality of the driver			External radiation exposure to response personnel and members of the public	Insignificant (radiation dose)	Possible (Data from comparison of number of heavy vehicles on road in Pilbara region* to number and type of heavy vehicle crashes in WA Ŧ╬)	Low	Tolerable
Rail Safety	Rail incident involving collision with an object	Fatigue/fitness for work Environmental conditions Train/rail failure Non-compliance with rail rules	Preferred supplier selection Transport Management Plan Preventative maintenance Competency based training Appropriate management of work	External radiation exposure to recovery personnel and members of the public	Insignificant (radiation dose)	Possible (Data obtained by comparison of serious injury frequency involving a railway train ж and distance travelled by train)	Low	Tolerable
	Rail incident			External	Insignificant	Unlikely	Very	Acceptable

	involving train leaving the track		hours Regular inspection of vehicles and route safety Contingency plans for adverse environmental conditions Route selection and timing of transports Auditing of compliance with transport regulations	radiation exposure to recovery personnel and members of the public	(radiation dose)	(Data obtained by comparison of serious injury frequency involving a railway train [ж] and distance travelled by train)	Low	
Loss of containment of UOC	Contamination from incorrectly sealed drums	Incorrect drum components Failure to follow procedures	Competency based training Accredited personnel undertaking final checks Calibrated instruments Record keeping Secondary containment Spill kits Bolt security seal	Contamination of processing plant controlled area Potential contamination of container interior	Minor (Radiation Dose) (Environment)	Possible	Low	Tolerable
	Road accident involving collision with an object	Fatigue/fitness for work Environmental conditions Vehicle failure Non-compliance with road rules	Preferred supplier selection Transport Management Plan Preventative maintenance Competency based training Appropriate management of work hours Regular inspection of vehicles and route safety Contingency plans for adverse environmental	Radiation exposure from external dose rates and/or ingestion or inhalation Release of UOC into the environment	Minor (radiation dose and Environmental damage)	Possible (Data from comparison of number of heavy vehicles on road in Pilbara region* to number and type of heavy vehicle crashes in WA [Ŧ╫])	Low	Tolerable
	Road accident involving collision with an object resulting in a fire			Radiation exposure from external dose rates and/or ingestion or inhalation	Moderate (radiation dose and Environmental damage)	Unlikely (Data from comparison of number of heavy vehicles on road in Pilbara region*	Low	Tolerable

			conditions **Route selection and timing of transports** **Auditing of compliance with transport regulations** **Emergency Response Plan** **Spill kits** **Driver duress alarm** **Security Plan** **Procedural control**	**Release of UOC into the environment**		**to number and type of heavy vehicle crashes in WA [Ŧ╫])**		
	Road accident involving collision with an object during heavy rain			**Radiation exposure from external dose rates and/or ingestion or inhalation** **Release of UOC into the environment**	**Minor** **(radiation dose and Environmental damage)**	**Possible** **(Data from comparison of number of heavy vehicles on road in Pilbara region* to number of type of heavy vehicle crashes in WA [Ŧ╫])**	**Low**	**Tolerable**
	Road accident involving collision into a waterway			**Radiation exposure from external dose rates and/or ingestion or inhalation** **Release of UOC into the environment**	**Moderate** **(radiation dose and Environmental damage)**	**Unlikely** **(Data from comparison of number of heavy vehicles on road in Pilbara region* to number and type of heavy vehicle crashes in WA [Ŧ╫])**	**Low**	**Tolerable**
	Road accident involving fatality of the driver			**Radiation exposure from external dose rates and/or ingestion or inhalation, especially to rescue personnel** **Release of UOC into the environment**	**Minor** **(radiation dose and Environmental damage)**	**Possible** **(Data from comparison of number of heavy vehicles on road in Pilbara region* to number and type of heavy vehicle crashes in WA [Ŧ╫])**	**Low**	**Tolerable**
Security Breach	**Unauthorised access to UOC**	**Malicious intention**	**Transport Management Plan**	**Report to Regulator**	**Minor**	**Unlikely**	**Low**	**Tolerable**

	material	**Theft** **Blockade/Protests**	**Appropriate training of Transport Personnel** **Emergency Response Plans** **Security Plan** **Checks of bolt security seals** **GPS system attached to truck** **Out-of-zone monitoring of the truck** **Monitor NGO activity** **Police/Government intervention**	**Some public concern** **Loss of asset**	**(Enterprise and Project)**			

***Pilbara Traffic Digest 2003/04 – 2008/09 Mainroads Western Australia, Western Australia Government**

Ŧ Fatal heavy vehicle crashes Australia, Quarterly bulletin, January – March 2009, ISSN 1835-0240, Department of Infrastructure, Transport, Regional Development and Local Government, Australian Government

ж Serious injury due to transport accidents involving a railway train, Australia, 2002-03 to 2006-07, Henley G. and Harrison JE

╬ Accident Transport Safety Bureau heavy truck crash databases, Curnow G. Australian Transport Safety Bureau, National Heavy Vehicle Safety Seminar, Melbourne, October 2002.

17. Alternative Transport Routes

There are a number of transport routes available to Cameco to transport the UOC from the mine site to a port of export.

The preferred route is by road from the Kintyre project site by sealed road to Parkeston near Kalgoorlie via Telfer, Marble Bar, Port Hedland, Newman, Mount Magnet, Sandstone, Leinster and Leonora. From there the route is to Darwin or Adelaide by rail or road.

Alternative routes exist either using secondary roads to detour Port Hedland, via Nullagine, and Mount Magnet, or using road transport from Kintyre to Darwin. These alternative routes area mixture of sealed and unsealed roads.

There is limited information available on crash risk associated with unsealed versus sealed roads. The majority of vehicle accidents in Australia occur on sealed roads but sealed roads also tend to support much higher volumes of traffic. Literature[3] suggests that crashes on unsealed roads are generally more common per vehicle kilometre than crashes on equivalent sealed roads. However it should be noted that the severity of crashes can be influenced by the time required for medical assistance to arrive if the sealed or unsealed road is remote.

Literature identifies a number of causes of crashes on unsealed roads. Due to economic limitations and the nature of the evolving development of unsealed roads, hazards can often co-exist. These include:

- A greater proportion of uncontrolled intersections and unsignalised rail crossings
- Low traffic volume and mixed traffic composition including a greater proportion of heavy vehicles.
- Poor road geometry
- Poor sight distance
- Poor surface quality and lower levels of surface friction
- Inadequate delineation and advisory signing

Other factors such as excessive speed, alcohol, fatigue, inexperience of drivers on unsealed roads and wild life can also increase the likelihood of crashes.

Boschert, Pyta and Turner (2008) identified that the highest proportion of crashes on unsealed roads occurred during favourable light and weather conditions. They also identified that the majority of rural casualty crashes in Australia were due to run-off road type crashes (77%).

When travelling on unsealed roads, drivers tend to choose the ‘best’ path rather than sticking to the left of the carriageway, resulting in a higher proportion of crashes where drivers failed to keep left on unsealed roads (28%) than sealed roads (19%).

When considering the route to be taken when transporting UOC, mitigation measures should be considered to minimise any potential increase in risk from driving on unsealed roads.

The introduction of mitigation measures that address the causes of the majority of accidents as described in this literature will significantly reduce the likelihood of an accident occurring.

---

[3] Boschert, Pyta and Turner, Crashes on unsealed roads, ARRB Australia, 2008.
Kidd & Willett, Crash patterns in Western Australia, 2001
Tsolakis, Patrick and Thoresen, Guide to project evaluation, Austroads NSW, 2005

By the use of a preferred transport supplier who are experienced at driving on unsealed roads, no excessive speeds for the road conditions, regular preventative maintenance, regular inspection of vehicles and routes travelled, by selecting routes based upon current condition of the road and weather and suitable management of work hours the likelihood of an accident decreases. Regular auditing of compliance with transport regulations, ensuring drivers have adequate competency based training, the installation of real time speed recorders in trucks, a transport management plan is developed and implemented and contingency plans for adverse environmental conditions that can occur along these routes are in place, will further reduce the likelihood and consequence of an accident when driving on a unsealed road.

From limited statistics there is a slight increase in the likelihood of an accident occurring on an unsealed road. However the implementation of mitigation measures discussed above will minimise this. If these are implemented and the current status of the unsealed roadways is monitored and assessed, the use of the proposed alternative routes will not significantly increase the risk.

However the use of alternative routes will require the same provisions to be present as for the preferred routes. This includes access to and training of local emergency response agencies and facilities, security resources and suitable communication options.

18. Recommendations and Conclusions

Based upon the results, the following recommendations and conclusions are made:

1. Of all of the scenarios assessed, the radiological risk of the transportation of UOC is considered to be low and tolerable.
2. There is a higher potential risk of a serious crush injury to personnel whilst loading and unloading containers. However further mitigations can be put in place to reduce this risk. This risk is non-radiological and is present regardless of the content of the transport container.
3. The use of alternative routes does not significantly increase the risk associated with the transportation on UOC, provided that mitigation measures are implemented, timely emergency response is available and the current condition of the road is assessed to be suitable. If the condition of unsealed roads deteriorates, the route should be assessed to determine if a higher level of risk has been introduced.

It is recommended that the mitigation measures discussed above are implemented. If any are not implemented an assessment should be made on the impact on the likelihood or consequence for each of the above scenarios.

The risk assessment is based upon the radiological risks during the transportation and only considers other non-radiological risks where there is potential radiological impact.

A separate risk assessment of non-radiological risks should be undertaken prior to commencement of operations.

19. References

AIHW: Henly G and Harrison JE 2009. Serious injury due to transport accidents involving a railway train, Australia 2002-03 to 2006-07. Injury research and statistics series no. 54. Cat. No. INJCAT 130. Canberra: AIHW. www.aihw.gov.au

Boschert L., Pyta V. and Turner B. Crashes on Unsealed Roads. ARRB Conference, Adelaide Australia. ARRP Group. 2008.

Curnow G., Accident Transport Safety Bureau heavy truck crash databases, Australian Transport Safety Bureau, National Heavy Vehicle Safety Seminar, Melbourne, October 2002.

Department of Infrastructure, Transport, Regional Development and Local Government, Fatal heavy vehicle crashes Australia, Quarterly bulletin, January – March 2009, ISSN 1835-0240, Australian Government

Department of Mines and Petroleum, 2010. Managing Naturally Occurring Radioactive Material (NORM) in mining and mineral processing – guideline. NORM-4.3 Controlling NORM – Transport of NORM: Resources Safety, Department of Mines and Petroleum, Western Australia

Driscoll O. P. Major Accident Investigation Report 2009, National Centre for Truck Accident Research

Henley G. and Harrison JE, Serious injury due to transport accidents involving a railway train, Australia, 2002-03 to 2006-07.

Kidd B. & Willett, Crash patterns in Western Australia, Road Safety Research, Policing and Education Conference, 2001.

Mainroads Western Australia, Pilbara Traffic Digest 2003/04 – 2008/09, Western Australia Government

Mainroads Western Australia, Mid West Traffic Digest 2003/04 – 2008/09, Western Australia Government

Road Safety Council, Analysis of Road crash Statistics, Western Australia 1990 to 1999, Project Transport/21, December 2000

Tsolakis D., Patrick S. and Thoresen T, Guide to project evaluation, Austroads NSW, 2005

.

20. Appendix A – Spill Kits

Suggested Spill Kit

During all transport activities an incident response kit would accompany the 20 ft GP containers packed with UOC. The lead road vehicle would carry the incident response kit, while in the case of rail transport, the kit would be loaded on to the train in a location determined to be appropriate.

The kit has been designed to assist in safe and efficient containment in the initial stages of a UOC spill during transport. The kit would include, but not be limited to, the following items:

- Personnel Protective Equipment (PPE);
- Emergency Position Indicating Radio Beacons (EPIRB);
- Personal hygiene materials;
- Workplace first aid kit;
- Dolphin torch and batteries;
- Traffic management devices;
- Containment equipment;
- Recovery equipment; and
- A copy of the Emergency Response Plan.

The spill kits would be held and maintained by the Transport Service Provider. Procedural control will ensure that the contents of the kits are checked on a regular basis to ensure they are maintained and ready for use at any time during the transport of UOC.