Investigation of Quantitative Explosive Risk Assessment Approach for Explosive Ordnances with the Australian Defence Force

SUPERVISED BY

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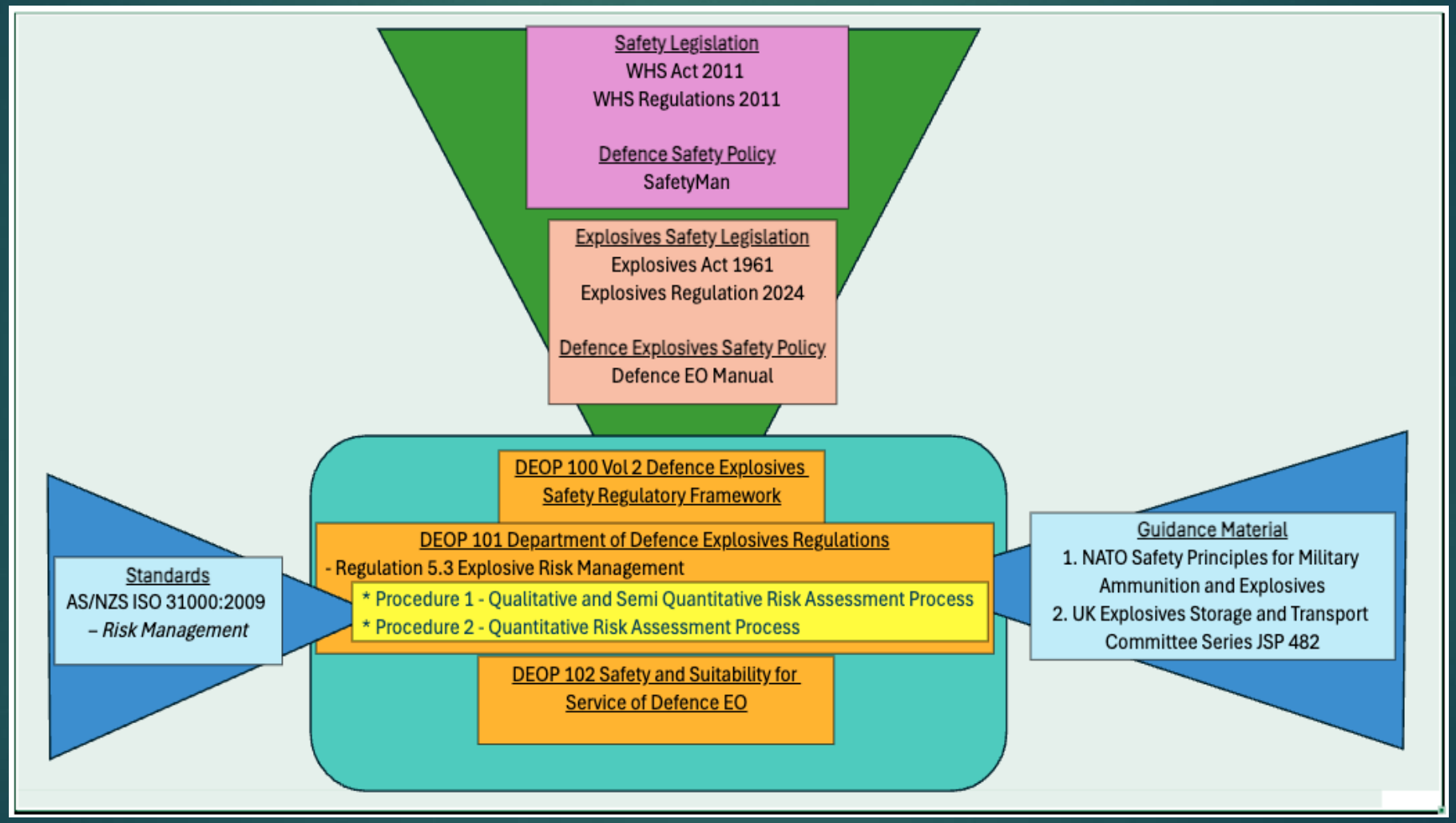
Aim and Objective

- Aim
  - Identify if Explosive Risk Assessment (ERA) for safe storage and safe road transport of Explosive Ordnance (EO) has been adequately covered within Defence Explosive Ordnance Publications (DEOP) and if deficient, propose an improved option for ERA for road transport and storage.
- Objective
  - The objective is achieved by working out a scenario involving road transport and storage of select EO between two Australian Defence Force (ADF) bases and exploring DEOP for adequacy in conducting a Quantitative Explosive Risk Analysis (QERA) and if deficient identify an improvement.

Introduction

- Explosive Ordnances (EO) are intrinsically hazardous and pose conceivable risks.
- Work Health and Safety (WHS) Act 2011 and WHS Regulations 2011 provide limited coverage for explosive safety hazards.
- Risk framework applicable to Australian Defence EO is Explosives Safety Regulatory Framework (ESRF).

Regulations



Applicability

- DEOP 100 mandates twelve principles covering aspects of safety management systems, safety & suitability for service, safe location and safe work practices.
- Seven of the twelve principles detail aspects of risk management directly linked to ERA and Quantity Distances (QD).
- Regulations for ADO Explosive Risk Management (ERM) is covered within DEOP 101.

eDEOP 101- Classification Storage and Transport Guidelines

- ERM - Hazard Classification - ADO uses UN classification for storage and transport of explosives.
- ERM – Storage
  - ERM principles detailed within Regulation 5.3 is applicable for NEQ less than 50 kg.
  - Quantity Distances (QD rules described in Regulation 5.4 is the basis for safe storage of EO for NEQ greater than 50 kg.
- ERM for Road Transport - Transport of Defence EO by road is regulated by the AE Code.

eDEOP 101 – Explosive Risk Assessment

- Qualitative and semi-quantitative Explosive Risk Assessment (ERA).
- Quantitative ERA (QERA)

eDEOP 101 – Limitations and Challenges

- Qualitative, semi quantitative and quantitative methods have been prescribed for storage of EO NEQ less than 50 kgs.
- Identifying probability figures for QERA involves extensive testing for each EO type and each scenario, which can be time consuming and expensive
- Assigning a likelihood value based on a qualitative definition can present a challenge in predicting the likely outcome of a risk.
- QD values, is not exhaustive enough to cover all aspects of EO application throughout its Capability Life Cycle (CLC).
- An area which would benefit from employment of ERA methods is the determination of safe route for transport based on Quantitative Explosive Risk Assessment (QERA).

Risk Management Methodology

- The select EO will be first classified into its hazard classification and compatibility groups using DEOP101 Section 2.
- EO will then be assigned into consignments accordance with DEOP101 Section 4 for storage compatibility and DEOP101 Section 3 for transport compatibility.
- Storage safe distances for the select EO will first be determined using Quantity Distance principles as prescribed in eDEOP101 Section 5 Regulation 5.4.
- Quantitative Explosive Risk Assessment Principles as prescribed in eDEOP101 Section 5 Regulation 5.3 will be utilised to quantify risks to individual and society

Risk Management Methodology

- The storage risk will also be analysed using a MIL-STD-882E based seven step risk assessment process.
- Transport risk evaluation for the part of the scenario involving road transport of select EO will first use guidelines provided in eDEOP101 Section 3 and AE Code.
- QERA from eDEOP101 Section 5 Regulation 5.3 will be utilised to examine applicability and improvement to extant transport regulations for EO.
- The storage risk will also be analysed using a MIL-STD-882E based seven step risk assessment process.
- Crime and accident comparison of en-route local government areas (LGA) is compared using geographical information systems to assess the best route for transport

Hazard Classification and Compatibility Groups

Item name	UN N0.	Hazchem code	Compatibility	Class/ Division	Quantity (NEQ/TEQ)
Explosive, Blasting, type E	332	E	D	1.5D	100kg
BARIUM AZIDE, dry or wetted with less than 50% water, by mass	224	E	A	1.1A	300 items
Rockets with inert heads	502	E	C	1.2C	150 kg

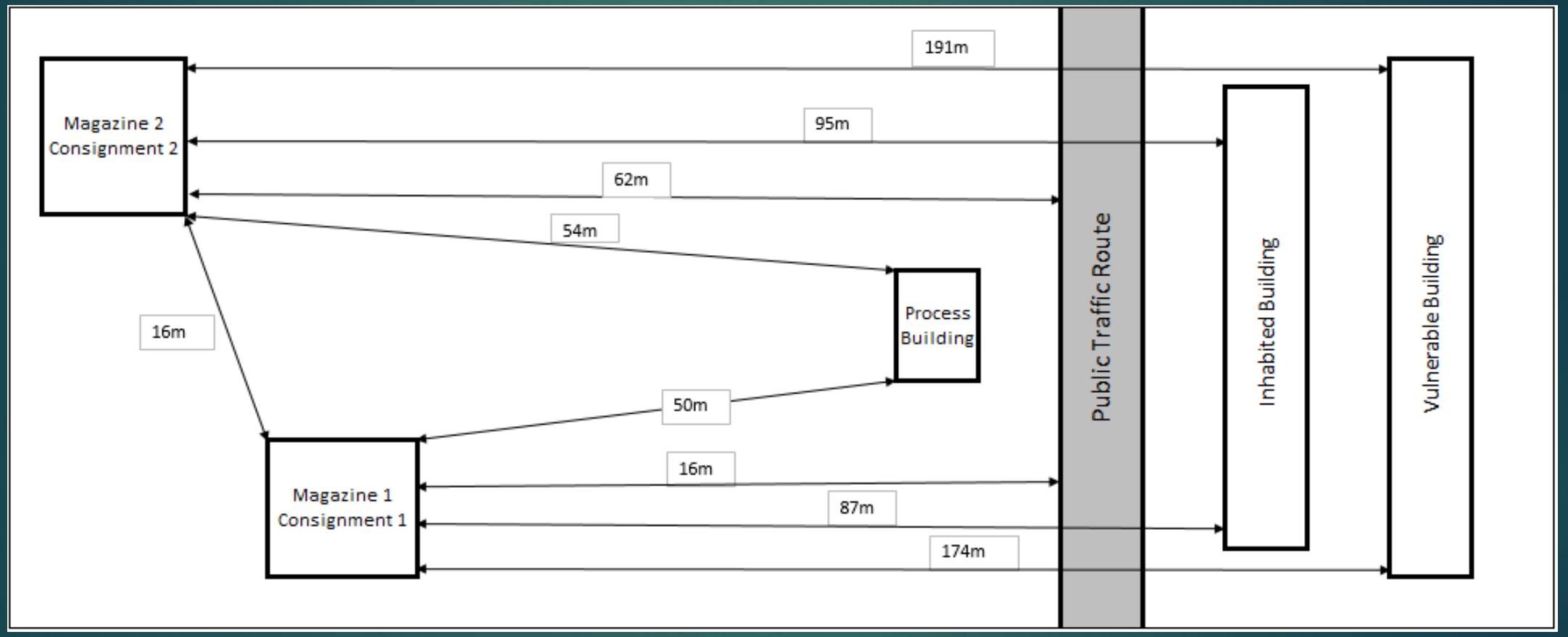
Storage Safety – Quantity Distance

QD type	QD sub-type	Min applicable distance	Prescribed D	Formula
IQD type	Inter Magazine Distance (IMD)	D1-10	D7	2.4 x Q^(1/3)
	Process Building Distance (PBD)	D10 and D13	D10	8 x Q^(1/3)
OQD type	Public Traffic Route Distances (PTRD)	2xD9 (for MIL only), D11, D13-17	D11	3.6 x Q^(1/2) (for NEQ <4500 kg)
	Inhabited Building Distance (IBD)	2 x D13	D13	5.5 x Q^(1/2) (for NEQ <4500 kg)
	Vulnerable Building Distance (VBD)	D13-15	2 x D13	11 x Q^(1/2)

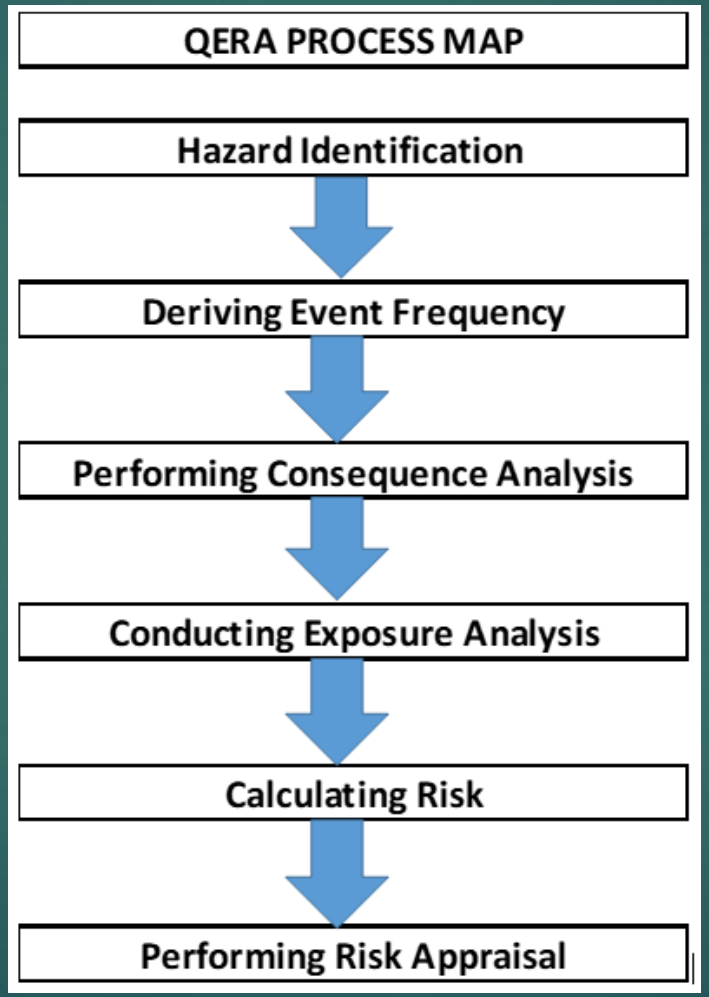
Storage Safety – Quantity Distance

QD type	QD sub-type	QD Consignment 1 (m)	QD Consignment 2 (m)
IQD type	Inter Magazine Distance (IMD)	15	16
	Process Building Distance (PBD)	50	54
OQD type	Public Traffic Route Distances (PTRD)	57	62
	Inhabited Building Distance (IBD)	87	95
	Vulnerable Building Distance (VBD)	174	191

Storage Safety – Quantity Distance

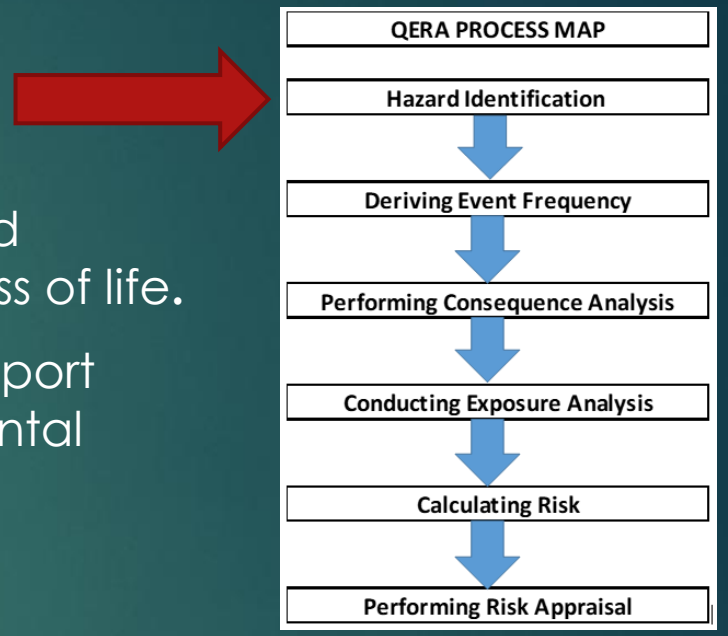


Storage Safety – QERA



Storage Safety – QERA

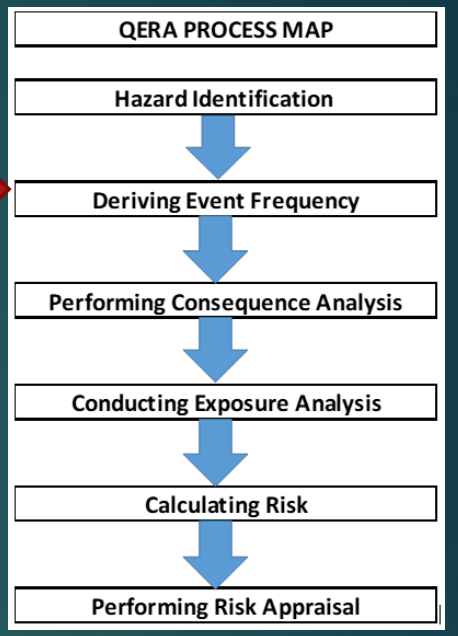
- Hazard Identification:
  - Hazard 1: Explosive Ordnance (EO) undergoes uncommanded initiation during transport leading to damage to facility and loss of life.
  - Hazard 2: EO undergoes uncommanded initiation during transport leading to release of harmful chemicals leading to environmental damage, contamination and sickness.



Storage Safety – QERA

Event Tree Analysis - QERA Storage - Event Frequency Determination

Initiating Event per	Start of Fire	Building Damage	Personnel Injured	Fatality	Outcome	Frequency per year
Explosion 1.00E-03	TRUE 1.00E+00	TRUE 8.00E-01	6.00E-01	TRUE 1.00E-01	**Fatality**	4.80E-05
				FALSE 9.00E-01	**Personnel Injury**	4.32E-04
			FALSE 4.00E-01		**Building Damage**	3.20E-04
		FALSE 2.00E-01			**Fire hazard**	2.00E-04
	FALSE 1.00E-04				**No explosion**	1.00E-07
					Event Frequency (Fe)	**1.00E-03**



$$F_e = F_1 + F_2 + F_n$$

Where

F_e= Frequency of the event

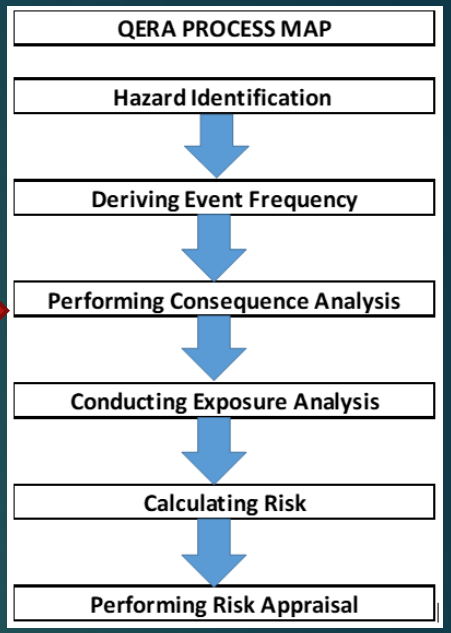
F_1= Frequency of hazard 1

F_2= Frequency of hazard 2

F_n= Frequency of hazard n

Storage Safety – QERA

QERA - Consequence Analysis	
Probobablity due to effects	Figure
Fatality probability resulting from blast effects (P_{blast})	0.3
Fatality probability resulting from primary fragment effects ($P_{fragmentation}$)	0.3
Fatality probability resulting from secondary fragment effects (P_{debris})	0.2
Fatality probability resulting from thermal radiation effects ($P_{thermal}$)	0.2
Fatality Probablity (P_f) ($P_{fatality} = P_{blast} + P_{fragmentation} + P_{debris} + P_{thermal}$)	1



$$P_f = P_{blast} + P_{fragmentation} + P_{debris} + P_{thermal}$$

Where:

P_{blast}= Fatality probability resulting from blast effects.

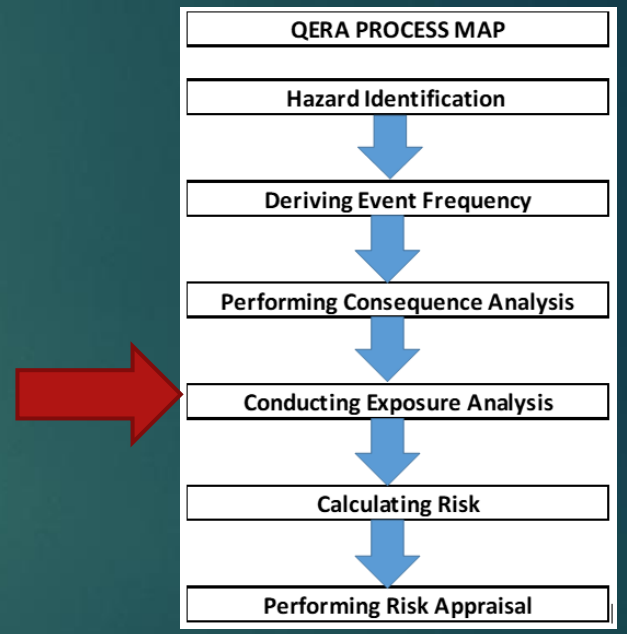
$P_{fragmentation}$ = Fatality probability resulting from primary fragment effects.

P_{debris}= Fatality probability resulting from secondary fragment effects.

$P_{thermal}$= Fatality probability resulting from thermal radiation effects.

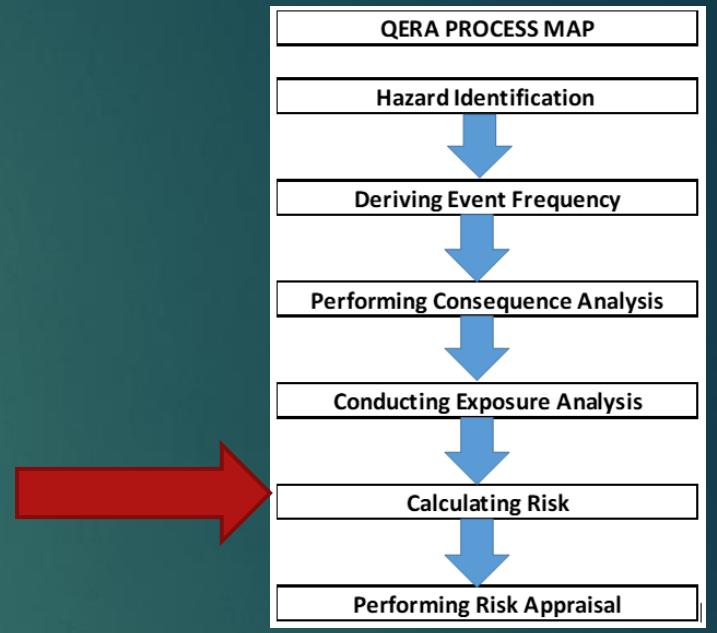
Storage Safety – QERA

QERA - Exposure Analysis			
Population Category	**Number of days in area**	**Exposure Hours per day**	**Exposure Individual ($E_{individual}$) per year**
Residents	365	24	1.000
Workers	200	9	0.205
Transients	50	2	0.011
PES exposure fraction	100		0.274



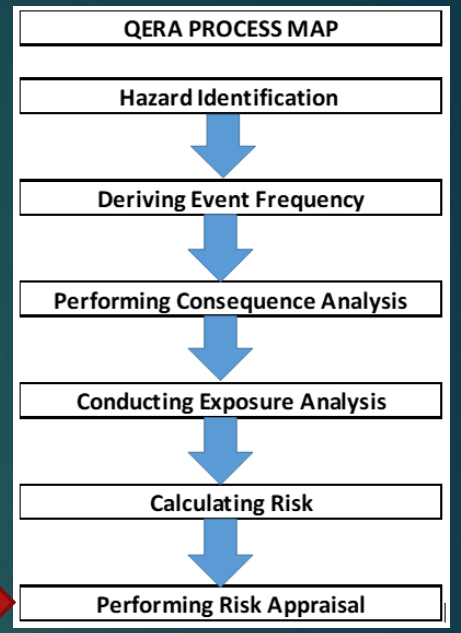
Storage Safety – QERA

Individual Risk for classes of individuals	Individual risk value
IR for Residents	2.740E-04
IR for Workers	2.055E-04
IR for Transients	1.142E-05



Storage Safety – QERA

Risk Dimension	Risk Value
Potential Risk	1.00E-03
Individual Risk - Resident	2.74E-04
Individual Risk - Worker	2.05E-04
Individual Risk - Transient	1.14E-05



PR = Event Frequency x Fatality Probability

$$PR = F_e \times P_f$$

Where:

F_e = Event Frequency (yr^1)

P_f = Fatality Probability

IR = Event Frequency X Fatality Probability X Fractional Exposure

$$IR = F_e \times P_f \times (E_{individual} \times E_{PES})$$

$E_{individual}$ = Exposure period for the particular individual at an ES expressed as a fraction of a year

E_{PES} = Period time the potential hazard present at the PES expressed as a fraction of a year

Storage Safety – QERA

Quantitative Risk Assessment Criteria for Individual Fatality Risk	
Land Use	**Risk Criteria**
Hospitals, Schools, Child Care Facilities, Old Age Housing Developments	5.00E-07
Residential developments and places of continual occupancy such as hotels and resorts	1.00E-07
Commercial developments - offices, retailers, warehouses, restaurants, entertainment.	5.00E-06
Sporting complexes and active open space areas	1.00E-05
Individual fatality risk level for industrial sites	5.00E-05

Transport Safety – AE Code

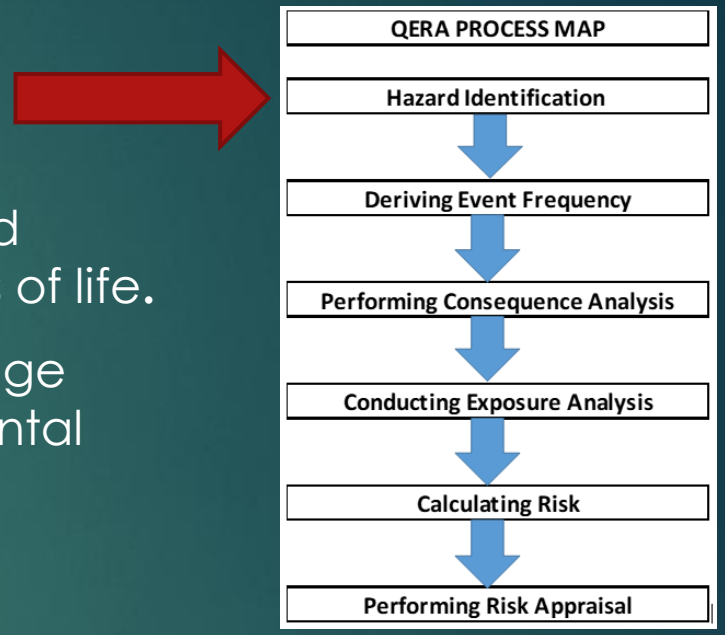
Proper Shipping Name and Description	Class Division	Quantity	Risk Categorisation
Explosive, Blasting, type E	1.5D	100 kg	Category 2 (Moderate Risk)
BARIUM AZIDE, dry or wetted with less than 50% water, by mass	1.1A	300 kg	Category 2 (Moderate Risk)
Rockets with inert heads	1.2C	150 kg	Category 2 (Moderate Risk)

Transport Safety – AE Code

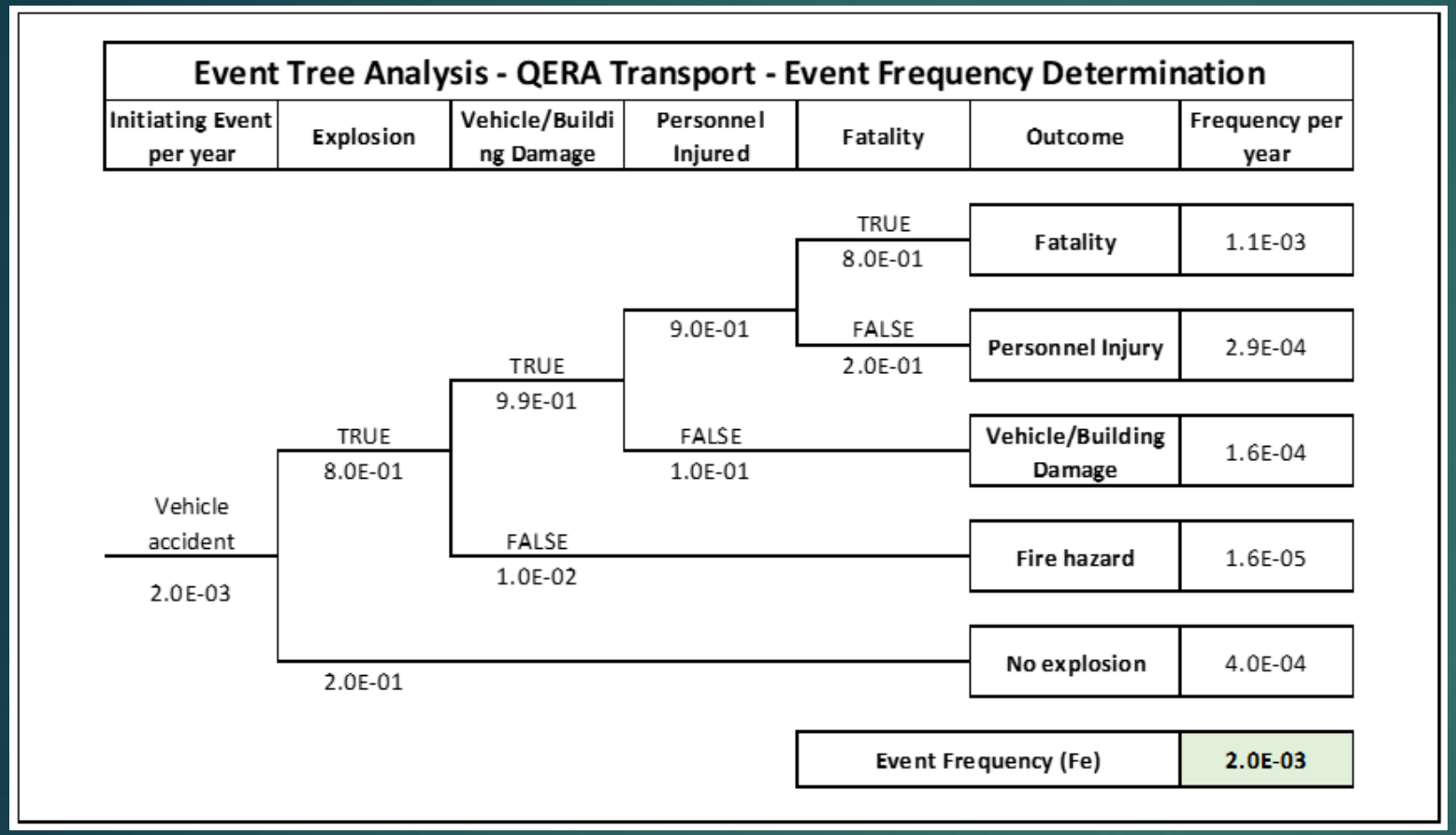
UN N0.	Proper Shipping Name and Description	Packaging and IBCs		Portable tanks & bulk containers	
		Instruction	Special Provision	Instruction	Special Provision
332	Explosive, Blasting, type E	P116, IBC100	PP61, PP62, PP65	T1	TP1, TP17, TP32
224	BARIUM AZIDE, dry or wetted with less than 50% water, by mass	P110 (a) or (b)	PP42		
502	Rockets with inert heads	P130, LP101	PP67, L1		

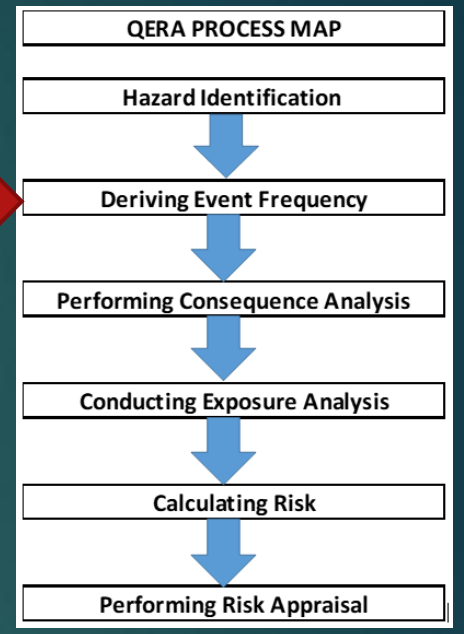
Storage Safety – QERA

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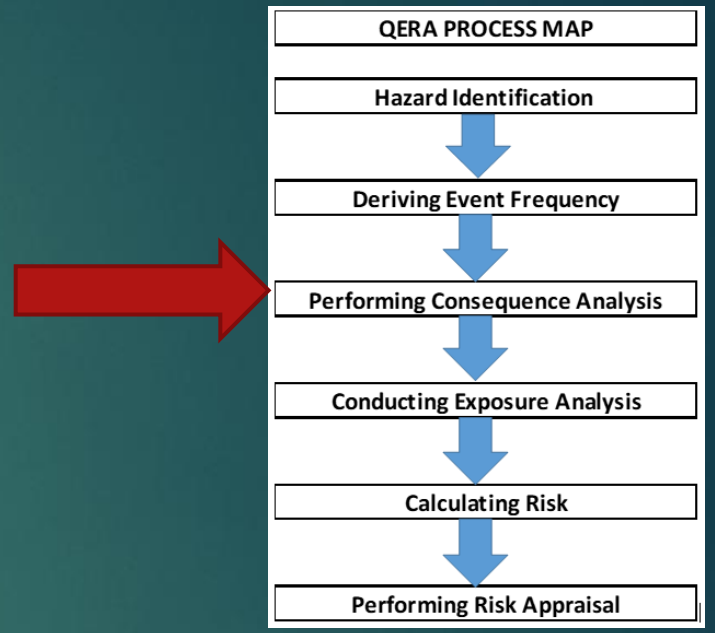
Transport Safety – QERA





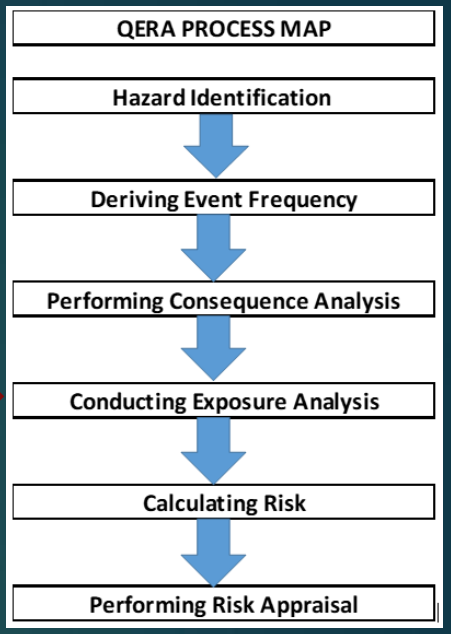
Transport Safety – QERA

QERA - Consequence Analysis	
Probobablity due to effects	**Figure**
Fatality probability resulting from blast effects (P_{blast})	0.2
Fatality probability resulting from primary fragment effects ($P_{fragmentation}$)	0.3
Fatality probability resulting from secondary fragment effects (P_{debris})	0.4
Fatality probability resulting from thermal radiation effects ($P_{thermal}$)	0.1
Fatality Probablity (P_f) ($P_{fatality} = P_{blast} + P_{fragmentation} + P_{debris} + P_{thermal}$)	1



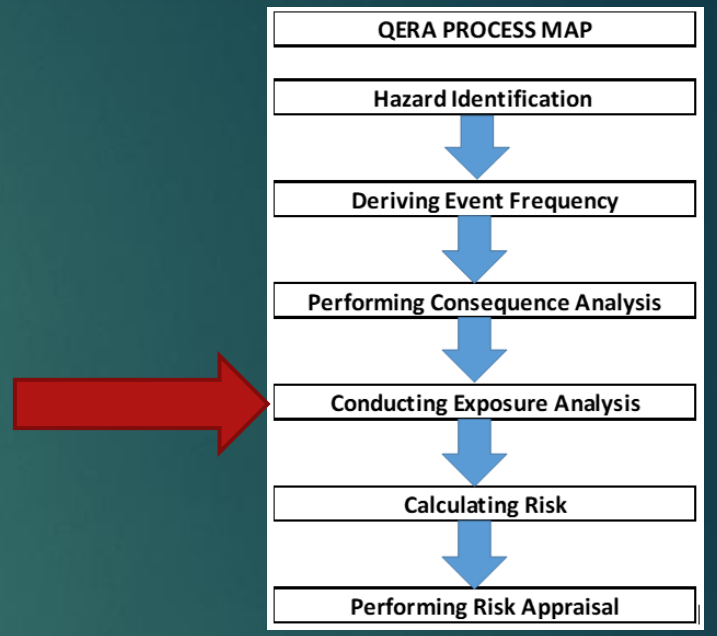
Transport Safety – QERA

LGA	Population Density (persons/sq km)	Area per 0.5km radius (sq km)	Population per 0.5 km radius (persons/sq km)
Port Stephens	90.6	0.785	71.1
Newcastle	933.4	0.785	732.7
Maitland	245.1	0.785	192.4
Cessnock	34.4	0.785	27.0
Singleton	5.2	0.785	4.1



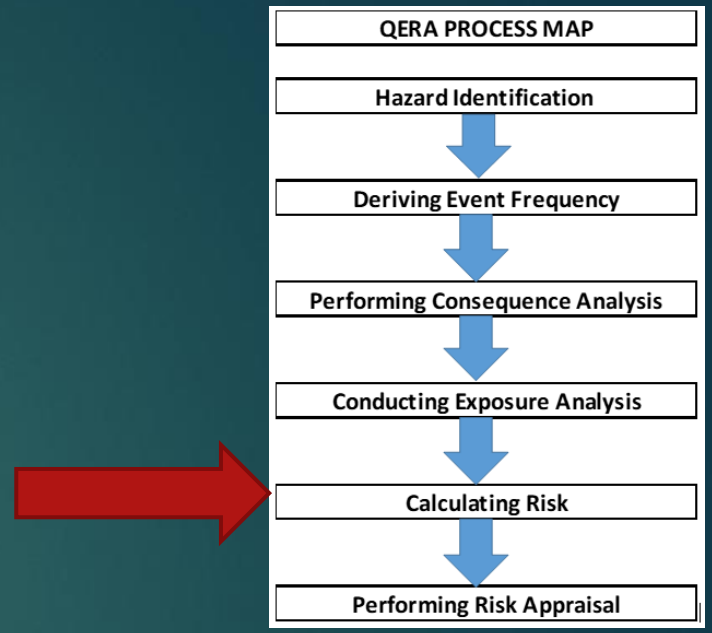
Transport Safety – QERA

LGA	Number of days in area	Exposure Hours per day	Exposure Individual ($E_{individual}$) per year
Port Stephens	1	1	1.14E-04
Newcastle	1	1	1.14E-04
Maitland	1	1	1.14E-04
Cessnock	1	1	1.14E-04
Singleton	1	1	1.14E-04
PES Fraction	1	1	1.14E-04

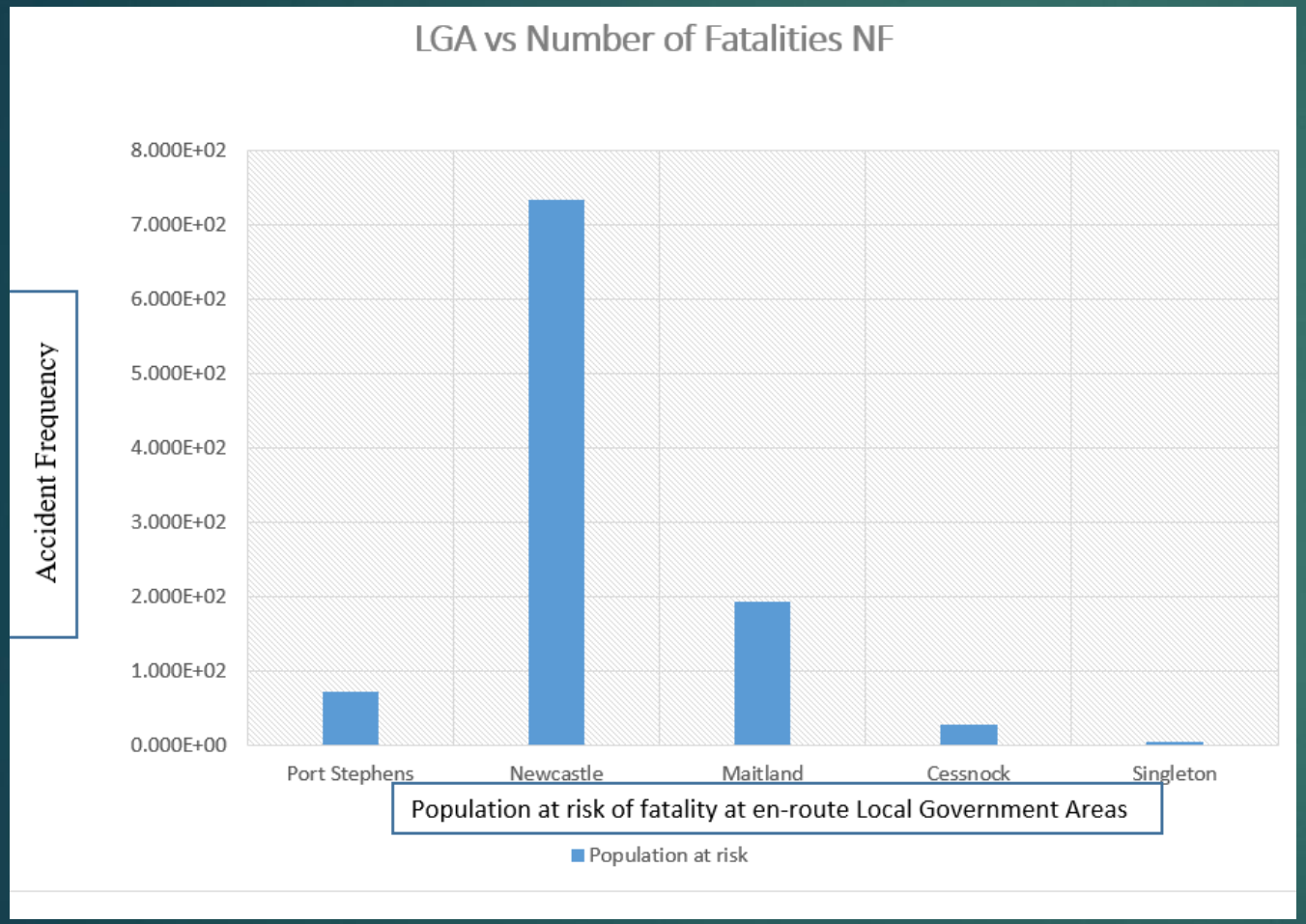


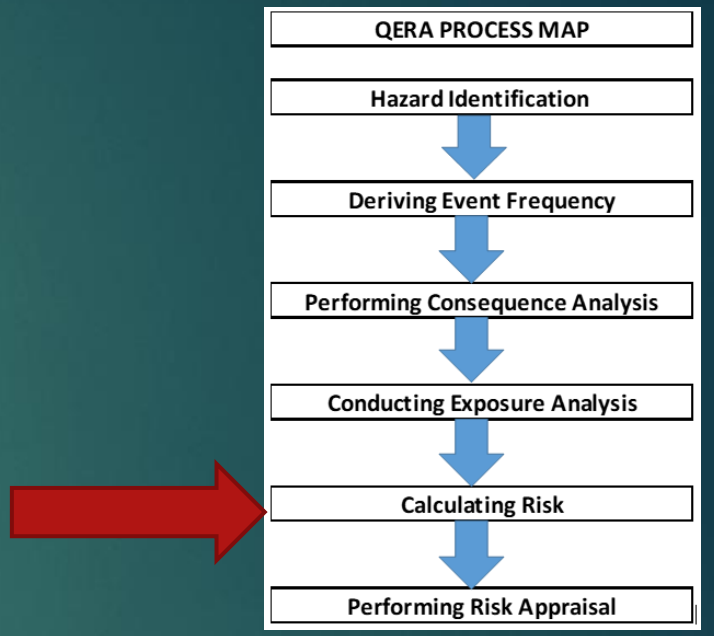
Transport Safety – QERA

Individual Risk for each LGA	Individual risk value
IR for Port Stephens	2.61E-11
IR for Newcastle	2.61E-11
IR for Maitland	2.61E-11
IR for Cessnock	2.61E-11
IR for Singleton	2.61E-11



Transport Safety – QERA

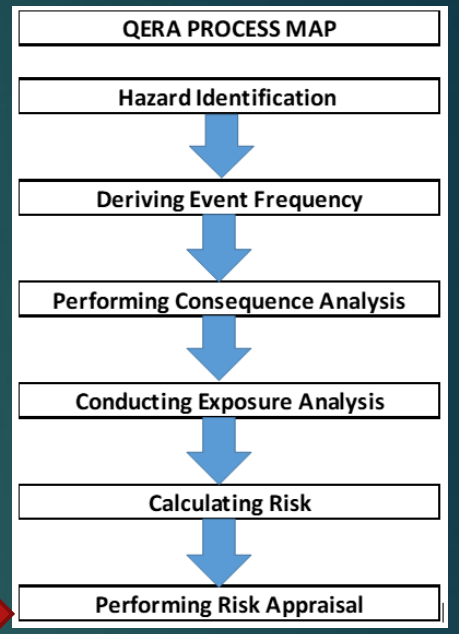




Transport Safety – QERA

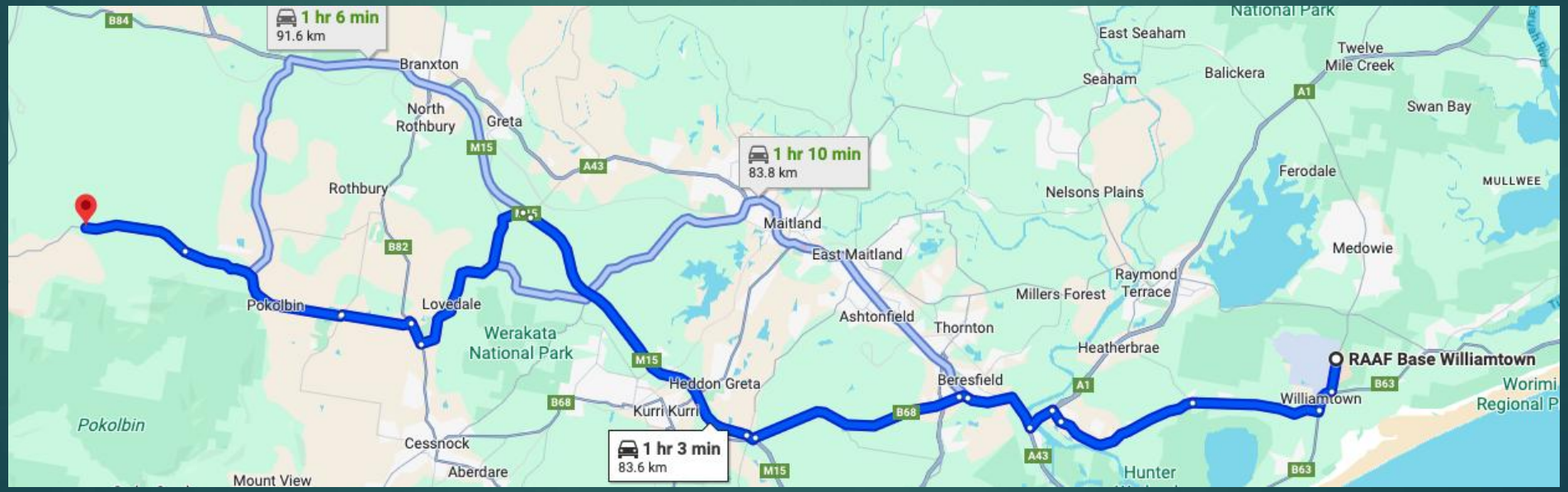
Risk Dimension	Risk Value
Potential Risk	2.00E-03
Individual Risk - Port Stephens	2.61E-11
Individual Risk - Newcastle	2.61E-11
Individual Risk - Maitland	2.61E-11
Individual Risk - Cessnock	2.61E-11
Individual Risk - Singleton	2.61E-11
Societal Risk	per graph

Quantitative Risk Assessment Criteria for Individual Fatality Risk	
Land Use	**Risk Criteria**
Hospitals, Schools, Child Care Facilities, Old Age Housing Developments	5.00E-07
Residential developments and places of continual occupancy such as hotels and resorts	1.00E-07
Commercial developments - offices, retailers, warehouses, restaurants, entertainment.	5.00E-06
Sporting complexes and active open space areas	1.00E-05
Individual fatality risk level for industrial sites	5.00E-05



Transport Safety – Safe Route

- The methodology used is to assess the safety and security threats on enroute local government areas (LGAs).
- Through maximising travel through the safest LGAs and minimise/eliminate travel through the safest LGAs minimise safety and security exposure to the transport activity, thereby minimising risk.



Transport Safety – Safe Route

Local Government Area (LGA)	Crimes per thousand people	Crime Rank per 100	Weapons and explosive offences	Weapons and explosive offences as a percentage of total of all crimes	Ranking amongst enroute LGAs
Port Stephens	22.53	54	112	112/5844 = 0.019%	2
Newcastle	50.85	64	326	326/21352 = 0.015%	5
Maitland	29.74	59	150	150/8221 = 0.018%	3
Cessnock	39.20	62	141	141/5967 = 0.024%	4
Singleton	72.72	52	61	61/1688 = 0.036%	1

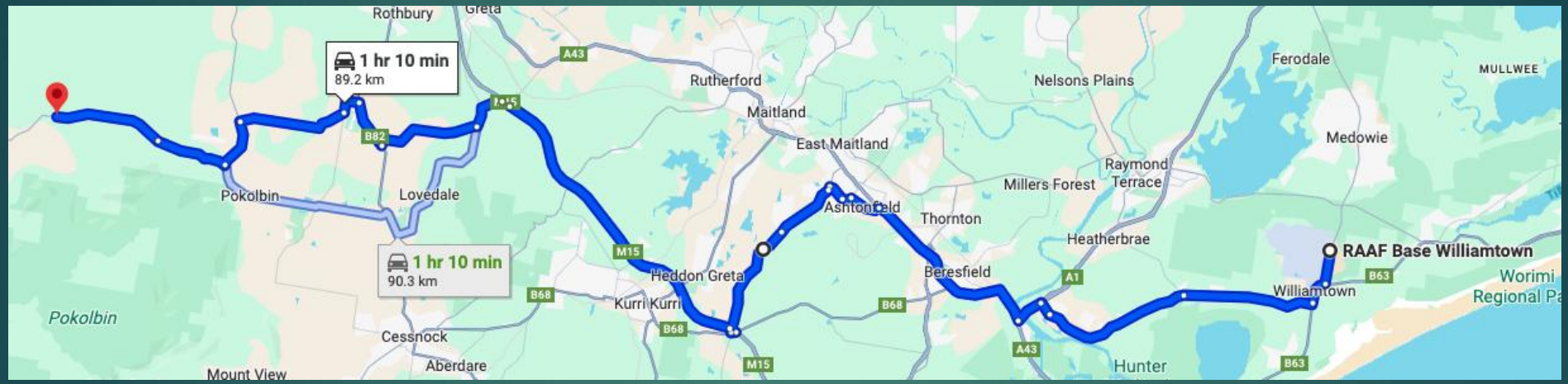
Transport Safety – Safe Route

LGA	Fatal	Serious Injury	Moderate Injury)	Minor Injury	Total	Rank
Port Stephens	2	39	40	8	89	2
Newcastle	1	87	140	70	298	5
Maitland	3	34	63	12	112	4
Cessnock	2	41	50	17	110	3
Singleton	3	23	30	8	64	1

Transport Safety – Safe Route

Suburb	Adjusted Ranking Value	Weighted Ranking
Port Stephens (RAAF Base Williamtown)	2.0	2
Newcastle	5.0	5
Maitland	3.4	4
Cessnock	3.6	3
Singleton (Singleton Military Area)	1.0	1

Transport Safety – Safe Route



Findings

- 1. [Finding 1] –QD does not adequately characterise quantitative potential risk, personnel risk and societal risk. QERA could be utilised to address this shortfall. supplementing QD with QERA methods achieves better quantification of risk to personnel and society thereby achieving SFARP outcomes in EO storage scenarios.
- 2. [Finding 2] –AE Code does not adequately address societal risk along the chosen route. Societal risk aspects could be used to minimise risk if appropriately quantified. Application of a tailored QERA as utilised in this report could help determine societal risks enabling improved risk minimisation.
- 3. [Finding 3] – Current EO transport policy does not prescribe a method for determining and assessing safety and security of en-route regions. The application of geographic information software for comparison of routes and en-route regions could help safest route.

Recommendations

- [Recommendation 1] - Consider mandating use of QERA to supplement QD for NEQ greater that 50kg as a risk management tool through amendment to DEOP101.
- [Recommendation 2] - Improve current QERA method detailed within DEOP101 to include provisions for application of QERA in EO transport scenario, in order to quantify societal risks en-route appropriately.
- [Recommendation 3] - Further explore use of geographic information systems to enable improved quantifying of societal and personnel risk in en-route regions due to EO transport.

Questions